DETERMINING THE EFFECT OF BUILDING GEOMETRY ON ENERY USE PATTERNS OF OFFICES DEVELOPMENTS

Category: Academic, MBSc

Major research project, Individual

Location: Toronto, ON, Canada

Year: 2012

Optimization of energy is a crucial factor in the design of office buildings. Decisions made at the early design stages of a project that affect building geometry, orientation, and glazing levels can have a significant impact on its lifetime energy performance. Effective guidance will help designers to contribute toward sustainable solutions.

OBJECTIVE

• Exploring the influence of building geometry on energy consumption of office spaces

• Identifying the importance of ‹shape› compared to building envelope factors: window to wall ratio (WWR) and external shading devices

IMPORTANCE

The findings are expected to provide useful guidelines to the architects to utilize building geometry as an energy saving measure while designing workplaces.

METHODOLOGY

Phase 1: Parametric analysis
- Geometry
- Window to wall ratio
- Shading design

Phase 2: Energy simulation
- Space heating
- Space cooling
- Interior lighting

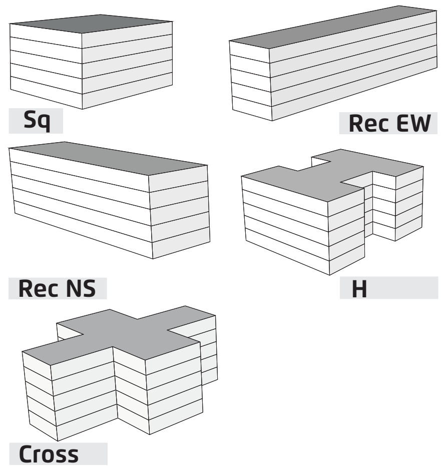
Phase 3: Result analysis
- Impact of design parameters on energy demands
- Dominance of design parameters on energy demands

GEOMETRY: Square, Rectangle elongated on East-West, Rectangle elongated on North- South, H- shape, and Cruciform

CLIMATE: Toronto, ON, Canada

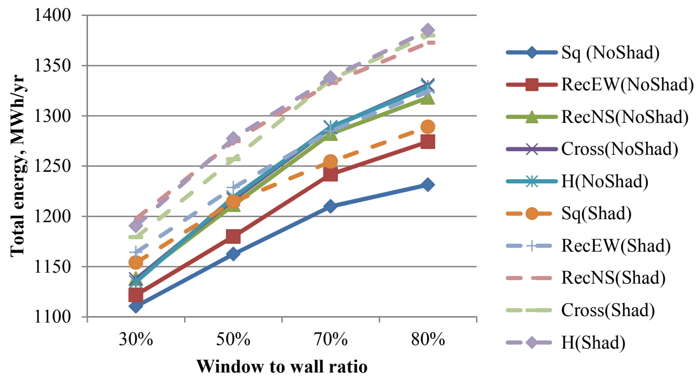
BUILDING FLOOR AREA: 6000 sq m

ENERGY MODELING SOFTWARE: IES Virtual Environment (Modules: SunCast, Radiance, and ApaceSim)



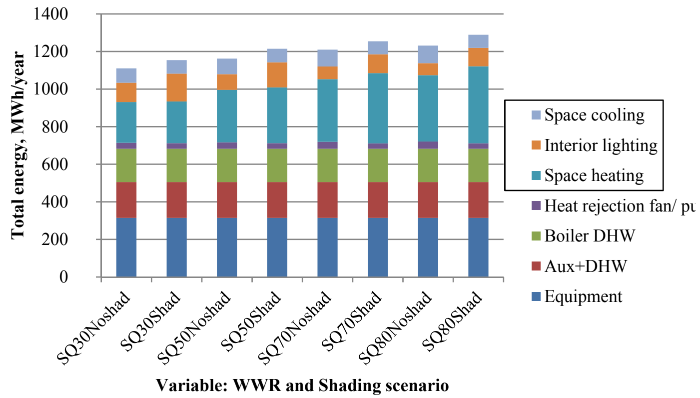
3D images of archetype buildings

RESULT 1: The increase of energy with respect to geometry is much less than the energy use for WWR.



Total energy results of five archetypes for 'no shading'

RESULT 2: Heating energy makes up the largest proportion of the total energy usage.



Annual energy results of archetype 'Sq'

RESULT 3: The most compact form has the least total energy consumption.

