Can Pre-Regulation Office Buildings be retrofitted to current NZEB standards in order to reduce its Net Carbon Output?

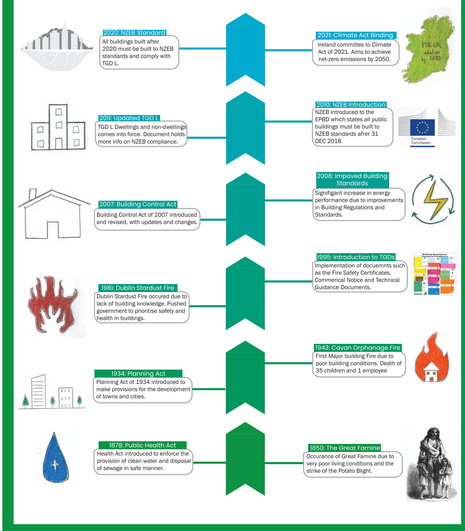
Objectives

- Perform a comparative analysis of the differneces between operational and embodied energy.
- Collate and analyse data on the Irish office building stock over different periods of construction.
- Establish how to achieve NZEB compliance and determine whther it is applicable.
- Devise a suitable retrofit design to use as a basis for comparison.
- Determine the most sustainable construction path for future of Pre-Regulation 1990 office buildings

Methodology

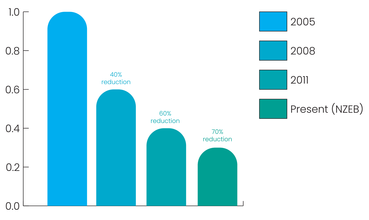
1. Analyse alternative office build typesusing databases and archives to be able to select a suitable case study building.
2. Revie the current TGD L NZEB requirements.
3. Apply NZEB principles to a retrofit design and demonstrate this using a created BIM Model.
4. Calculate energy consumption of proposed buildings using Energy Simulation Software such as Revit System Analysis.
5. Calculate and compare carbon costs of the differing building construction paths.

Building Control Timeline



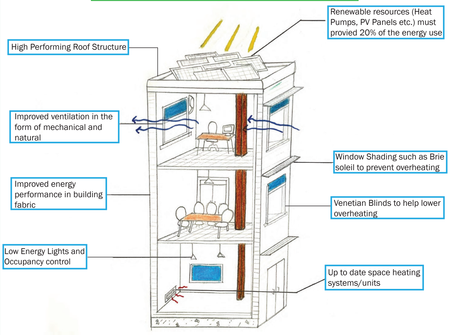
What is NZEB?

'NZEB (Nearly zero-energy building) means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources'



NZEB has slowly been making its appearance over the last couple of years. The graph above shows the relative change in the EPC (Energy performance coefficient) over the years. There has been a 70% improvement in the required EPC value today compared to 2005.

NZEB Properties and Requirements



To comply with NZEB, a building must have their Maximum Permitted Energy Performance Coefficeint (MPEPC), Maximum Permitted Carbon Performance Coefficient (MPCPC) and Renewable Energy Ratio (RER) comply within the standards of TGD L. These figures can be calculated using the NEAP (Non-dwelling Energy Assessment software) software which is provided for free by the government.

MPEPC	MPCPC	RER
1.0	1.15	0.2

Major Retroffiting Requirements

If more than 25% of the surface area of the building envelope undergoes change, it is considered a major retrofit. Surface works include:

The following improvements are required to be done for major retrofits and are considered cost optimal and economically feasible:

Upgrade Area	Improvements
Heating Boilers	-Oil, gas or biomass boilers older than 15 years old must be up-graded -Boilers must match the efficiency shown in *Table 2* of TGD L
Space Heating	-Direct electric space heating systems to be upgraded to efficiency shown in Table 2 of TGD L
Lighting	-General Lighting Systems older than 15 years to be upgraded
Cooling and Ventilation	-Cooling and ventilation systems older than 15 years must be upgraded -Seasonal Energy Efficiency ratio (SEER) less than that in the Eco-Design Regulations

