ÉcoTerra Home

Net Zero Energy Building Overview

The EcoTerra house is a prefabricated detached house built in a wooded area in Eastman, Quebec. The house aims at fulfilling the objectives of the EQuilibrium initiative led by Canada's Housing and Mortgage Corporation (CMHC): to provide a healthy, affordable and comfortable living space, while reaching the goal of annual net-zero energy consumption.

This is one of thirty case study factsheets collected by participants in Subtask C of the IEA 'Net Zero Energy Buildings' (NZEBs) research project. Subtask C focuses on documenting and analysing current NZEBs design and technologies. The case studies form the basis of a proposed Source Book describing NZEB Solution Sets and guidelines and documenting monitored performance and lessons learned.

Completion Date
Winter 2008

Location
9, de la Héronnière
Eastman
Quebec
Canada

Latitude	Longitude
North	West
45.3 N	72.3 W

Climate Challenge Definition
Buildings are either cooling dominated, heating dominated or mixed heating and cooling dominated. A building is climate dominated if one of a reference buildings space conditioning processes is 70% or greater of the total space conditioning load.

Climate Challenge
Heating Dominated

Building Type
Residential

Site Context
Open Site

Net Floor Area (m²)
230

Conditioned Floor Area (m²)
230

Occupancy (m² per Person)
0.01

Number of Storeys
2

Cost US$/(Net) m² Floor Area
1,500

Cost US$/(Net)m² typical similar building
1,000

For more information
http://www.cmhc-schl.gc.ca

Google earth
N/A

Architectural Design Concept

The house is oriented due south. The footprint is roughly a rectangle with an aspect ratio of about 1.4. The south façade of the house (and hence the roof as well) is longer to receive more direct solar radiation. A family room with large glazing area is located in the south portion of the ground floor. It is the main direct gain zone for passive solar heating. A skylight window with an area of about 1 square meter located above the stairways brings in daylight for the kitchen and dining area. All rooms are equipped with windows except the north portion of the basement, where the mechanical room is located. Large south facing windows and open space architectural layout help improving daylight distribution. The length of the overhangs (e.g. soffit) over the south facing windows was optimized to block most of the direct solar radiation in the summer, but to allow the window to be fully exposed to direct solar radiation in the winter. All the windows are operable. This enables cross ventilation for passive free cooling.

Measured Energy Production and Consumption:

These data compare the overall energy consumption with the total energy generated though renewable energy onsite.

Energy Demand (kWh/m².year)

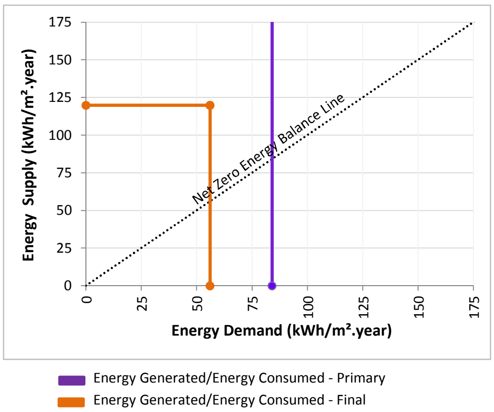
Electricity		**Natural Gas**
Final:	56.03	
Primary:	84.05	

Energy Supply (kWh/m².year)

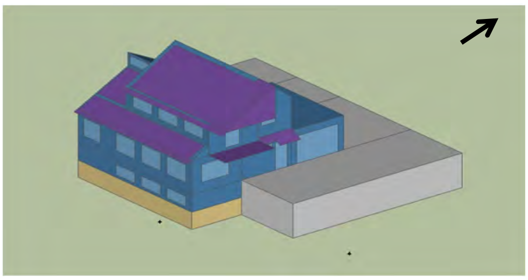
Renewable Energy	
Final:	119.87
Primary:	179.80

Source to Site Conversion Factor (Electricity): 1.5

*In the graph **Final Energy Demand** is the sum of all delivered energy (kWk/m².year) obtained by summing all energy carriers. **Final Energy Supply** is the sum of all energy generated on site from renewable sources. The Primary Energy Demand and Primary Energy Credit have been calculated based upon the Primary Energy Conversion Factors for each energy carrier for this location.*



EnergyPlus Model

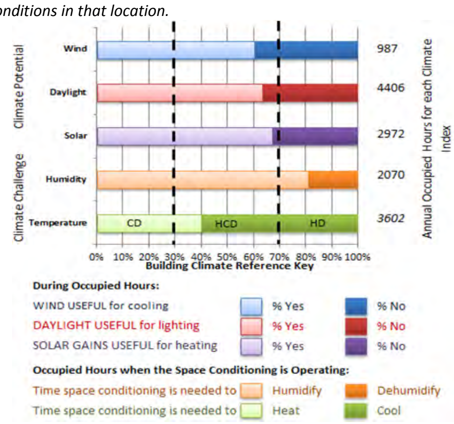


This model has been created by the STC participants to assist in the standardised analysis of the performance of this building. It calculates internal temperatures and energy consumption and production.

Key to colours:
Blue = Outside (sun and wind exposed)
Yellow = Ground (floors and basement walls)
Purple = Building shading
Grey = Site shading (ground surfaces)

Climate Analysis

The building climate method uses a reference residential building built to the local building code minimum insulation requirements to test the interaction between a building built in a location and the external climatic conditions in that location.



The Climate Challenge for the building designer is HEATING DOMINATED (HD) if the green bars meet between 70 and 100%; it is COOLING DOMINATED (CD) if they meet between 0 and 30%; it is MIXED HEATING AND COOLING (HCD) if they meet between 30 and 70%.

The icons at the end of each section provide a visual key for the reader who wants to quickly organize all the case studies. They symbolically summarize the individual technology solution sets used in each building. Please see the key to the right for more information

H *- Heating*	***P*** *- Plug Load*
L *- Lighting*	***W*** *- Water Heating*
V *- Ventilation*	***E*** *- Energy Export*
C *- Cooling*	

Construction

Walls - Construction Elements

Facing Solar Noon

U-value (W/m² ºC) 0.16

Solar Absorptivity 0.70

Wood siding, BASF Walltite, Neopor and Enertite insulation

East

U-value (W/m² ºC) 0.16

Solar Absorptivity 0.70

Wood siding, BASF Walltite, Neopor and Enertite insulation

Facing Polar Direction

U-value (W/m² ºC) 0.16

Solar Absorptivity 0.70

Wood siding, BASF Walltite, Neopor and Enertite insulation

West

U-value (W/m² ºC) 0.16

Solar Absorptivity 0.70

Wood siding, BASF Walltite, Neopor and Enertite insulation

Roofs

U-value (W/m² ºC) 0.16

Solar Absorptivity 0.80

Cathedral ceiling and attic type of roof

Ground floor

U-value (W/m² ºC) 0.68

Floor is below-grade

Windows - Construction Elements

Solar Noon

U-value (W/m² ºC) 1.18

g-value 0.53

Argon-filled, triple-glazed, low-e coating

East

U-value (W/m² ºC) 1.176

g-value 0.532

Argon-filled, triple-glazed, low-e coating

Polar Direction

U-value (W/m² ºC) 1.18

g-value 0.53

Argon-filled, triple-glazed, low-e coating

West

U-value (W/m² ºC) 1.18

g-value 0.53

Argon-filled, triple-glazed, low-e coating

As Built

Air permeability is the total building air leakage ($m^3.h^{-1}$) per m^2 of building envelope at a reference pressure difference of 50 Pa.

0

1.611158192

Compactness (m-1)

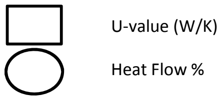
0.53

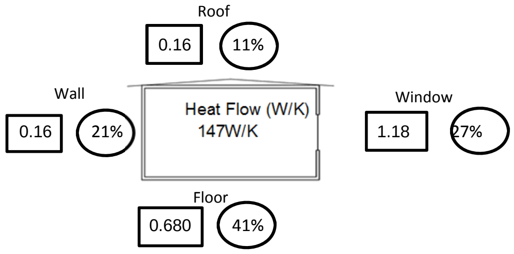
Passive Approaches:

Passive design techniques or solutions are design measures that require no direct purchased energy input. These design measures include optimisation of solar energy collection, storage and shading, plus natural ventilation and advanced day lighting measures. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of passive measures for this climate did not need to include this particular measure.

Heat Flow (W/ºC)

High resistance to heat flow (high R-value, low U-value) is important in climate where energy using services are used to maintain a large temperatures difference between indoors and outdoors.





Solution Sets are: A set of passive, energy efficiency, and/or renewable energy solutions used to mitigate or lessen the building challenges and achieve the design goal.

***Building Challenge Solution Set** - The set of solutions used to lower the energy needed by a particular building challenge.*

***Whole Building Solution Set** - The set of solutions used to lower the energy consumption of the whole building.*

Heating

Thermal Mass

A concrete floor and half-wall in the south facing zone store solar energy passively.

Thermal Mass

The hollow-core concrete slab of the basement is actively charged with the thermal energy coming from the BIPV/T roof, but discharges its energy passively.

Heat Recovery

There is a drain water heat recovery system to recover part of the heat of the water coming down the shower drain.

Cooling

Sunshading

There are overhangs over the south facing windows that block most of the direct solar radiation in the summer season.

Natural Ventilation

Passive cooling is promoted with all the windows being operable to allow cross ventilation.

Daylight Systems

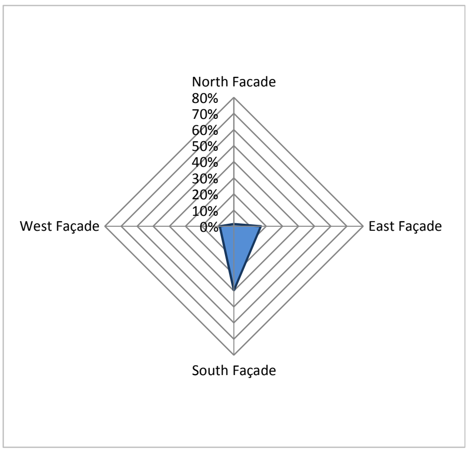
Skylight and south-facing windows

A skylight window located above the stairways brings in daylight for the kitchen and dining area. All rooms are equipped with windows except the north portion of the basement where the mechanical room is located. Large south facing windows and open space architectural layout help to improve daylight distribution.

Window Distribution Information

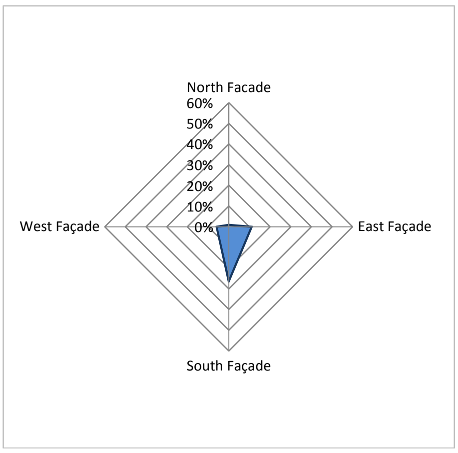
Distribution of Window Areas per Façade

In Passive design, the orientation of the windows and their size has an extreme effect on the heating, cooling and the daylight harvesting potential of the building. This graph enables simple comparison of these properties for each climate and building type.