Archetype buildings	Compactness F/E	Compactness V/S	Total energy, MWh/year
Sq	1.51	4.64	1110.5- 1289
Rec EW	1.28	4.09	1121.8- 1324
Rec NS	1.28	4.09	1137.8- 1372.6
H	1.214	3.9	1137.5- 1380
Cross	1.214	3.9	1384- 1385

F/E increases

V/S increases

Energy increases

V/S= volume/ surface area (wall+ roof+ ground)

F/E= usable floor area/ above grade enclosure area(wall+roof)

CONCLUSION

• WWR has a stronger impact on the energy use pattern of a building than its shape.

• With more fenestration, energy usage of different forms varies within a larger range compared to the forms with less fenestration.

DESIGN OF A NET- ZERO ENERGY STRAWBALE HOUSE

Category: Academic, MBSc
Building Design Studio (BL8104), Group of 4
Location: Peterborough, ON, Canada
Land area: 650 sq m
Client: The Endeavour Center, Canada
Year: 2012

The proposal outlines design and system strategies to achieve various energy efficient and environmentally conscious building standards for a residential building. The intent of the residential building is to integrate a variety of technologies and design strategies to create a low energy straw bale house.

Straw bale construction is an innovative alternative assembly method using modern technology, which meets the performance requirements of the building code and reduces the embodied energy of the homes.

DESIGN PRINCIPLES

•Net zero energy home
•PassivHaus requirements
•Living Building Challenge

BUILDING FORM

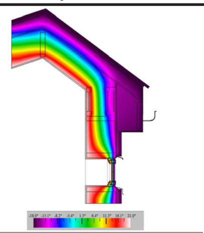
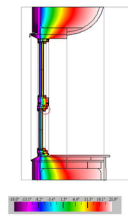
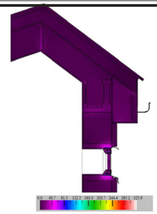
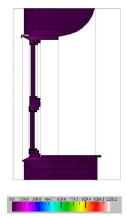
•Open concept plan
•Living spaces (occupied during day) located on the south
•Bedrooms (occupied during night) and services oriented on the north
•Living room allowing potential for solar energy to penetrate into
•Second floor above the living space is mezzanine
•Basement to house the technological systems
•A central plumbing wall
•Clerestory windows on north for daylighitng and natural ventilation
•Southern sloped roof to optimal sun angle for solar hot water and PV panels

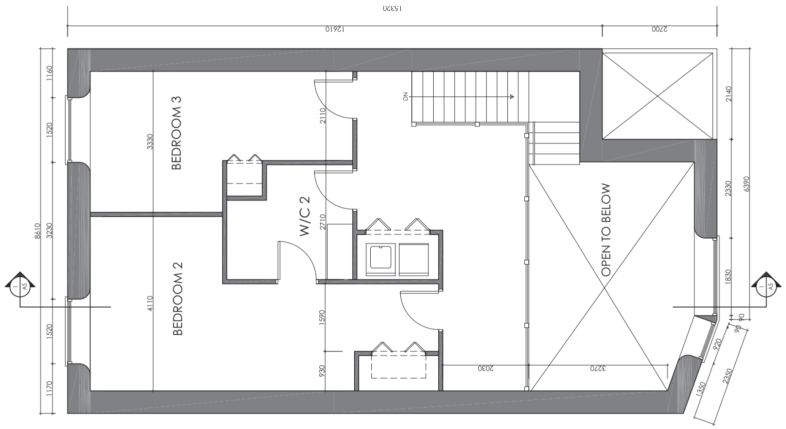
ENVELOPE R- VALUES

Assemblies	Passive House Value	Design Value
Exterior Wall	R-40 to R-60 [RSI7.0–10.5]	Strawbale R-43.3 ICF R-43.4
Roof	R-50 to R-90 [RSI9.0–16.0]	R-57.3
Slab	R-30 to R-50 [RSI5.5–9.0]	R-36
Window	R-6.5 to R-8 [RS1.18–1.43]	R-4 – R-4.9