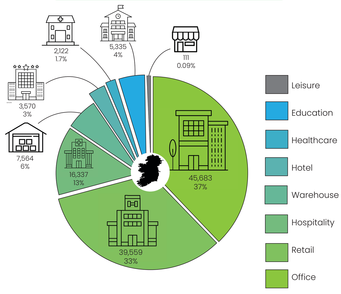
Table 13 Whole Building Cost Optimal Level

Building Type	Major Renovation - Cost Optimal Performance kWh/m²yr primary energy
Retail	338
Air-Conditioned	
Office	124
Naturally Ventilated Offices and Other Buildings	
Office	180
Air-Conditioned	
Hotel	342
Air-Conditioned	
Schools	60
Other Air-Conditioned Buildings	336
Other Naturally Ventilated Buildings	124

As an alternative, if the building achieves the primary energy performance levels outline in Table 13 of TGD L, this can be considered the cost optimal level of performance.

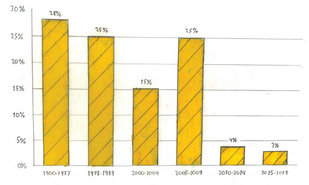
Irish Commercial Building Stock

2019 SEAI Building Survey



In 2019, a Survey was done by the SEAI which showcased a breakdown of the different buildings in the Commercial Sector. 33% of the buildings were office buildings and a signifigant portion of all buildings recorded did not have modern sustainability properties such as triple glazed glass.

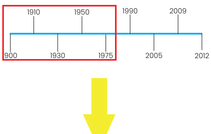
From the same survey, the period of construction built for each building was also recorded. Over 50% of the recorded commercial buildings were built between 1900-1999.



These results show that these old buildings possess huge potential in saving energy and carbon

Selecting a Case Study Building

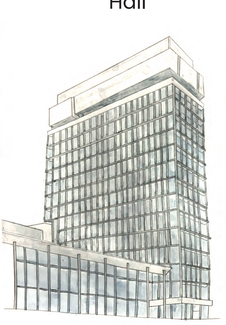
Selection Criteria



NATIONAL INVENTORY of ARCHITECTURAL HERITAGE

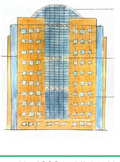
IRISH ARCHITECTURAL ARCHIVE
Cartlann Ailtireachta na hÉireann

Cork County Hall



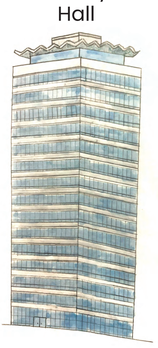
Constructed in 1960 by Architect Patrick McSweeney
17-storey Office Block building
Located in Carrigrohane Road, Cork
Received a develepment project which involved the re-cladding of the existing facade. An active louvre facade was implemented which improved the building's energy gain

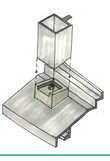
BT Riverside Tower



Constructed in 1998 by Micheal Laird Architects.
Located in Lanyon Place, Belfast.
14 Floor building, used as a headquarters for British Telecom Northern Ireland.
Overall lack of relevent Architectural info and resources.
Difficult to obtain info as it is situated in North Dublin

Liberty Hall



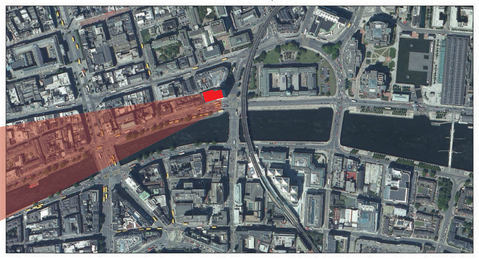


Constructed in 1965 by Desmond Rea O' Kelly.
Located in Eden Quay, Dublin.
Currently being used as a Headquarters Office building for SIPTU.
Proposal to demolish and rebuild rejected by an Bord Pleanala due to Liberty Hall being a building of historical signifigance.

Chosen Building: Liberty Hall

Site Location

Liberty Hall is located in North City of Dublin 1 Eden Quay Bereseford Place



Built in 1965, the adjoining seventeen-story glazed office building has a two-story hall added to the west. Architect and Structural Engineer Desmond O'Kelly created it as the trade union's headquarters. A cantilevered canopy with zigzag mosaic tiles leading to a recessed top level and a lift shaft projection on top is included. The building is horizontally glazed on all four sides, with fifteen fluted-paneled aluminum windows on each elevation and continuous mosaic floor panels that have been painted over. Tower with mosaic tiles on the ground floor, supported by eight structural columns. The ground floor is recessed and rests on a pedestal covered in stone. Some of the panels are filled with red brick.