Façade Porosity - Percentage of Openings per Facade

In Passive Design, the orientation of the openings for Natural Ventilation is a response to the wind and the site. This graph enables a simple comparison of the porosity of each façade for each climate and building type.



Optimised Floor Plan	Thermal Zoning	Improved/Advanced Envelope	Advanced Glazing	Advanced Day lighting	Sun Shading	Natural Ventilation	Evaporative Cooling	Passive Solar Heat Gain	Thermal Chimney
									

Innovative Technologies

The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular technology.

Energy Reduction Measures for Plug Loads and Appliances

Most plug loads and appliances are energy-efficient.

Energy Storage

The basement hollow-core slab stores the heat from the BIPV/T roof preheated air (heating season) and the coolness from the night outdoor air (cooling season). Concrete floor and half-wall in the south facing zone ensure passive storage of solar gains

Other

The BIPV/T roof consists of amorphous silicon PV laminates directly attached to a metal roof, with air passing under the metal to recover heat. This heat is used for both space or water heating.

HVAC Systems

Space heating is provided by geothermal heat pump and a BIPV/T roof. This BIPV/T system is coupled with a hollow-core ventilated concrete slab located in the basement and an air-to-water heat exchanger to provide domestic hot water.

Artificial Lighting

Computer Management

Control of Systems

A commercial system based on the BACNet protocol is used to manage the BIPV/T collector, exterior motorized awnings and heat pump.

Energy Efficiency Systems:

Energy efficient technologies are specific equipment and appliances that focus on reducing the use of energy, in the building, through more efficient means. These energy efficient technologies are used in harmony with the passive design to lower the overall energy consumption of the building. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular system.

System Design Parameters

Outside Air Requirements per Person (L/s-p)

12.5

Appliances / Plug Loads

Power Density Installed (W/m²) :

Artificial Lighting

Power Density Installed (W/m²) : Unknown

Computer Network

Power Density Installed (W/m²) : Unknown

Datacentre ? No

Internal Environmental Systems and Domestic Hot Water

This section describes how the design team has provided for the internal space conditioning. Central systems place the heating, cooling and ventilation equipment in a separate space from the occupied rooms. The heating or cooling of the rooms requires a distribution system taking heat to or away from the occupied rooms using water (hydronic) or air. Distributed systems have separate heating, cooling and possibly ventilation equipment installed for each space.

Cooling

Central Plant	No
Distributed Plant	No
Openable Windows	See Passive Systems
Ceiling Fans	Yes
Hydronic distribution	No
Air distribution	Yes

Description

Cooling is achieved with a geothermal heat pump and pre-cooling of the hollow-core slab in the basement. There is also automatic control of th awnings.

Heating

Central Plant	no
Distributed Plant	No
Hydronic distribution	No
Air distribution	Yes

Description

Heating is provided by the BIPV/T roof and a geothermal heat pump with back-up electrical element. The BIPV/T roof is coupled with a hollow-core ventilated concrete slab in the basement for space heating, an air-to-water heat exchanger for DHW and the clothes dryer.

Ventilation System

Heat Recovery Type	Yes
Central Air supply	Yes
Local Air Recirc plus Central Fresh Air	No

Description

The house has a heat recovery ventilator (HRV).

DHW - Domestic Hot Water

Solar?	Yes
Waste Water Heat Recovery?	Yes
Gas?	Yes
Electrical?	No
Other? (Less than 200 words:)	No

Description

DHW is supplied by the BIPV/T roof (through an air-to-water heat exchanger), the heat pump desuperheater, a drain water heat recovery unit and back-up electricity.

Control Systems

The critical feature of a successful ultra low energy building is the user interaction. Without control systems that are responsive to user needs and easily understood successful operation is extremely difficult.

Lighting

Description

HVAC

Description

The user interface is located a the entrance. The heating/cooling schedules and setpoints can be adjusted by the user.

Energy Storage

Latent Storage?	No
Fuel Cell?	No
Compressed Air?	No

User Interactions

User Manual Provided? No

Description

There is a user interface in the house to indicate weather and the PV system energy production.

Energy Efficient Lighting	Advanced Lighting Controls	Efficient Office Equipment	Efficient Appliances	Efficient HVAC Equipment	Earth Tube Heat Exchanger	Thermal Storage	Hot Water Conservation	Radiant Structure	Monitoring & LoadManagem.	Heat Recovery

Design Team

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Address

Email

Web Address
http://www.maisonalouette.com

Funding
Source and Type of Funding
The house was built by Alouette Homes with support from the Canadian Solar Buildings Research Network, Canada's Mortgage and Housing Corporation (CMHC), Natural Resources Canada

Principal Actors
This house was developed by Alouette Homes and a Concordia University team as part of Canada's Mortgage and Housing Corporation (CMHC) EQuilibrium initiative.

Author

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email
Veronique.Delisle@nrcan-rncan.gc.ca

This project has been organised under the framework of two International Energy Agency implementing agreements: Solar Heating and Cooling and Energy Conservation in Buildings and Community Systems. For more information please visit: www.iea-shc.org/task40

Energy Supply and Integration of Renewable Energy:

"By definition, a renewable energy source is a fuel source that can be replenished in a short amount of time. (American Society Of Heating, Refridgerating and Air-Conditioning Engineers, 2006)" Through the use of these replenishing energy sources, the annual energy demand of an already low-energy building can be offset through the renewable energy generation. Renewable energy sources are converted to energy using renewable energy generation technologies or solutions. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy supply and integration of renewable energy for this climate did not need to include this particular measure.

Electricity Production

Photovoltaic (PV)

Building Integrated PV?	YES
Ground mounted	NO
Roof mounted	YES
Position	Fixed
Tilt (angle)	30
Azimuth	0
Technology	Amorphous silicone
Nominal Power (kWp)	2.9
Area (m²)	45
Yield (kWh/m².year)	43
Expected generation (kWh)	
Measured generation (kWh)	

Solar Water Heating

Hot Water

Solar Thermal	Yes
Technology	Heat recovery from BIPV
Position	30 deg Tilt, 0 deg azimuth
Area (m²)	45
Production (kWh/m².year)	n/a
Annual % of Hot Water	n/a

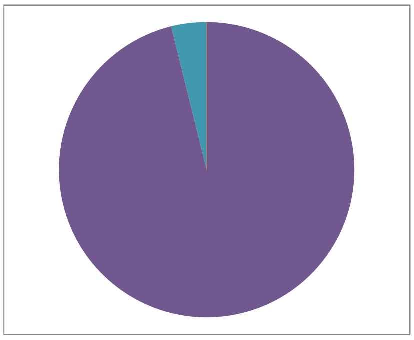
Production of Heating and Cooling

Heating Equipment

	Others	**Ground / Water Source Heat Pump**
Technology	BIPV/T air	Two-stage
Power	n/a	10.5 kW
Efficiency (%)	n/a	COP of 4.2 at full load
Production (kWh/m².yr)	328.9	2530.0
Annual % of Heating	n/a	

Cooling Equipment

	Heat Pump
Technology	Ground-source, two-stage
Power	11.1 kW
Efficiency (%)	ER of 19.8 at full load
Production (kWh/m².year)	115
Annual % of Cooling	n/a



This graph shows the expected proportion of generation (kWh/m²) of energy produced by the various renewable energy sources based on design calculations.

Solar heating
Heating energy production
Cooling energy production
Energy produced from Photovoltaic Panels
Energy produced from on site Wind Turbines
Hybrid energy production

PV Array	Onsite Wind Turbine	Boiler	CHP	Use of offsite Green Power	Solar Thermal Hot Water	Solar Thermal Space Heating	Solar Cooling System	PV/Thermal Array
								

References
American Society of Heating, Refridgerating and Air-Conditioning Engineers. Ashrae Green Guide: The Design, Construction, and Operating of Sustainable Buildings USA: Elsevier 2006.
Belleri, Annamaria, Assunta Napolitano, and Roberto Lollini. "Net Zeb Evaluation Tool - User Guide " (2012).

ENERPOS

Net Zero Energy Building Overview

ENERPOS is the first Net ZEB of the French overseas departments in tropical climates. The building has been designed with priority given to the passive components such as cross natural ventilation and solar shading. In terms of energy use, it consumes one seventh of the average for university buildings in Reunion Island and produces seven times its consumption by BIPV roofs. The building has a high level of monitoring with min by min data separated by end use.

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Completion Date
Construction completed August 2008

Location
40 avenue de Soweto
Saint-Pierre
Reunion Island
France

Latitude	Longitude
South	West
21° 20'	55° 29'

Climate Challenge Definition
Buildings are either cooling dominated, heating dominated or mixed heating and cooling dominated. A building is climate dominated if one of a reference buildings space conditioning processes is 70% or greater of the total space conditioning load.

Climate Challenge
Cooling Dominated

Building Type
Non-residential_Educational

Site Context
Suburban Site - single family houses 1-2 storey spaced 3-5m apart

Net Floor Area (m²)
739

Conditioned Floor Area (m²)
681

Occupancy (m² per Person)
0.1

Number of Storeys

Cost US$/(Net) m² Floor Area
4,581

Cost US$/(Net) m² typical similar building

Web Address
http://lpbs.univ-reunion.fr/enerpos

For more information:
http://tinyurl.com/Enerpos-FR-RE

Architectural Design Concept

Passive techniques: Cross natural ventilation (2 building wings orientated to be exposed to the summer thermal breezes), native plants around the building
Solar shading of all windows and walls
Insulation of the roof (+ BIPV over-roof)

Measured Energy Production and Consumption:

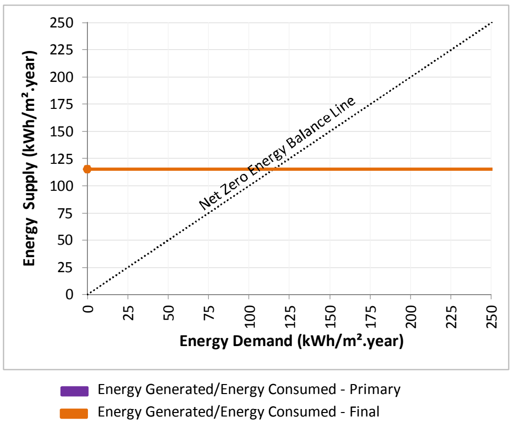
These data compare the overall energy consumption with the total energy generated though renewable energy onsite.