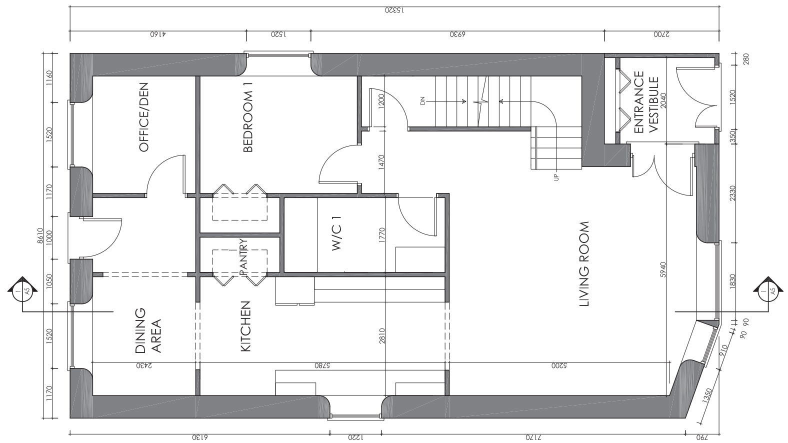
THERM ANALYSIS

THERM analysis is performed to investigate the interaction between assembly components in regards to thermal transfer.

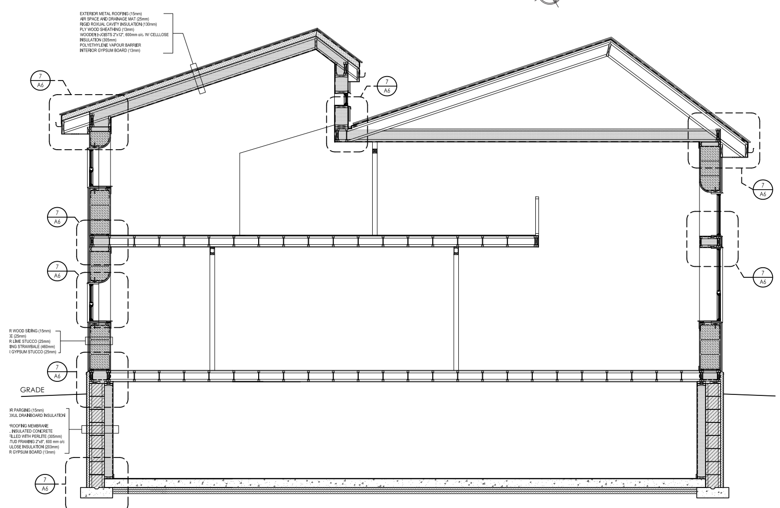
Detail	North roof to wall connection with clerestory windows	Window sill & head connection
Thermal gradient		
Heat flux magnitude		