Artist Impression

Historical Significance

Liberty Hall is seen as the embodiment of the functional aesthetic of the International style. The cantilevered copper roof and the glazed curtain wall provide architectural signifigance. The site has considerable historical releveance as it has played a part in Irish events in the past such as the Easter Rising and and the 1913 Lockout. It is an icon of Dublin with contributions in the cultural heritage of the city.

Recent Controversy

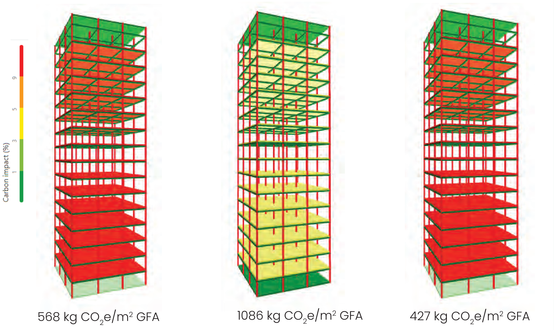
Although Liberty Hall is recognized as a Protected Building today, there has been some rejected plans to demolish and rebuild the building. There are also some differing opinions regarding the state of Liberty Hall. There are arguments 'it is an eye sore of a building' or that it is too old for the modern city of Dublin.

This study could possibly provide another option for the future of Liberty Hall

Early Construction

Building Demolition Study

Concrete Frame (Existing) | Steel Frame | Timber and Concrete Frame Hybrid

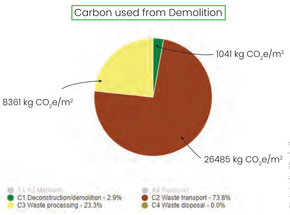


Baseline Design

+91% below Baseline

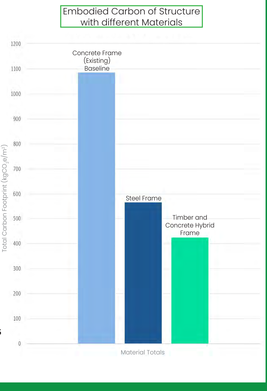
-25% below Baseline

Carbon used from Demolition



35887 kg CO_2e/m^2 is predicted to be used for the demolition of the existing Liberty Hall Building

Embodied Carbon of Structure with different Materials



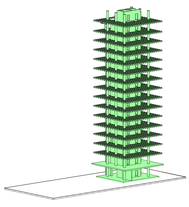
Adding up the demolition carbon figures as well as the embodied carbon required to build the proposed new building, it is seen that a huge amount of carbon is required for this demolition scheme. This scheme does not look to be a very viable construction option from a carbon perspective based on these early tests.

Can Pre-Regulation Office Buildings be retrofitted to current NZEB standards in order to reduce its Net Carbon Output?

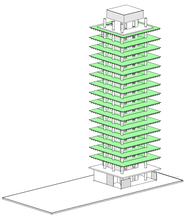
Existing Liberty Hall Technical Exploration