Energy Demand (kWh/m².year)
Electricity
Final: 11602
Primary: 38288

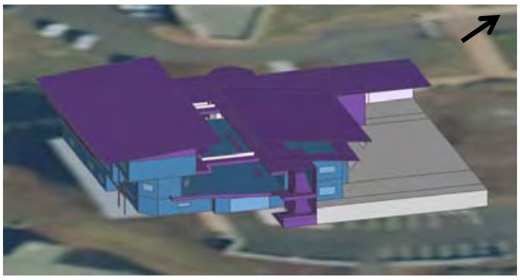
Energy Supply (kWh/m².year)
Renewable Energy
Final: 115
Primary: 380

Source to Site Conversion Factor (Electricity): 3.3

In the graph ***Final Energy Demand*** *is the sum of all delivered energy (kWk/m².year) obtained by summing all energy carriers.* ***Final Energy Supply*** *is the sum of all energy generated on site from renewable sources. The Primary Energy Demand and Primary Energy Credit have been calculated based upon the Primary Energy Conversion Factors for each energy carrier for this location.*



EnergyPlus Model



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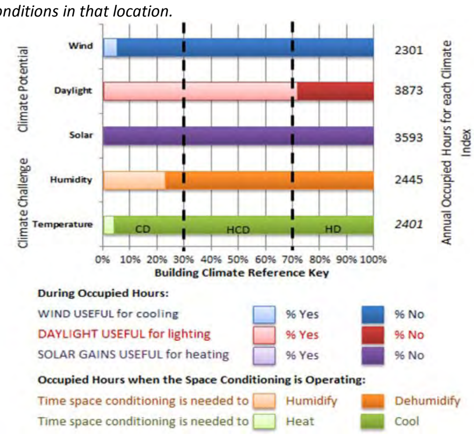

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H - Heating
L - Lighting
V - Ventilation
C - Cooling
P - Plug Load
W - Water Heating
E - Energy Export

Construction

Walls - Construction Elements

Facing Solar Noon

U-value (W/m² ºC) 3.79

Solar Absorptivity 0.40

Concrete (20 cm) + Solar shading

East

U-value (W/m² ºC) 0.90

Solar Absorptivity 0.40

Concrete (20 cm) + Insulation (… cm of mineral wool) + Wooden siding

Facing Polar Direction

U-value (W/m² ºC) 3.79

Solar Absorptivity 0.40

Concrete (20 cm) + Solar shading

West

U-value (W/m² ºC) 0.90

Solar Absorptivity 0.40

Concrete (20 cm) + Insulation (… cm of mineral wool) + Wooden siding

Roofs

U-value (W/m² ºC) 0.27

Solar Absorptivity 0.80

Concrete + Insulation (10 cm of polystyrene) + BIPV over-roof

Ground floor

U-value (W/m² ºC) 1.08

Windows - Construction Elements

Solar noon

U-value (W/m² ºC) 5.90

g-value 0.87

Saint-Gobain SGG STADIP Clear

East

U-value (W/m² ºC)

g-value

Polar direction

U-value (W/m² ºC) 5.90

g-value 0.87

Saint-Gobain SGG STADIP Clear

West

U-value (W/m² ºC)

g-value

Air permeability (m³/m²h@50pa)

Air permeability is the total building air leakage (m3.h-1) per m2 of building envelope at a reference pressure difference of 50 Pa.

As Built

Compactness (m-1)

Passive Approaches:

Passive design techniques or solutions are design measures that require no direct purchased energy input. These design measures include optimisation of solar energy collection, storage and shading, plus natural ventilation and advanced day lighting measures. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of passive measures for this climate did not need to include this particular measure.

Heat Flow (W/ºC)

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U-value (W/ºC)

Heat Flow %

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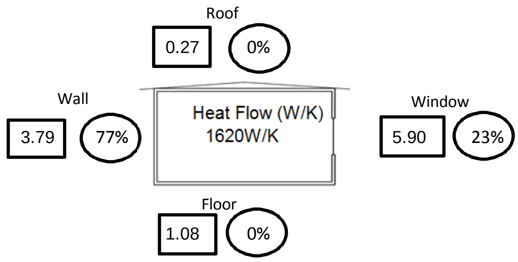


Heating

Cooling

Natural Ventilation

Porosity of main facade : 30% (PERENE requirement : 20%), louvers

Green Roof/Façade

Vegetalisation of the facade to avoid overheat of entering air, vegetalised patio on top of an underground parking, use of native plants to avoid plant care

Sunshading

Main facades (North and South) are solar protected with wooden strips that were sized with SketchUp and optimized with daylight simulation (Daysim)

Daylight Systems

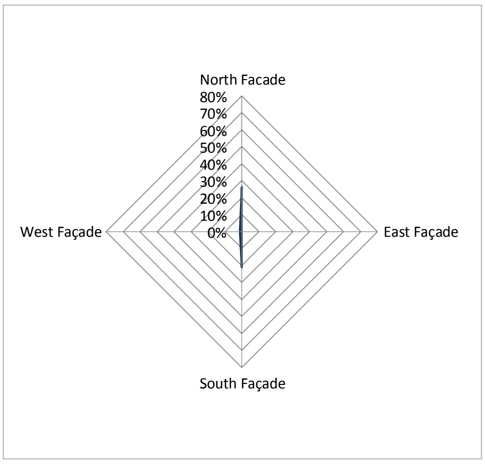
High value of porosity combined with solar shadings

Daylight autonomy in classrooms in about 90%

Window Distribution Information

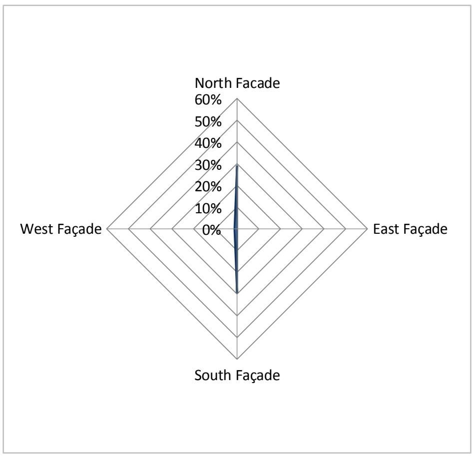
Distribution of Window Areas per Façade

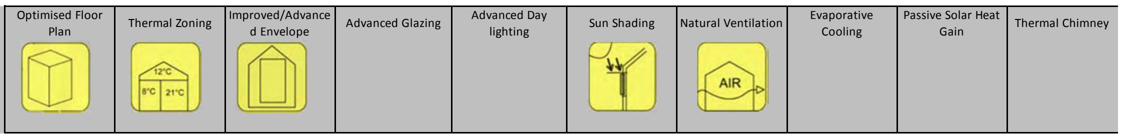
In Passive design, the orientation of the windows and their size has an extreme effect on the heating, cooling and the daylight harvesting potential of the building. This graph enables simple comparison of these properties for each climate and building type.



Façade Porosity - Percentage of Openings per Façade

In Passive Design, the orientation of the openings for Natural Ventilation is a response to the wind and the site. This graph enables a simple comparison of the porosity of each façade for each climate and building type.





Energy Efficiency Systems:

Energy efficient technologies are specific equipment and appliances that focus on reducing the use of energy, in the building, through more efficient means. These energy efficient technologies are used in harmony with the passive design to lower the overall energy consumption of the building. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular system.

System Design Parameters

Outside Air Requirements per Person (L/s-p)
xxx

Appliances / Plug Loads
Power Density Installed (W/m²) : 16

Artificial Lighting
Power Density Installed (W/m²) : 3,7 W/m²

Computer Network
Power Density Installed (W/m²) : 1.45374449
Datacentre ? No

Internal Environmental Systems and Domestic Hot Water

This section describes how the design team has provided for the internal space conditioning. Central systems place the heating, cooling and ventilation equipment in a separate space from the occupied rooms. The heating or cooling of the rooms requires a distribution system taking heat to or away from the occupied rooms using water (hydronic) or air. Distributed systems have separate heating, cooling and possibly ventilation equipment installed for each space.

Cooling

Central Plant	Yes
Distributed Plant	No
Openable Windows	See Passive Systems
Ceiling Fans	Yes
Hydronic distribution	No
Air distribution	Yes

Description
VRV air-conditioning (only for offices & computer rooms) - cooling period: 6 weeks/y

Heating

Central Plant	Yes
Distributed Plant	No
Hydronic distribution	No
Air distribution	No

Description

Ventilation System

Heat Recovery Type	No
Central Air supply	Yes
Local Air Recirc plus Central Fresh Air	Yes

Description

DHW - Domestic Hot Water
Solar?
Waste Water Heat Recovery?
Gas?
Electrical?
Other?

Description

Control Systems

The critical feature of a successful ultra low energy building is the user interaction. Without control systems that are responsive to user needs and easily understood successful operation is extremely difficult.

Lighting
BMS for exterior lighting (timetable) + 2 hours timers for interior lighting in the classrooms.

HVAC
BMS: timetable, individual control in each offices of the set temperature

Energy Storage
Latent Storage?
Fuel Cell?
Compressed Air?

User Interactions
User Manual Provided? yes

Description
Users can control the ciling fans (nearly one ceiling fan/ pers in the offices) and all windows are openable manually. The lighting is also manual except for the classrooms where there is a 2 hours timer in case the users forget to turn off the lights. The VRV system functions on timetable.

Innovative Technologies
The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular technology.

Energy Reduction Measures for Plug Loads and Appliances
eg. Elevator : reduction of half the consumption with stand-by mode on (thanks to the measured data)

Energy Storage

Other
Ceiling fans in all rooms and offices (1/10m²)

HVAC Systems
VRV system for AC + split systems in the technical rooms

Artificial Lighting
Offices : mood lighting (100 Lux) + LED desk lamps (>300 Lux on the work area) 3,7 W/m²
Classrooms : 7,3 W/m²

Computer Management
Theory : computers delocalized in a technical room - not realized yet

Control of Systems
Building Management System

Energy Efficient Lighting	Advanced Lighting Controls	Efficient Office Equipment	Efficient Appliances	Efficient HVAC Equipment	Earth Tube Heat Exchanger	Thermal Storage	Hot Water Conservation	Radiant Structure	Monitoring & LoadManagem.	Heat Recovery

Energy Supply and Integration of Renewable Energy:

"By definition, a renewable energy source is a fuel source that can be replenished in a short amount of time. (American Society Of Heating, Refridgerating and Air-Conditioning Engineers, 2006)" Through the use of these replenishing energy sources, the annual energy demand of an already low-energy building can be offset through the renewable energy generation. Renewable energy sources are converted to energy using renewable energy generation technologies or solutions. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy supply and integration of renewable energy for this climate did not need to include this particular measure.

Electricity Production

Photovoltaic (PV)	Yes
Building Integrated PV?	The PV panels are integrated
Ground mounted	No
Roof mounted	yes
Position	Fixed
Tilt (angle)	9°
Azimuth	PV1 : -166° North / PV2 : 14° North
Technology	Polycristalline cells
Nominal Power (kWp)	50
Area (m²)	PV1 : 219 m² / PV2 : 146 m² >> total: 365m²
Yield (kWh/m².year)	70
Expected generation (kWh)	77000.00
Measured generation (kWh)	50000.00

Wind Turbine
Position
Number of Turbine
Technology
Nominal Power (kWp)
Energy Production (kWh/m².year)

Solar Water Heating

Hot Water
Solar Thermal
Technology
Position
Area (m²)
Production (kWh/m².year)
Annual % of Hot Water

Combined (Cooling) Heat and Power

Combined (Cooling) Heat and Power
Type
Fuel
Efficiency (%)
Electricity
Water Heating
Space Heating
Cooling
Production (kWh/m².year)
Electricity
Water Heating
Space Heating
Cooling

Renewable Production of Heating and Cooling

Heating Equipment There is no active heating system installed in the building.

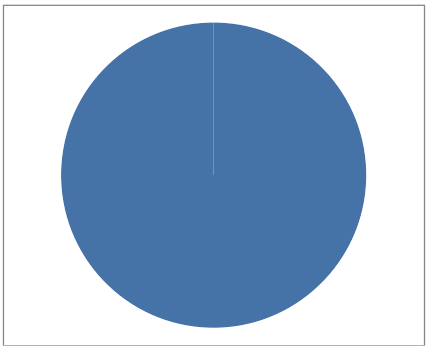
Technology

Power
Efficiency (%)
Production (kWh/m².yr)
Annual % of Heating

Cooling Equipment There is no active cooling system installed in the building.