SECOND FLOOR



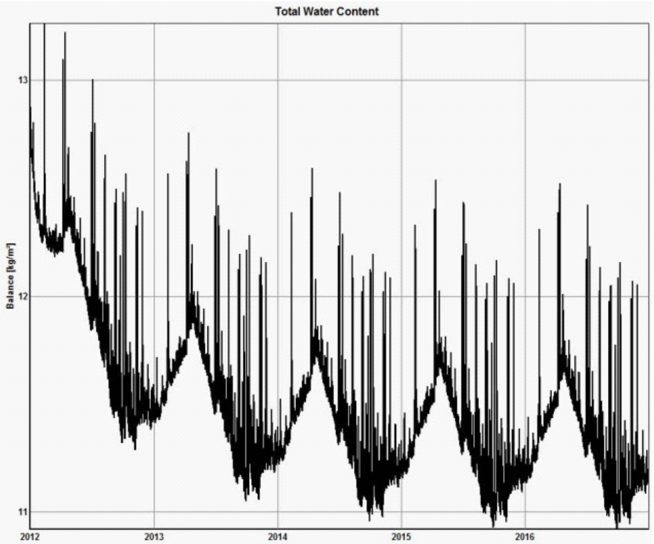
GROUND FLOOR



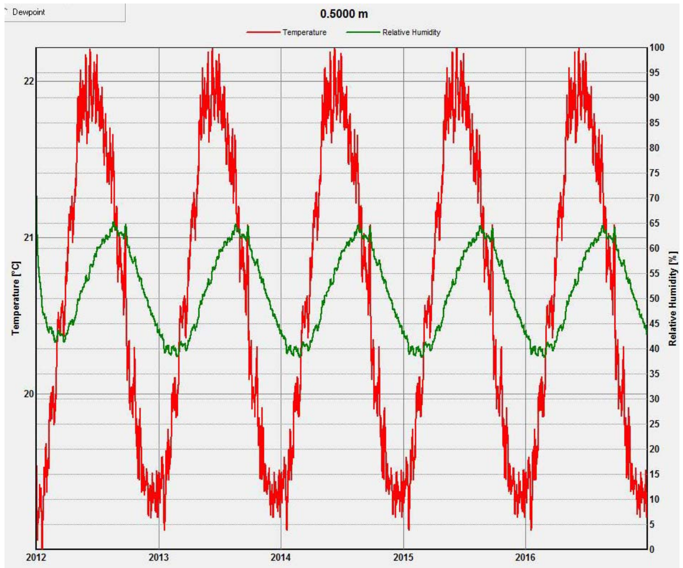
SECTION

WUFI ANALYSIS

WUFI simulations to calculate the transient heat and moisture transport in materials and building constructions. Results are discussed concerning relative humidity and water content profile in critical parts of the envelope.



TOTAL WATER CONTENT OF THE ABOVE GRADE WALL



RH PROFILE AT THE STRAWBALE LAYER

MECHANICAL SYSTEMS

• Geothermal heat pump

The straw bale house will use a ground-loop heat pump to provide heat to the spaces while keeping space heating energy to a minimum.

• Radiant floor heating

Radiant floors are more efficient at delivering heat to spaces compared to a forced-air system. Pipes are placed in the floors instead of the walls is because of the open concept layout of the house.

• Solar hot water

Four south facing, roof mounted solar collectors measuring 11.5 sq m each, are installed. The collectors generate 4255kWh/yr which is equivalent to 84% of domestic hot water demand of the house.

ELECTRICAL SYSTEMS

• Appliances

Appliances are chosen on the basis of energy efficiency and availability in Southern Ontario.

• Interior lighting

Halogen light bulbs are used as accompanying task lighting with LEDs.

• Ventilation

To maintain a healthy indoor air quality, the ventilation requirements for the building is 46.8 L/s. The fresh air will be regulated and pre-conditioned by a heat recovery unit, located in the mechanical room of the house.

• Photovoltaic systems

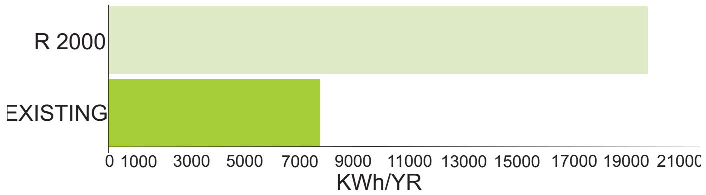
The total electricity required in the house for heating, cooling, domestic hot water, auxiliary, and household electricity is 95.6 kWh/sq m/yr. The south facing roof area will allocate 20 PV panels with the area of 33 sq m, generating 74 kWh/sq m/yr of electricity. As a result almost 80% of required electricity is generated on site and CO2 emission avoided is 15.6 kg/sq m/yr.

RAINWATER HARVESTING TO MEET THE LIVING BUILDING CHALLENGE

Rainwater catchment area: 175.7 m2
Proportion of roof surface collected: 100%
Annual Rainwater Demand
Indoor Rainwater Demand: 88.1 m3/year
Outdoor Rainwater Demand: 65.8 m3/year
Tank size: 5000L
Proportion of demand met: 58%

HOT 2000 REPORT

Simulation are done to estimate the energy consumption of the house and estimate potential savings.



ANNUAL HEATING+HOT WATER ENERGY CONSUMPTION (KWH)

PHPP ANAYSIS

To calculate the energy balance of PassivHaus

	PASSIVHAUS STANDARD	DESIGN VALUE
Specific space heating demand (kWh/m2/yr)	15	22.5
Specific primary energy demand (kWh/m2/yr)	120	103.27

Since the original design does perform exceptionally for SPED and has practical values to SSHD in a Canadian climate, sticking with it proves to be a sensible move in achieving low energy.

WHOLE BUILDING ENERGY MODELING AND ENERGY EFFICIENCY IMPROVEMENT OF A MULTI-UNIT RESIDENTIAL BUILDING

Category: Academic, MBSc

Building Design Studio (BL8104), Group of 4

Location: Toronto, ON, Canada

Year: 2012

The scope of this project will consist of simulating an existing 8-story multi-unit residential building, located in Toronto, to further reducing the energy consumption. The building has been designed to comply with Ontario Building Code 2006 and Toronto Green Standard.