Liberty Hall Construction Sequence

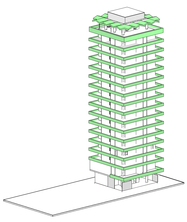
Phase 1



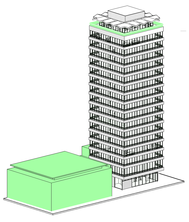
Phase 2



Phase 3

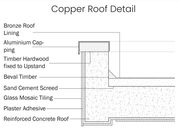


Phase 4

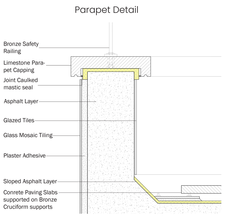


Liberty Hall South Elevation

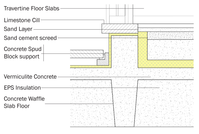
Copper Roof Detail



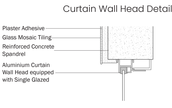
Parapet Detail

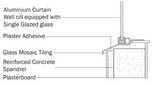


16th Floor Terrace Detail



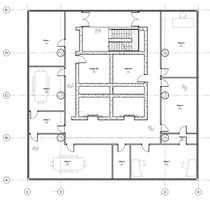
Curtain Wall Head Detail





Curtain Wall Cill Detail

Typical Tower Floor Plan



BIM Model Perspective View

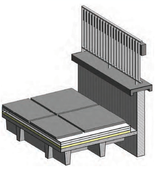
External Wall U-Value Calculation

External Wall

	Description	Thickness(m)	Conductivity (W/m.K)	Resistance (m².K/W)
1	Mosaic Glass Tiling	0.01	1.3	0.01
2	Cement Screed	0.05	0.41	0.12
3	RC Concrete Slab/roof	0.2	2.5	0.08
4	Plasterboard	0.0125	0.25	0.05
5	Air			0.14
Total				0.39

R-value(total)	0.39	m²K/W
Conductivity(Total)	2.56	W/m²K

16th Floor Terrace U-Value Calculation

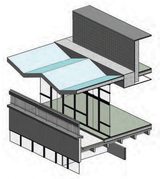


Terraced 16th Floor

	Description	Thickness(m)	Conductivity (W/m.K)	Resistance (m².K/W)
1	Concrete Paving Slabs	0.05	1.15	0.04
2	Sand cement screed	0.05	1.15	0.04
3	Asphalt Layer	0.2	1.15	0.17
4	Sloped Asphalt Layer	0.1	1.15	0.09
5	Glazed Tiles/Roof	0.0025	0.25	0.01
6	Air			0.14
Total				0.49

R-value(total)	0.49	m²K/W
Conductivity(Total)	2.04	W/m²K

Zigzag Copper Roof U-Value Calculation

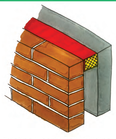


Zigzag Copper Roof

	Description	Thickness(m)	Conductivity (W/m.K)	Resistance (m².K/W)
1	Bronze Roof Lining	0.005	1.98	0.0013
2	Timber Hardwood fixed to Upstand	0.2	1.15	0.17
3	Reinforced Concrete Roof	0.2	2.5	0.08
4	Plaster Adhesive	0.12	0.41	0.29
5	Mineral Wool Slab	0.1	0.04	2.5
6	Air			0.14
Total				3.16

R-value(total)	3.16	m²K/W
Conductivity(Total)	0.32	W/m²K

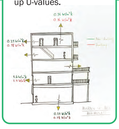
Fire Safety



- Existing Liberty Hall Building had little to no use of Fire Safety Techniques.
- The revision of TGD B Fire Safety Techniques must be revisited when
- performing retrofit.
- Cavity barriers, Fire proof insulation, seperating partition walls etc.

Thermal Performance

- External Construction build ups do not comply with Elemental U-Values in TGD L
- Minimal Insulation used and sometimes not
- present at all.
- Cold Bridges Present in key junctions.
- Different Insulation types are to be tested to bring up U-values.

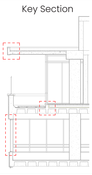


Curtain Glazing

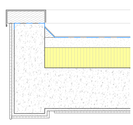
-Curtain Wall Glazing only equipped with Single glazed glass.
-Glazing makes up majority of external wall fabric percentage so this needs to be upgraded.
-Double glazing or triple glazing to be used for retrofit.

Liberty Hall Retrofit Proposal

Key Section



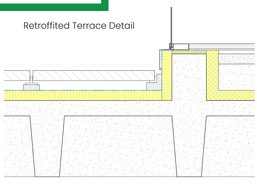
Retrofitted Copper Roof Detail



Roof Insulation Choices

Changes Made:
-Kingspan Thermaroof TR 27 Insulation added to comply with TGD L minimum U-value of 0.20 W/m2k
-Glass Mosaic Tiling to be removed + reapplied due to poor conditions
-Proprietry Roofing membrane to be applied for proper water proofing