Technology

Power
Efficiency (%)
Production (kWh/m².year)
Annual % of Cooling



This graph shows the expected proportion of generation (kWh/m²) of energy produced by the various renewable energy sources based on design calculations.

PV Array	Onsite Wind Turbine	Boiler	CHP	Use of offsite Green Power	Solar Thermal Hot Water	Solar Thermal Space Heating	Solar Cooling System	PV/Thermal Array
								

References
American Society of Heating, Refridgerating and Ait-Conditioning Engineers. Ashrae Green Guide: The Design, Construction, and Operating of Sustainable Buildings USA: Elsevier 2006.
Belleri, Annamaria, Assunta Napolitano, and Roberto Lollini. "Net Zeb Evaluation Tool - User Guide " (2012).

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Funding
Source and Type of Funding
General council of La Reunion (4M€) ; City of Saint Pierre (800 000€ ; land contribution) ; Regional council of La Reunion

Principal Actors
University of La Reunion (client) ; Thermal Engineer Office

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This project has been organised under the framework of two International Energy Agency implementing agreements: Solar Heating and Cooling and Energy Conservation in Buildings and Community Systems. For more information please visit: www.iea-shc.org/task40

Kleehäuser

Net Zero Energy Building Overview

Passive house with very low heat demand following the idea of the 2000 Watt society. Intensive use of differnet renewables energy sources and CHP

This is one of thirty case study factsheets collected by participants in Subtask C of the IEA 'Net Zero Energy Buildings' (NZEBs) research project. Subtask C focuses on documenting and analysing current NZEBs design and technologies. The case studies form the basis of a proposed Source Book describing NZEB Solution Sets and guidelines and documenting monitored performance and lessons learned.

Completion Date
Jun-05

Location
Paul-Klee Str. 6
79100 Freiburg
Baden-Württemberg
Germany

Latitude	Longitude
North	West
47°58'36.47"	7°49'18.93"

Climate Challenge Definition
Buildings are either cooling dominated, heating dominated or mixed heating and cooling dominated. A building is climate dominated if one of a reference buildings space conditioning processes is 70% or greater of the total space conditioning load.

Climate Challenge
Heating & Cooling Dominated

Building Type
Residential

Site Context
Suburban Site - single family houses 1-2 storey spaced 3-5m apart

Net Floor Area (m²)
2520

Conditioned Floor Area (m²)
2520

Occupancy (m^2 per Person)
0.029761905

Number of Storeys
3 and 5

Cost US$/(Net) m² Floor Area
1,923

Cost US$/(Net) m² typical similar building

For more information
www.kleehaeuser.de

Google earth
http://tinyurl.com/Kleehauser

Architectural Design Concept

The two buildings have a very compact structure to lower the heated volume. Hence the stairs are outside of this volume (acces balconies). The surface is very good insulated and triple glazed windows are used. The passive solar design is supported by an assymetric window arrangement. Extensively glazed facades facing south optimise passive solar energy gains in winter. Cantilevered balconies oriented towards the south and extending up to two meters provide shade and prevent overheating in summer. The remaining facades feature a smaller degree of window surfaces. The layout follows the same principle: living spaces are generally oriented towards the south and other areas are on the northern side of the buildings.

Measured Energy Production and Consumption:

These data compare the overall energy consumption with the total energy generated though renewable energy onsite.

Energy Demand (kWh/m².year)

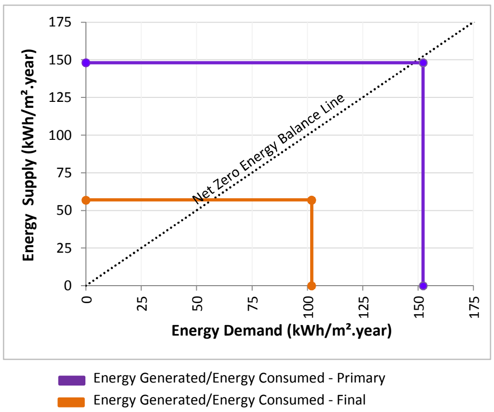
	Electricity	Natural Gas
Final:	26.73	75.25
Primary:	69.50	82.775

Energy Supply (kWh/m².year)

	Renewable Energy
Final:	56.94
Primary:	148.04

Source to Site Conversion Factor (Electricity): 2.6

*In the graph **Final Energy Demand** is the sum of all delivered energy (kWk/m².year) obtained by summing all energy carriers. **Final Energy Supply** is the sum of all energy generated on site from renewable sources. The Primary Energy Demand and Primary Energy Credit have been calculated based upon the Primary Energy Conversion Factors for each energy carrier for this location.*



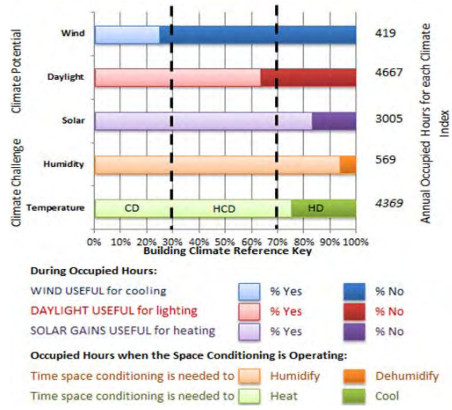
EnergyPlus Model

This model has been created by the STC participants to assist in the standardised analysis of the performance of this building. It calculates internal temperatures and energy consumption and production.

Key to colours:
Blue = Outside (sun and wind exposed)
Yellow = Ground (floors and basement walls)
Purple = Building shading
Grey = Site shading (ground surfaces)

Climate Analysis

The building climate method uses a reference residential building built to the local building code minimum insulation requirements to test the interaction between a building built in a location and the external climatic conditions in that location.



The Climate Challenge for the building designer is HEATING DOMINATED (HD) if the green bars meet between 70 and 100%; it is COOLING DOMINATED (CD) if they meet between 0 and 30%; it is MIXED HEATING AND COOLING (HCD) if they meet between 30 and 70%.

The icons at the end of each section provide a visual key for the reader who wants to quickly organize all the case studies. They symbolically summarize the individual technology solution sets used in each building. Please see the key to the right for more information

***H** - Heating*	***P** - Plug Load*
***L** - Lighting*	***W** - Water Heating*
***V** - Ventilation*	***E** - Energy Export*
***C** - Cooling*	

Construction

Walls - Construction Elements

Facing Solar Noon

U-value (W/m² ºC) 0.17

Solar Absorptivity

On the balcony and porch fronts white fiber cement panels alternate with triple-glazed timber frame windows.

East

U-value (W/m² ºC) 0.17

Solar Absorptivity

Externally reinforced concrete walls or infilled wood stud walls insulated with 30 cm mineral wool. Wood planks or untreated steel plates dress the gables.

Facing Polar Direction

U-value (W/m² ºC) 0.17

Solar Absorptivity

On the balcony and porch fronts white fiber cement panels alternate with triple-glazed timber frame windows.

West

U-value (W/m² ºC) 0.17

Solar Absorptivity

Externally reinforced concrete walls or infilled wood stud walls insulated with 30 cm mineral wool. Wood planks or untreated steel plates dress the gables.

Roofs

U-value (W/m² ºC) 0.11

Solar Absorptivity

Reinforced concrete of flat roof is insulated with 30 cm of expanded polystyrene (EPS).

Ground floor

U-value (W/m² ºC) 0.18

Thermal envelope of basement is insulated with rigid foam boards.

Windows - Construction Elements

Solar noon

U-value (W/m² ºC) 0.98

g-value 0.60

triple glazed windwows

East

U-value (W/m² ºC) 0.98

g-value 0.6

triple glazed windwows

Polar direction

U-value (W/m² ºC) 0.98

g-value 0.60

triple glazed windwows

West

U-value (W/m² ºC) 0.98

g-value 0.60

triple glazed windwows

As Built

Air permeability is the total building air leakage ($m^3.h^{-1}$) per m^2 of building envelope at a reference pressure difference of 50 Pa.

0

0.6

Compactness (m-1)

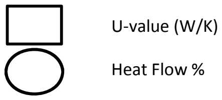
0.38

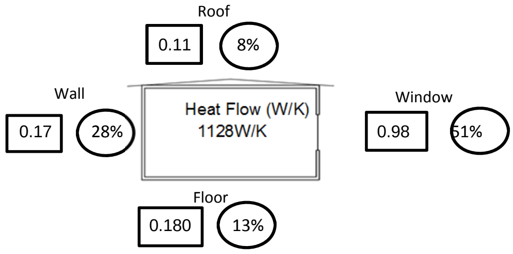
Passive Approaches:

Passive design techniques or solutions are design measures that require no direct purchased energy input. These design measures include optimisation of solar energy collection, storage and shading, plus natural ventilation and advanced day lighting measures. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of passive measures for this climate did not need to include this particular measure.

Heat Flow (W/ºC)

High resistance to heat flow (high R-value, low U-value) is important in climate where energy using services are used to maintain a large temperatures difference between indoors and outdoors.





Solution Sets are: A set of passive, energy efficiency, and/or renewable energy solutions used to mitigate or lessen the building challenges and achieve the design goal.

Building Challenge Solution Set *- The set of solutions used to lower the energy needed by a particular building challenge.*

Whole Building Solution Set *- The set of solutions used to lower the energy consumption of the whole building.*

Heating

Thermal Mass

In some apartments loam buffers moisture

Heat Recovery

Individually controlled air by the ventialtion system ensures a comfortable indoor climate. Directly at each apartment entrance door is a switch that can be used to regulate the air flow individually and in three stages (85%)

An improved thermal insulation standard of the distribution pipelines of the ventilation system reduces heat losses

Cooling

Sunshading

South facades are solar protected with balconies and/or blinds

Natural Ventilation

Normal option to open the windows

Daylight Systems

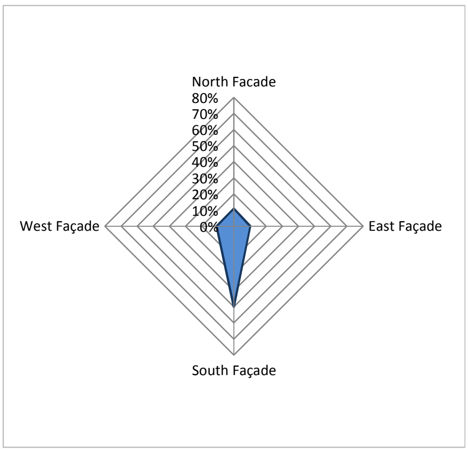
Windows

High value of porosity combined with solar shadings

Window Distribution Information

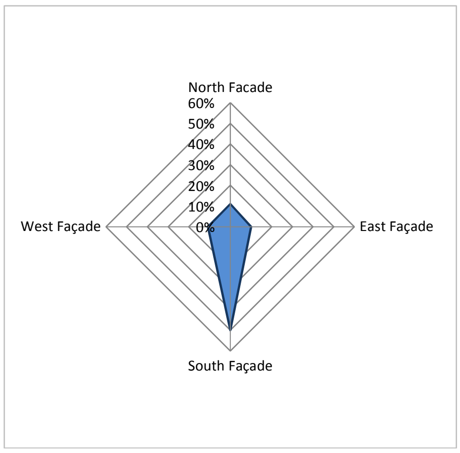
Distribution of Window Areas per Façade

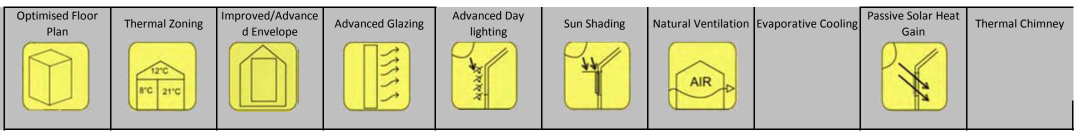
In Passive design, the orientation of the windows and their size has an extreme effect on the heating, cooling and the daylight harvesting potential of the building. This graph enables simple comparison of these properties for each climate and building type.