A goal of 30% energy reduction has been set over the baseline building. This will be achieved by analyzing and proposing changes to the envelope and mechanical systems.

- **Modeling software:** eQUEST
- **Standard reviewed**: ASHRAE 90.1- 2010
- **Simulation inputs:** Seven seperate shells are created to model various spaces within the building

BUILDING ENVELOPE IMPROVEMENT MEASURES

Improvement measures are primarily discussed in terms of:

- Increased R-value of above- grade walls, roofs, and floors
- Modified construction system of above grade walls, roof, and floors
- Modification of ceiling and interior walls based on construction and insulation R-value
- Improved performance of glazing units in terms of U-factor and SHGC
- Reduced window to wall ratio
- Impact of external shading on the fenestration

MECHANICAL SYSTEM IMPROVEMENT MEASURES

- A Packaged Split System heat pump with an economizing cycle is included as the terminal unit instead of Fan Coils
- A Fluid Cooler in place of the Cooling Tower
- Based on these changes, the baseline showed a 56% reduction in energy results
- The energy use on pumps and auxiliary devices increased due to the operation of the new compressors

COMPARISON OF RESULTS

- The improvement measures resulted a reduction in energy consumption by a total of 69%, exceeding the requested 30% reduction
- More could be done to consider the effects of appliance and lighting efficiencies, as they have the largest impacts on electricity consumption;
- Although, space heating has the greatest impact overall

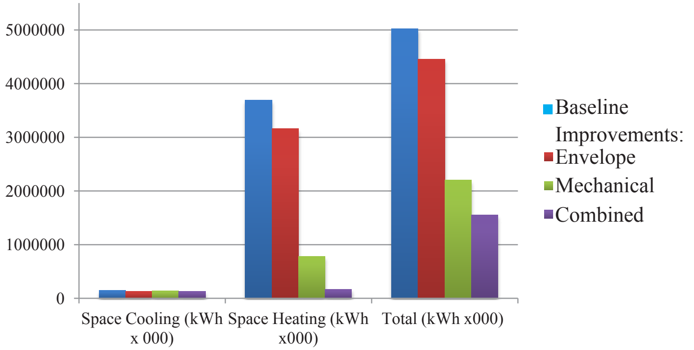


Fig 1: Comparison of energy consumption values of building as various improvements were made.

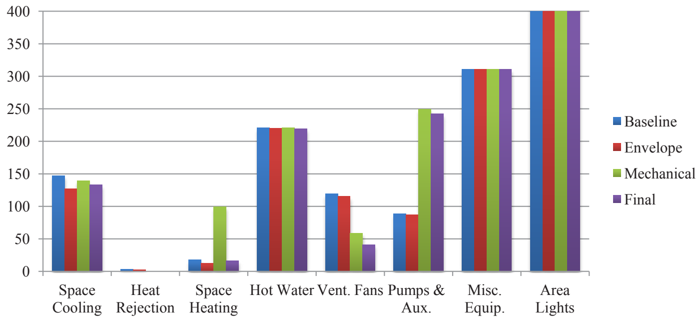


Fig 2: Comparison of electricity consumption end uses in kWh (x000) for each phase of project.

LEARNING EXPERIENCE

- The project is a perfect opportunity for working in a very broad interdisciplinary team.
- Simulating the baseline building provides a clear understanding how certain decisions and assumptions can have an impact on the overall output.

RESIDENTIAL LIFE CYCLE ASSESSMENT

Category: Academic, MBSc

Life Cycle Assessment (BL8214), Individual

Location: Halifax, NS, Canada

Year: 2012

Life cycle assessment (LCA) is an analytical tool used to quantify environmental flows to and from earth, over the life cycle of a product and/or service. LCA of a building considers production stage, construction process, in use, and end of life of the whole building.

The assignment investigates life cycle effects of a proposed single detached dwelling located at Halifax, NS. Embodied effects and operating energy effects are analyzed separately for the dwelling with a service life of 60 years.