Façade Porosity - Percentage of Openings per Facade

In Passive Design, the orientation of the openings for Natural Ventilation is a response to the wind and the site. This graph enables a simple comparison of the porosity of each façade for each climate and building type.





Energy Efficiency Systems:

Energy efficient technologies are specific equipment and appliances that focus on reducing the use of energy, in the building, through more efficient means. These energy efficient technologies are used in harmony with the passive design to lower the overall energy consumption of the building. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular system.

System Design Parameters

Outside Air Requirements per Person (L/s-p)
Indoor air changed 1/2 per hour

Appliances / Plug Loads
Power Density Installed (W/m²) : No information available

Artificial Lighting
Power Density Installed (W/m²) : Unknown

Computer Network
Power Density Installed (W/m²) : Unknown
Datacentre ? No

Internal Environmental Systems and Domestic Hot Water

This section describes how the design team has provided for the internal space conditioning. Central systems place the heating, cooling and ventilation equipment in a separate space from the occupied rooms. The heating or cooling of the rooms requires a distribution system taking heat to or away from the occupied rooms using water (hydronic) or air. Distributed systems have separate heating, cooling and possibly ventilation equipment installed for each space.

Cooling

Central Plant	No
Distributed Plant	No
Openable Windows	Yes
Ceiling Fans	No
Hydronic distribution	No
Air distribution	No

Description
No cooling plant

Heating

Central Plant	Yes
Distributed Plant	No
Hydronic distribution	No
Air distribution	No

Description
A natural gas-powered cogeneration plant (capacity 14 kWel / 30 kWth) generates electricity for the own small electricity grid and covers the heat demand of the two houses. 61.2 m² of flat plate collectors feed heat into a small heat grid between the two houses. A solar heat storage has a total volume of 3900 liters.

Ventilation System

Heat Recovery Type	Yes
Central Air supply	Yes
Local Air Recirc plus Central Fresh Air	Yes

Description
Ventilation with 85% heat recovery

DHW - Domestic Hot Water

Solar?	Yes
Waste Water Heat Recovery?	No
Gas?	No
Electrical?	Yes
Other?	Yes

Description
Solar thermal system and a CHPP

Control Systems

The critical feature of a successful ultra low energy building is the user interaction. Without control systems that are responsive to user needs and easily understood successful operation is extremely difficult.

Lighting
Description
no information available because of residential use

HVAC
Description
HVAC is controlled by normal systems(related to the CHPP). By a switch in each apartment the air flow can be adjusted (to conserve moisture when absent)

Energy Storage

Latent Storage?	No
Fuel Cell?	No
Compressed Air?	No

User Interactions
User Manual Provided? yes

Description
User related by efficient appliances

Innovative Technologies

The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular technology.

Energy Reduction Measures for Plug Loads and Appliances
Partly efficient appliances, efficient elevator, switcher for the ventilation system in each appartment

Energy Storage
Thermal buffer storage (3900 l)

Other
Common used refrigerators and washing mashines with hot water tab in cellar rooms

HVAC Systems
small scale CHP

Artificial Lighting
LEDs and very efficient light bulbs

Computer Management

Control of Systems
Building Management System

Energy Efficient Lighting	Advanced Lighting Controls	Efficient Office Equipment	Efficient Appliances	Efficient HVAC Equipment	Earth Tube Heat Exchanger	Thermal Storage	Hot Water Conservation	Radiant Structure	Monitoring & LoadManagem.	Heat Recovery

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Funding
Source and Type of Funding
The two buildings were built by a assembly and hence funded completly private.

Principal Actors
Main actor was a building assembly. Engineers forced the project to a zeroHaus-certificate (consumptions are equalized by renewables)

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This project has been organised under the framework of two International Energy Agency implementing agreements: Solar Heating and Cooling and Energy Conservation in Buildings and Community Systems. For more information please visit: www.iea-shc.org/task40

Energy Supply and Integration of Renewable Energy:

"By definition, a renewable energy source is a fuel source that can be replenished in a short amount of time. (American Society Of Heating, Refridgerating and Air-Conditioning Engineers, 2006)" Through the use of these replenishing energy sources, the annual energy demand of an already low-energy building can be offset through the renewable energy generation. Renewable energy sources are converted to energy using renewable energy generation technologies or solutions. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy supply and integration of renewable energy for this climate did not need to include this particular measure.

Electricity Production

Photovoltaic (PV)	Yes	
Building Integrated PV?	No	Off-site
Ground mounted	No	one
Roof mounted	Yes	???
Position	Fixed	6300 kW
Tilt (angle)	30°	26.52
Azimuth	0° South	
Technology	Polycrstalline cells	
Nominal Power (kWp)	23 kWp	
Area (m²)	202 m²	
Yield (kWh/m².year)	43	
Expected generation (kWh)	23000	
Measured generation (kWh)	22529	

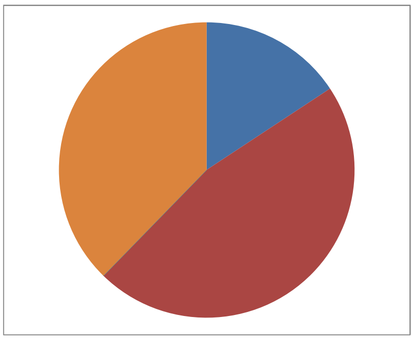
Solar Water Heating

Hot Water		
Solar Thermal	Yes	natural gaspowered CHP
Technology	flat plate collectors	Gas
Position	on the roof	ca. 90 %
Area (m²)	56.4	0.3
Production (kWh/m².year)	efficiency measure	0.3
Annual % of Hot Water	ca. 70 %	0.3
		0
		21
		21,48 kWh/m²y
		71,51 kWh/m²y
		see above
		no
		0.3

Production of Heating and Cooling

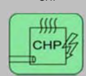
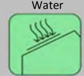
Heating Equipment		
	Others	
Technology	natural gaspowered CHP	0
Power	capacity 14 kWel / heat output 30 kWth	
Efficiency (%)	ca. 90 %	
Production (kWh/m².yr)	7151.0	
Annual % of Heating	0 % because ist natural gas	

Cooling Equipment	There is no active cooling system installed in the building.
Technology	
Power	
Efficiency (%)	
Production (kWh/m².year)	
Annual % of Cooling	



This graph shows the expected proportion of generation (kWh/m²) of energy produced by the various renewable energy sources based on design calculations.

- Solar heating
- Heating energy production
- Cooling energy production
- Energy produced from Photovoltaic Panels
- Energy produced from on site Wind Turbines
- Hybrid energy production

PV Array	Onsite Wind Turbine	Boiler	CHP	Use of offsite Green Power	Solar Thermal Hot Water	Solar Thermal Space Heating	Solar Cooling System	PV/Thermal Array
								

References
American Society of Heating, Refridgerating and Air-Conditioning Engineers. Ashrae Green Guide: The Design, Construction, and Operating of Sustainable Buildings USA: Elsevier 2006.
Belleri, Annamaria, Assunta Napolitano, and Roberto Lollini. "Net Zeb Evaluation Tool - User Guide " (2012).

Leaf House

Net Zero Energy Building Overview

The Leaf House inspiration is the Italian rural house an autonomous and sustainable microcosm where every resource was exploited and nothing wasted. Its main features are: North South orientation, high thermal mass boundary walls, and glazed surfaces on the South facade. Transforming a traditional morphology into a Net ZEB, integrating the best available technologies, makes the integration of this building in peripheral areas of our cities easier.

This is one of thirty case study factsheets collected by participants in Subtask C of the IEA 'Net Zero Energy Buildings' (NZEBs) research project. Subtask C focuses on documenting and analysing current NZEBs design and technologies. The case studies form the basis of a proposed Source Book describing NZEB Solution Sets and guidelines and documenting monitored performance and lessons learned.

Completion Date
Jun-05

Location
Petrarca (via F. Petrarca)
Rosora
Ancona
Italy

Latitude	Longitude
North	West
43° 28' 43" N	13° 04' 03" E

Climate Challenge Definition
Buildings are either cooling dominated, heating dominated or mixed heating and cooling dominated. A building is climate dominated if one of a reference buildings space conditioning processes is 70% or greater of the total space conditioning load.

Climate Challenge
Heating & Cooling Dominated

Building Type
Residential

Site Context
Village, Urban Edge - 2-5 storey buildings with at most narrow lanes between adjacent buildings and street widths of 20 - 40m

Net Floor Area (m²)
477

Conditioned Floor Area (m²)
477

Occupancy (m^2 per Person)
0.025

Number of Storeys

Cost US$/(Net) m² Floor Area
943,600

Cost US$/(Net) m² typical similar building

704,200

For more information
http://www.leafcommunity.com/?page_id=5&lang=en

Google earth
http://tinyurl.com/LeafHouseAlbum

Architectural Design Concept

The Leaf House is N-S oriented and presents a compact shape; to increase its thermal performance, the North facade is set into a bank, enhancing thermal exchange with the ground. On the South facade, the glazed surfaces allow for good daylight in the building, and for enhancing the useful solar gains useful in Winter.
During the hotter season a large photovoltaic roof, integrated into the envelope protects the building from the sun, by overhanging on the South facade, so as to shadow the upper level of the building (3rd level). The second level is shadowed by a canopy made out of 7 thermal modules; the overhang of the balcony at the second level, provides shadow to the first level. These overhangs have been designed using dynamic simulations which have been used to design the optimized control of the building services through the building automation system, reducing not only the energy consumption of the building but its impact on the grid.

Measured Energy Production and Consumption:

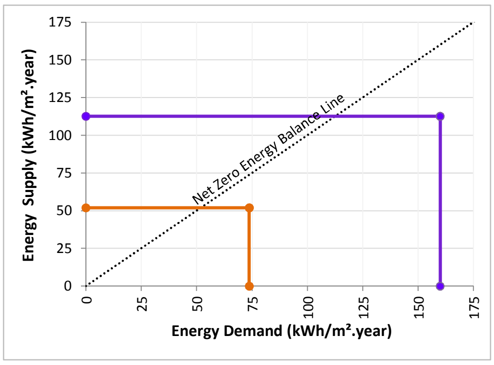
These data compare the overall energy consumption with the total energy generated though renewable energy onsite.

Energy Demand (kWh/m².year)
Electricity
Final: 73.75
Primary: 160.05

Energy Supply (kWh/m².year)
Renewable Energy
Final: 51.89
Primary: 112.60

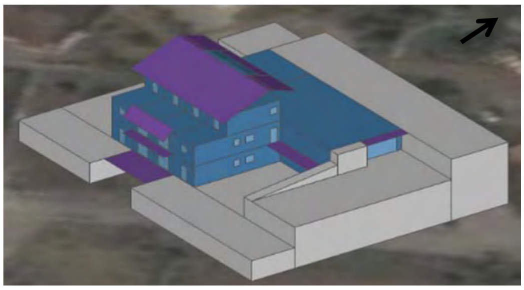
Source to Site Conversion Factor (Electricity): 2.2

In the graph ***Final Energy Demand*** *is the sum of all delivered energy (kWk/m².year) obtained by summing all energy carriers.* ***Final Energy Supply*** *is the sum of all energy generated on site from renewable sources. The Primary Energy Demand and Primary Energy Credit have been calculated based upon the Primary Energy Conversion Factors for each energy carrier for this location.*



Energy Generated/Energy Consumed - Primary
Energy Generated/Energy Consumed - Final

EnergyPlus Model

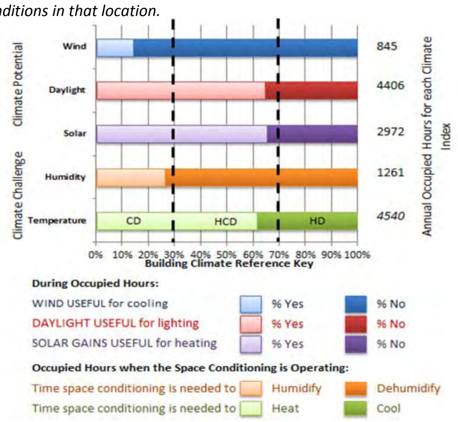


This model has been created by the STC participants to assist in the standardised analysis of the performance of this building. It calculates internal temperatures and energy consumption and production.

Key to colours:
Blue = Outside (sun and wind exposed)
Yellow = Ground (floors and basement walls)
Purple = Building shading
Grey = Site shading (ground surfaces)

Climate Analysis

The building climate method uses a reference residential building built to the local building code minimum insulation requirements to test the interaction between a building built in a location and the external climatic conditions in that location.



The Climate Challenge for the building designer is HEATING DOMINATED (HD) if the green bars meet between 70 and 100%; it is COOLING DOMINATED (CD) if they meet between 0 and 30%; it is MIXED HEATING AND COOLING (HCD) if they meet between 30 and 70%.

The icons at the end of each section provide a visual key for the reader who wants to quickly organize all the case studies. They symbolically summarize the individual technology solution sets used in each building. Please see the key to the right for more information

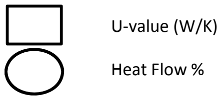
H *- Heating*
L *- Lighting*
V *- Ventilation*
C *- Cooling*
P *- Plug Load*
W *- Water Heating*
E *- Energy Export*

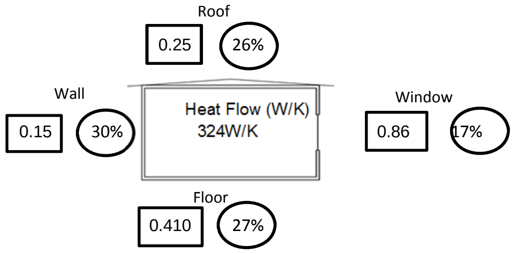
Passive Approaches:

Passive design techniques or solutions are design measures that require no direct purchased energy input. These design measures include optimisation of solar energy collection, storage and shading, plus natural ventilation and advanced day lighting measures. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of passive measures for this climate did not need to include this particular measure.

Heat Flow (W/ºC)

High resistance to heat flow (high R-value, low U-value) is important in climate where energy using services are used to maintain a large temperatures difference between indoors and outdoors.





Solution Sets are: A set of passive, energy efficiency, and/or renewable energy solutions used to mitigate or lessen the building challenges and achieve the design goal.

Building Challenge Solution Set *- The set of solutions used to lower the energy needed by a particular building challenge.*

Whole Building Solution Set - *The set of solutions used to lower the energy consumption of the whole building.*

Heating

Thermal Mass

Walls and floors have an high thermal mass

Sunspaces

Wide windows on the southern facade allow solar radiation to heat up the building

Heat Recovery

Preconditioning in an underground duct of the fresh air

Cooling

Sunshading

The roof, solar thermal panels and the balcony behave like solar shields

Green Roof/Façade

Ventilated roof reduces the solar loads during summer

Ground Cooling

Preconditioning in an underground duct of the fresh air

Daylight Systems

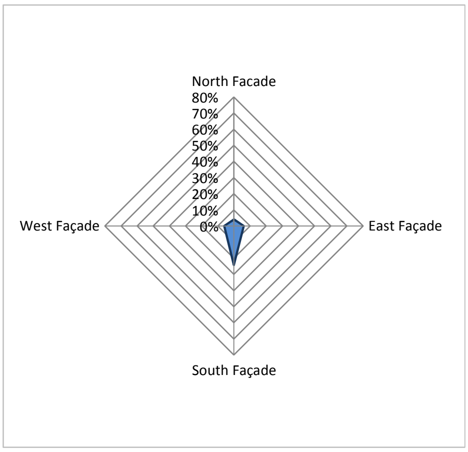
Solar tubes

The two apartments of the ground floor and the two apartments of the first floor have a bathroom not provided with windows: solar tubes allows natural light to light these rooms

Window Distribution Information

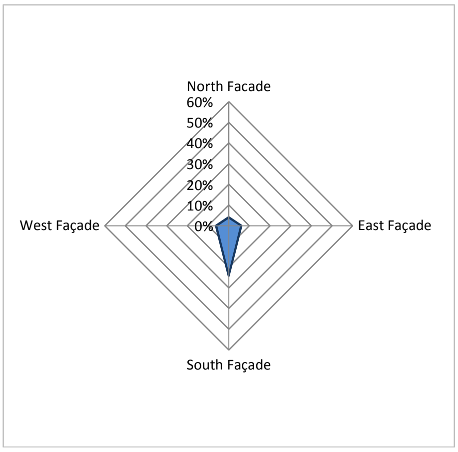
Distribution of Window Areas per Façade

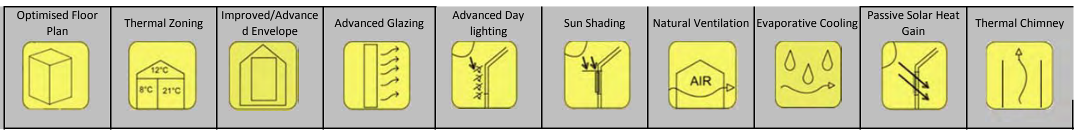
In Passive design, the orientation of the windows and their size has an extreme effect on the heating, cooling and the daylight harvesting potential of the building. This graph enables simple comparison of these properties for each climate and building type.



Façade Porosity - Percentage of Openings per Facade

In Passive Design, the orientation of the openings for Natural Ventilation is a response to the wind and the site. This graph enables a simple comparison of the porosity of each façade for each climate and building type.





Construction

Walls - Construction Elements

Facing Solar Noon

U-value (W/m² ºC) 0.15

Solar Absorptivity

2cm Plaster, 30cm Poroton Brick, 18cm Polystyrene Rofix EPS 100, 2cm Plaster

East

U-value (W/m² ºC) 0.15

Solar Absorptivity

Facing Polar Direction

U-value (W/m² ºC) 0.15

Solar Absorptivity

124 of them below grade

West

U-value (W/m² ºC) 0.15

Solar Absorptivity

Roofs

U-value (W/m² ºC) 0.25

Solar Absorptivity

3x1cm Plasterboard Pregyplac, 10cm woodfibre, 10 cm rockwool, 4cm airspace, 2cm Pinewood

Ground floor

U-value (W/m² ºC) 0.41

2cm ceramic tile, 5cm concrete, 4cm polyurethane, 5cm concrete, 0.5cm bitumen, 20cm concrete, 19cm air, 11.80cm gravel

Windows - Construction Elements

Solar noon

U-value (W/m² ºC) 0.86

g-value 0.61

Internorm, Edition, double glazing filled with argon

East

U-value (W/m² ºC) 0.86

g-value 0.61

Polar direction

U-value (W/m² ºC) 0.86

g-value 0.61

West

U-value (W/m² ºC) 0.86

g-value 0.61

As Built

Air permeability is the total building air leakage ($m^3.h^{-1}$) per m^2 of building envelope at a reference pressure difference of 50 Pa.

0

1.91

Compactness (m-1)

0.47

Energy Efficiency Systems:

Energy efficient technologies are specific equipment and appliances that focus on reducing the use of energy, in the building, through more efficient means. These energy efficient technologies are used in harmony with the passive design to lower the overall energy consumption of the building. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular system.

System Design Parameters

Outside Air Requirements per Person (L/s-p)

Appliances / Plug Loads
Power Density Installed (W/m²) :

Artificial Lighting
Power Density Installed (W/m²) : Unknown

Computer Network
Power Density Installed (W/m²) : Unknown
Datacentre ? No

Internal Environmental Systems and Domestic Hot Water

This section describes how the design team has provided for the internal space conditioning. Central systems place the heating, cooling and ventilation equipment in a separate space from the occupied rooms. The heating or cooling of the rooms requires a distribution system taking heat to or away from the occupied rooms using water (hydronic) or air. Distributed systems have separate heating, cooling and possibly ventilation equipment installed for each space.

Cooling

Central Plant	Yes
Distributed Plant	No
Openable Windows	See Passive Systems
Ceiling Fans	No
Hydronic distribution	Yes
Air distribution	No

Description
Cooling provided by the radiant floor, cooling demand covered by an heat pump. An electric dehumidifier is switched on if the UR becomes critical (few hour a year)

Heating

Central Plant	Yes
Distributed Plant	No
Hydronic distribution	Yes
Air distribution	No

Description
Space heating (radiant floors) and domestic hot water demands are covered by an electric heat pump operating with three ground probes and by the heat produced from flat plate solar thermal collectors in the facade at first floor.

Ventilation System

Heat Recovery Type	Yes
Central Air supply	Yes
Local Air Recirc plus Central Fresh Air	No

Description
Entalpic

DHW - Domestic Hot Water

Solar?	Yes
Waste Water Heat Recovery?	No
Gas?	No
Electrical?	No
Other?	

Description
DHW is produced completely or partially (depending on the season) from seven flat solar thermal collectors.

Control Systems

The critical feature of a successful ultra low energy building is the user interaction. Without control systems that are responsive to user needs and easily understood successful operation is extremely difficult.

Lighting
Description

HVAC
Description

Energy Storage

Latent Storage?	No
Fuel Cell?	No
Compressed Air?	No

User Interactions
User Manual Provided? No

Description

Innovative Technologies
The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular technology.

Energy Reduction Measures for Plug Loads and Appliances
High efficiency appliances, stand by button

Energy Storage

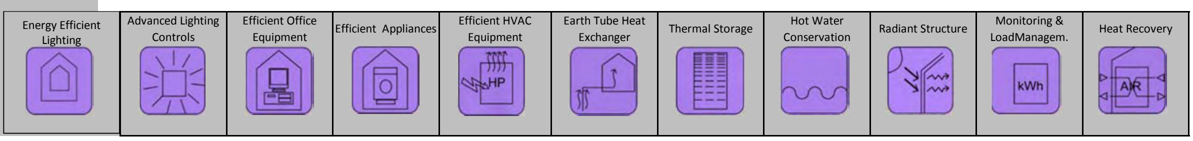
Other

HVAC Systems
Geothermal Heat Pump

Artificial Lighting
Fluorescent

Computer Management
Building Automation, remote monitoring

Control of Systems



Energy Supply and Integration of Renewable Energy:

"By definition, a renewable energy source is a fuel source that can be replenished in a short amount of time. (American Society Of Heating, Refridgerating and Air-Conditioning Engineers, 2006)" Through the use of these replenishing energy sources, the annual energy demand of an already low-energy building can be offset through the renewable energy generation. Renewable energy sources are converted to energy using renewable energy generation technologies or solutions. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy supply and integration of renewable energy for this climate did not need to include this particular measure.