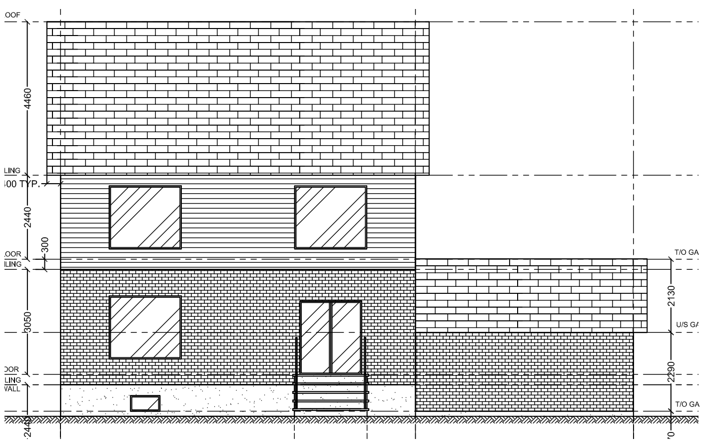


Fig 1: North elevation, baseline building

CASE 1 (BASELINE) - EMBODIED EFFECTS

- Embodied effects- the emissions associated with materials and their disposal throughout the life cycle of the building
- The scope of materials is quantified for the building assemblies- foundation, column and beams, floors, roof, perimeter walls, and interior walls
- Embodied effects are calculated using the ATHENA EcoCalculator (EC)
- Energy use (fossil fuel consumption) and global warming potential (GWP) the most critical among

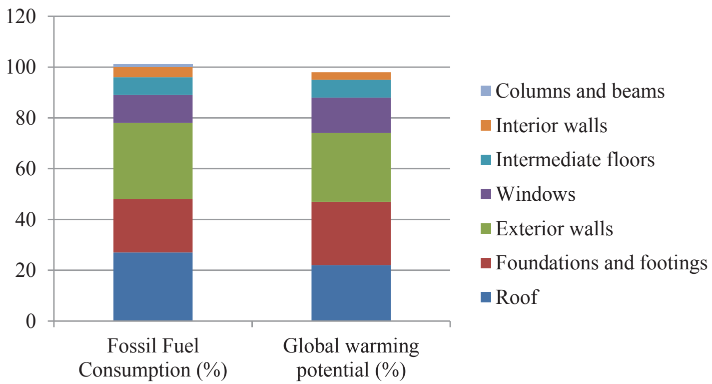


Fig 2: Impact summary, Fossil fuel consumption and GWP

CASE 1 (BASELINE) – OPERATING ENERGY EFFECTS

- Annual fuel consumption are calculated
- Life cycle operating energy effects for space heating, space cooling, water heating, and appliances/lighting/ventilation are determined using data (life cycle emission factors for fuel use) from ATHENA Impact Estimator

CASE 2 (MATERIAL USE)

- To reduce the GWP of the baseline design assembly substitutions are done maintaining the similar thermal performance
- Operating energy effects do not change
- Global warming decreased by 29.76% in case 2.
- Trade-off: Weighted resource use and smog potential are increased by 8.67% and 0.37% respectively

	Case 1	Case 2
Roofs	Wood I-joist w/plywood decking	Wood truss w/plywood decking
Foundations	Concrete blocks	Cast in place
Exterior walls	Wood studs w/metal cladding	Wood based SIP w/ stucco over metal mesh

Fig 3: Assembly substitutions to reduce GWP

CASE 3 (ENERGY USE)

- To reduce the predicted GWP, the baseline water heating system (Electric) is substituted with natural gas
- Embodied effects are assumed to be the same as the Baseline
- GWP reduces by 15.89%
- Trade-off: Eutrophication increased by 3.83%

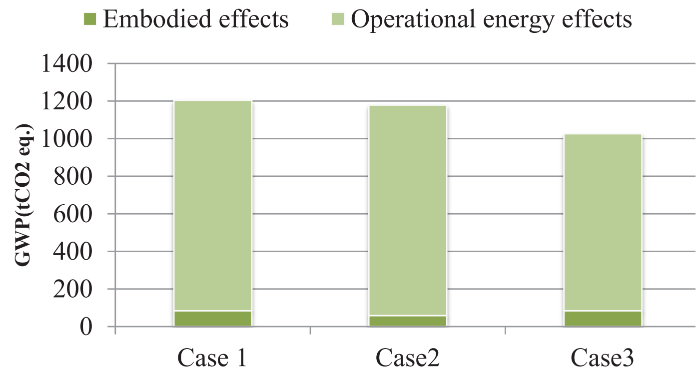


Fig 4: LCA results graph, comparing the three cases