Electricity Production

Photovoltaic (PV)	Yes	
Building Integrated PV?	Integrated roof	On-site
Ground mounted	No	
Roof mounted	Yes	
Position	Fixed	
Tilt (angle)	22°	
Azimuth	0°	
Technology	(115x) Shuco 175-SMG-S (Monocrystalline silicon)	
Nominal Power (kWp)	20.1	
Area (m²)	150 (0.31 m2/m2)	
Yield (kWh/m².year)	43	
Expected generation (kWh)	52	
Measured generation (kWh)	25650	

Solar Water Heating

Hot Water	
Solar Thermal	Yes
Technology	flat plate collectors Shuco Sol S
Position	Positioned in order to behave like solar shields for the first floor
Area (m²)	18.83
Production (kWh/m².year)	8.9
Annual % of Hot Water	63

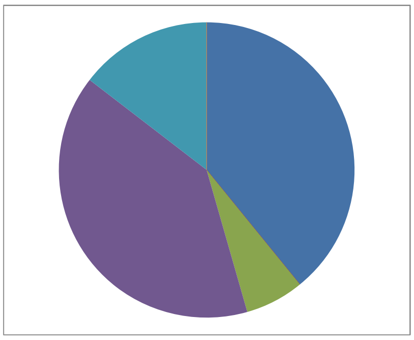
Production of Heating and Cooling

Heating Equipment

	Heat Pump	Ground / Water Source Heat Pump
Technology	Geothermal Heat Pump	3 vertical 100 m probes
Power	16.6	16.6
Efficiency (%)	4.6	4.6
Production (kWh/m².yr)	27.4	27.4
Annual % of Heating		

Cooling Equipment

	Heat Pump
Technology	Geothermal Heat Pump
Power	13
Efficiency (%)	4
Production (kWh/m².year)	20
Annual % of Cooling	100



This graph shows the expected proportion of generation (kWh/m²) of energy produced by the various renewable energy sources based on design calculations.

Solar heating
Heating energy production
Cooling energy production
Energy produced from Photovoltaic Panels
Energy produced from on site Wind Turbines
Hybrid energy production

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Funding
Source and Type of Funding
Project completely financed by Loccioni Group

Principal Actors
Architect, energy expert consultant, MEP

Author

Contact
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This project has been organised under the framework of two International Energy Agency implementing agreements: Solar Heating and Cooling and Energy Conservation in Buildings and Community Systems. For more information please visit: www.iea-shc.org/task40

References
American Society of Heating, Refridgerating and Air-Conditioning Engineers. Ashrae Green Guide: The Design, Construction, and Operating of Sustainable Buildings USA: Elsevier 2006.
Belleri, Annamaria, Assunta Napolitano, and Roberto Lollini. "Net Zeb Evaluation Tool - User Guide " (2012).

Pixel Building

Net Zero Energy Building Overview

The world's first carbon neutral office building - Intensive use of energy efficient measures, also includes renewable energy sources. Biogas plant, solar PV and wind turbines provide a significant portion of the building's energy. The building is also water self-sufficient. Highly sustainable materials selection, excellent indoor environment quality and ultra-low emissions building.

Completion Date
2010

Location
205 Queensberry St
Melbourne
Victoria
Australia

Latitude South	Longitude West
37° 48' 16" S	144° 57' 43" E

Climate Challenge Definition
Buildings are either cooling dominated, heating dominated or mixed heating and cooling dominated. A building is climate dominated if one of a reference buildings space conditioning processes is 70% or greater of the total space conditioning load.

Climate Challenge
Cooling Dominated

Building Type
Non-residential_Office

Site Context
Urban Centres - over 5 storey average height of neighbouring buildings, adjacent buildings touching, street widths 40+m

Net Floor Area (m²)
1084.6

Conditioned Floor Area (m²)
837.4

Occupancy (m² per Person)
14.3

Number of Storeys

Cost US$/(Net) m² Floor Area
4,556,548

Cost US$/(Net) m² typical similar building

3,500,000

Web Address
www.pixelbuilding.com.au

For more information:
http://tinyurl.com/Pixel-AU

This is one of thirty case study factsheets collected by participants in Subtask C of the IEA 'Net Zero Energy Buildings' (NZEBs) research project. Subtask C focuses on documenting and analysing current NZEBs design and technologies. The case studies form the basis of a proposed Source Book describing NZEB Solution Sets and guidelines and documenting monitored performance and lessons learned.

Architectural Design Concept

No more than 500 words - e,g, compact design with small highly insulated windows; passive solar design with narrow plan design open to Natural ventilation/solar gain and daylight;

Designed Energy Production and Consumption:

These data compare the overall energy consumption with the total energy generated though renewable energy onsite.

Energy Demand (kWh/m².year)

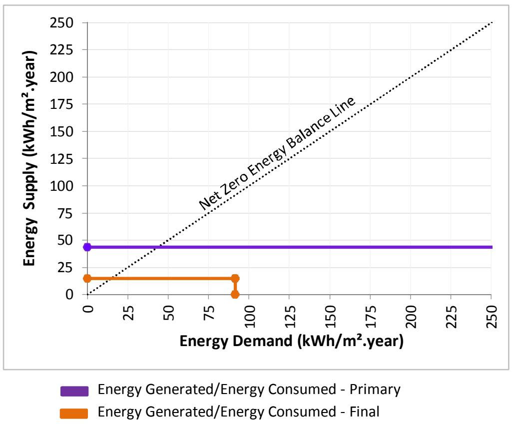
	Electricity	Natural Gas
Final:	57	35
Primary:	170	105

Energy Supply (kWh/m².year)

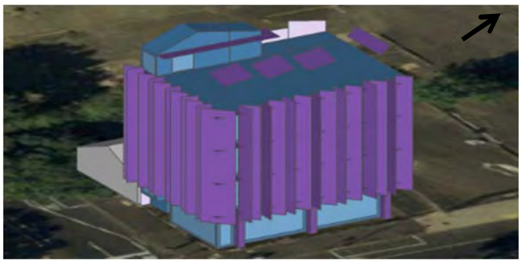
	Renewable Energy
Final:	15
Primary:	44

Source to Site Conversion Factor (Electricity): 3

In the graph ***Final Energy Demand*** *is the sum of all delivered energy (kWk/m².year) obtained by summing all energy carriers.* ***Final Energy Supply*** *is the sum of all energy generated on site from renewable sources. The Primary Energy Demand and Primary Energy Credit have been calculated based upon the Primary Energy Conversion Factors for each energy carrier for this location.*



EnergyPlus Model

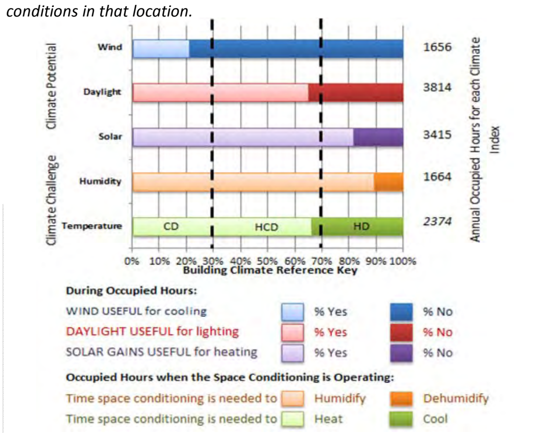


This model has been created by the STC participants to assist in the standardised analysis of the performance of this building. It calculates internal temperatures and energy consumption and production.

Key to colours:
Blue = Outside (sun and wind exposed)
Yellow = Ground (floors and basement walls)
Purple = Building shading
Grey = Site shading (ground surfaces)

Climate Analysis

The building climate method uses a reference non-residential building built to the local building code minimum insulation requirements to test the interaction between a building built in a location and the external climatic conditions in that location.



The Climate Challenge for the building designer is HEATING DOMINATED (HD) if the green bars meet between 70 and 100%; it is COOLING DOMINATED (CD) if they meet between 0 and 30%; it is MIXED HEATING AND COOLING (HCD) if they meet between 30 and 70%.

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H *- Heating*
L *- Lighting*
V *- Ventilation*
C *- Cooling*
P *- Plug Load*
W *- Water Heating*
E *- Energy Export*

Construction

Walls - Construction Elements

Facing Solar Noon
U-value (W/m² ºC)
Solar Absorptivity #VALUE!

East
U-value (W/m² ºC)
Solar Absorptivity #VALUE!

Facing Polar Direction
U-value (W/m² ºC)
Solar Absorptivity #VALUE!

West
U-value (W/m² ºC)
Solar Absorptivity #VALUE!

Roofs
U-value (W/m² ºC)
Solar Absorptivity #VALUE!

Ground floor
U-value (W/m² ºC)

Windows - Construction Elements

Solar noon
U-value (W/m² ºC)
g-value

East
U-value (W/m² ºC)
g-value

Polar direction
U-value (W/m² ºC)
g-value

West
U-value (W/m² ºC)
g-value

Air permeability (m³/m²h@50pa)
Air permeability is the total building air leakage (m3.h-1) per m2 of building envelope at a reference pressure difference of 50 Pa.

As Built

Compactness (m-1)

Passive Approaches:

Passive design techniques or solutions are design measures that require no direct purchased energy input. These design measures include optimisation of solar energy collection, storage and shading, plus natural ventilation and advanced day lighting measures. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of passive measures for this climate did not need to include this particular measure.

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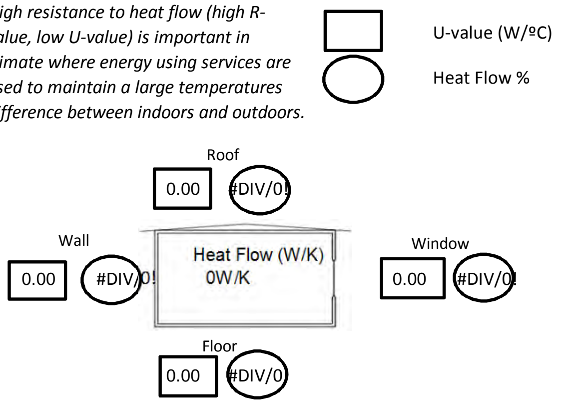


Solution Sets are: A set of passive, energy efficiency, and/or renewable energy solutions used to mitigate or lessen the building challenges and achieve the design goal.

Building Challenge Solution Set *- The set of solutions used to lower the energy needed by a particular building challenge.*

Whole Building Solution Set - *The set of solutions used to lower the energy consumption of the whole building.*

Heating

Heat Recovery

Air is exhausted from the building via the air handling unit through the toilet exhaust, photocopy exhaust and the spill air grilles. All of these exhausts are combined as part of a single exhaust system that is drawn through a sealed air to air heat exchanger in the air handling unit before being exhausted from the building.

Cooling

Green Roof/Façade

The planting on the roof and around the living edges of Pixel provide local environemental cooling and insulation to the building envelope.

Natural Ventilation

There are high levels windows to the north and west facades that are operated at night in summer by the BMS. These windows open for pasive night purge but they are also enabled to flood the office floors with cool night air so that the exposed ceiling absorbs that coolth, thsu reducing the requirement for hydronic cooling in the morning at start-up.

Sunshading

The building is designed with an extensive system of external shading that extends across the north and west facades and partially across the south. In addition to providing glare control these panels shade the building in the warm summer months to reduce the thermal load on the fabric and office space.

Daylight Systems

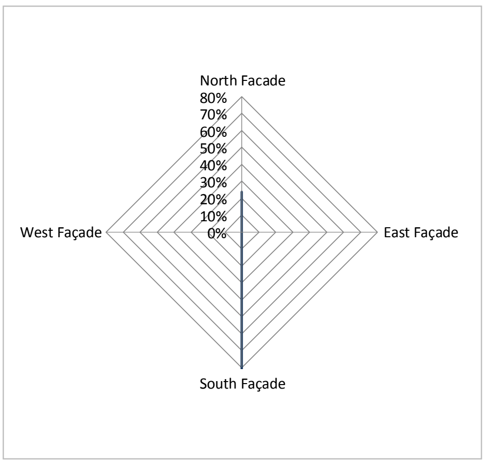
Exteroir Panel System to the North, West and South

The building is designed with an extensive system of external shading that extends across the north and west facades and partially across the south. Modelling has been performed to demonstrate that the external shading limits direct sun at the working plane 1.5m in from the facade for greater than 80% of working hours for each typical glazing configuration on each of the North, West, South and East facades. The software Ecotect has been used to calculate the total number of sunlight hours at a range of grid points throughout each floor plate. The

Window Distribution Information

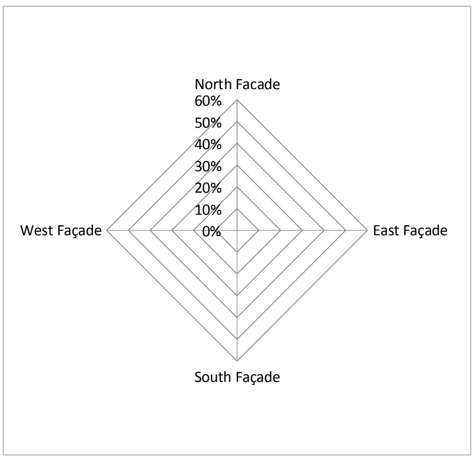
Distribution of Window Areas per Façade

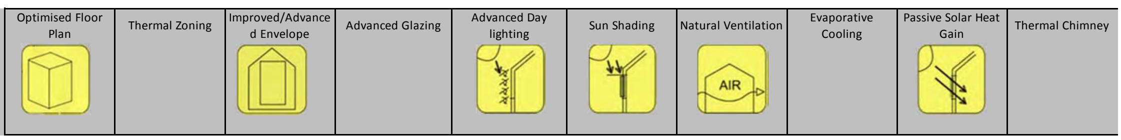
In Passive design, the orientation of the windows and their size has an extreme effect on the heating, cooling and the daylight harvesting potential of the building. This graph enables simple comparison of these properties for each climate and building type.



Façade Porosity - Percentage of Openings per Façade

In Passive Design, the orientation of the openings for Natural Ventilation is a response to the wind and the site. This graph enables a simple comparison of the porosity of each façade for each climate and building type.





Energy Efficiency Systems:

Energy efficient technologies are specific equipment and appliances that focus on reducing the use of energy, in the building, through more efficient means. These energy efficient technologies are used in harmony with the passive design to lower the overall energy consumption of the building. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular system.

System Design Parameters

Outside Air Requirements per Person (L/s-p)
19

Appliances / Plug Loads
Power Density Installed (W/m²) : 10

Artificial Lighting
Power Density Installed (W/m²) : 3

Computer Network
Power Density Installed (W/m²) : 4.2
Datacentre ? Yes

Internal Environmental Systems and Domestic Hot Water

This section describes how the design team has provided for the internal space conditioning. Central systems place the heating, cooling and ventilation equipment in a separate space from the occupied rooms. The heating or cooling of the rooms requires a distribution system taking heat to or away from the occupied rooms using water (hydronic) or air. Distributed systems have separate heating, cooling and possibly ventilation equipment installed for each space.

Cooling

Central Plant	Yes
Distributed Plant	No
Openable Windows	See Passive Systems
Ceiling Fans	No
Hydronic distribution	Yes
Air distribution	Yes

Description
Cooling is provided through hydronic in-slab pipework in chilled ceilings. Ceilings are 100% exposed concrete. Supplementary cooling is provided through air supply (underfloor air distribution) with 100% outdoor air.

Heating

Central Plant	Yes
Distributed Plant	No
Hydronic distribution	No
Air distribution	Yes

Description
Space heating is provided by via the ventilation air supply (100% outdoor air), with the heat for this provided by the gas-fired heat pump (heating hot water coil). Heating is required only intermittently throughout the year, mostly in mid-winter.

Ventilation System

Heat Recovery Type	Yes
Central Air supply	Yes
Local Air Recirc plus Central Fresh Air	No

Description
100% outdoor air with air to air heat exchanger

DHW - Domestic Hot Water

Solar?	
Waste Water Heat Recovery?	
Gas?	
Electrical?	Yes
Other?	

Description
Domestic hot water is generated using a gas-fired boiler. The primary fuel source for the DHW plant is biogas from the anaerobic digester (AD) that is produced from the vacuum toilet waste discharge. Backup is mains supplied natural gas, but full capacity is provided under normal operating conditions by the AD plant.

Control Systems

The critical feature of a successful ultra low energy building is the user interaction. Without control systems that are responsive to user needs and easily understood successful operation is extremely difficult.

Lighting
Switching panels are located at the entrance to each floor, and are zoned so that each level contains 3 lighting zones. Lighting is switched on & off via occupancy sensors, and daylight sensors control the lighting levels in response to daylight. Task lighting is located on each workstation, with occupancy sensors also connected to this system. Out of hours control is via switching in the space, with occupancy sensors switching off. All lighting is switched off during the hours of 11pm-5am to eliminate light pollution.

HVAC
The building automation system controls the space temperature, slab surface temperature and chilled/heating hot water temperatures to maintain the occupant comfort within the required band. The air andling unit supply air temperature to the plenum modulates down to a minimum of 17.5ºC (17°C + 0.5°C temp rise) in full cooling to maintain the average space temperature set point of 25.0°C. On a call for heating the supply air temperature to the plenum modulates up to a maximum of 36.0ºC (adjustable) in full

Energy Storage

Latent Storage?	No
Fuel Cell?	No
Compressed Air?	No

User Interactions
User Manual Provided? Yes

Description
General temperature levels are controlled on the air side by user selection of temperature. Every individual then has control over the temperature at their workstation through the use of an adjustable floor diffuser for air supply quantity. Task lighting enables individual adjustment of the lighting levels at each workstation.

Innovative Technologies
The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy efficient Systems for this climate did not need to include this particular technology.

Energy Reduction Measures for Plug Loads and Appliances
Highly efficient applicances selected as policy

Energy Storage
No

Other
Active mass cooling system in conjunction with underfloor air delivery; use of anaerobic digester to generate biogas for domestic hot water generation; Living Edge wetlands on each level of building; 'Pixelcrete' high recycled content concrete; rainwater harvesting and processing for water self-sufficiency

HVAC Systems
Robur Units x 4

Artificial Lighting
Daylight Harvesting, general artificial lighting is max 2.5W/m2

Computer Management
Optergy BMS system

Control of Systems
Dynamic BMS management

Energy Efficient Lighting	Advanced Lighting Controls	Efficient Office Equipment	Efficient Appliances	Efficient HVAC Equipment	Earth Tube Heat Exchanger	Thermal Storage	Hot Water Conservation	Radiant Structure	Monitoring & LoadManagem.	Heat Recovery

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Source and Type of Funding
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No more than 200 words

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Energy Supply and Integration of Renewable Energy:

"By definition, a renewable energy source is a fuel source that can be replenished in a short amount of time. (American Society Of Heating, Refridgerating and Air-Conditioning Engineers, 2006)" Through the use of these replenishing energy sources, the annual energy demand of an already low-energy building can be offset through the renewable energy generation. Renewable energy sources are converted to energy using renewable energy generation technologies or solutions. The information below is organised under headings in the case study database. Where a field is blank it is because the building design team decided that the NZEB design solution set of energy supply and integration of renewable energy for this climate did not need to include this particular measure.

Electricity Production

Photovoltaic (PV)	Yes
Building Integrated PV?	No
Ground mounted	No
Roof mounted	Yes
Position	Tracking
Tilt (angle)	Tracking
Azimuth	Tracking
Technology	SunPower 210W panel
Nominal Power (kWp)	4
Area (m²)	27
Yield (kWh/m².year)	8
Expected generation (kWh)	6665.00
Measured generation (kWh)	Not yet finalised

Wind Turbine	
Position	On-site
Number of Turbine	3
Technology	Vertical
Nominal Power (kWp)	1.7 kWp
Energy Production (kWh/m².year)	13.50

Solar Water Heating

Hot Water	
Solar Thermal	No
Technology	Biogas System
Position	Roof unit
Area (m²)	
Production (kWh/m².year)	2.60
Annual % of Hot Water	100

Combined (Cooling) Heat and Power

Combined (Cooling) Heat and Power

Type
Fuel
Efficiency (%)
Electricity
Water Heating
Space Heating
Cooling
Production (kWh/m².year)
Electricity
Water Heating
Space Heating
Cooling

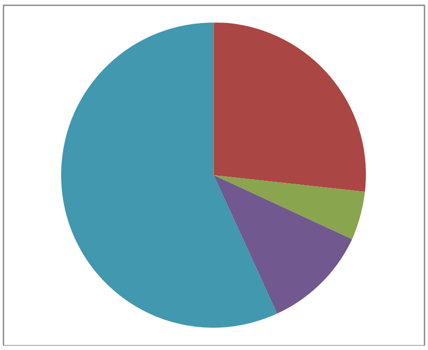
Renewable Production of Heating and Cooling

Heating Equipment

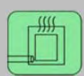
		Heat Pump
Technology	Robur gas-fire	Robur gas-fired ammonia absorption heat pump
Power		100.8kW
Efficiency (%)		1.4
Production (kWh/m².yr)		5.65
Annual % of Heating		1

Cooling Equipment

	Heat Pump	
Technology	Robur gas-	
Power		
Efficiency (%)		0.67
Production (kWh/m².year)		28.70
Annual % of Cooling		1



This graph shows the expected proportion of generation (kWh/m²) of energy produced by the various renewable energy sources based on design calculations.

PV Array	Onsite Wind Turbine	Boiler	CHP	Use of offsite Green Power	Solar Thermal Hot Water	Solar Thermal Space Heating	Solar Cooling System	PV/Thermal Array
								

References

American Society of Heating, Refridgerating and Ait-Conditioning Engineers. Ashrae Green Guide: The Design, Construction, and Operating of Sustainable Buildings USA: Elsevier 2006.

Belleri, Annamaria, Assunta Napolitano, and Roberto Lollini. "Net Zeb Evaluation Tool - User Guide " (2012).