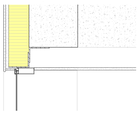
Retrofitted Terrace Detail

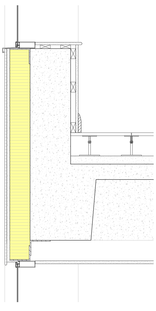


Terrace Insulation Choices

Changes Made:
-Insulation upgraded to Kingspan OPTIM-R Insulation to meet TGD minimum U-value of 0.20 W/m2k
-Curtain Wall system to be replaced with ETEM 85 curtain wall system. Equipped with double-glazed glass with a U-value of 1.60 W/m2k
-Proprietry waterproofing membrane added

Retrofitted Spandrel External Wall Detail





Spandrel Insulation Choices

Changes Made:
-Glass Mosaic Tiling to be removed and reapplied due to poor conditions
-Raised Access Floor to be implemented to accomadate modern building services
-Suspended Ceiling void to be implemented to accomadate modern building services
-Curtain wall to be replaced with ETEM 85 Curtain wall system. Equipped with double glazed glass with a U-value of 1.60 W/m2k

3 Insulation Types were compared to determine which is the more optimal choice:

KORE EPS

-Thermal Conductivity of 0.031 W/mk
-Suitable for wide range of construction
-Fire Proof
-Lack of EPDS available

Foamglass T4+

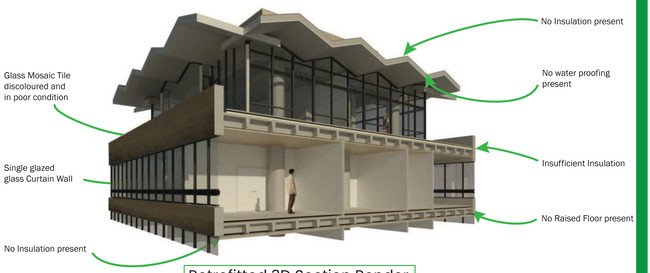
-Thermal Conductivity of 0.041 W/mk
-Used in recent Aer Lingus Office NZEB Retrofit project
-EPDS available online
-Thickest thickness to reach required U-value

Koolthern K5

-Thermal Conductivity of 0.022 W/mk
-Usually used for masonry wall construction
-Fire Proof
-EPDS available online
-Thinnest thickness to reach required U-value

Foamglass T4+ was chosen as the most optimal insulation choice. This is due to it having the most reliable information online and already being proved to be successful in a recent NZEB retrofit project.

Existing 3D Section Render



Retrofitted 3D Section Render

How much Carbon is required for the Proposed Retrofit?

Quantity (kg)

Embodied Carbon Factor (ECF)

Emmitted Embodied Carbon

Material	Quantity (kg)	Embodied Carbon Factor (ECF)	Emmitted Embodied Carbon (kgCO2e-kg)
Foamglass Insulation	208900	-	0
Glass Mosaic Tiling	44150	1.22	53863
Mosaic Adhesive	15670	0.393	6158.31
Double Glazed Glass	29600	1.63	43358
OPTIM-R Insulation	9780	3.48	34034.4
Thermaroof TR27	32200	2.32	74704

equivalent to:

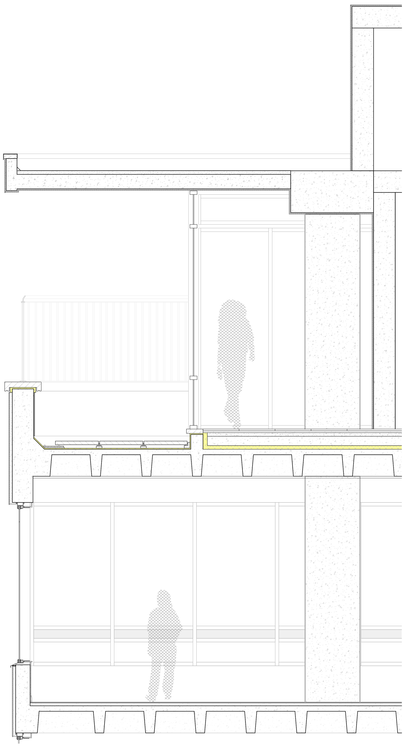
41.3 homes' electricity use for one year

25,802,560 smartphones charged

Tons 21211771
Kilograms of Carbon dioxide (Co2) equivalent

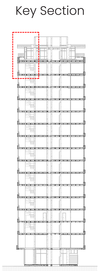
23,868 gallons of gasoline consumed

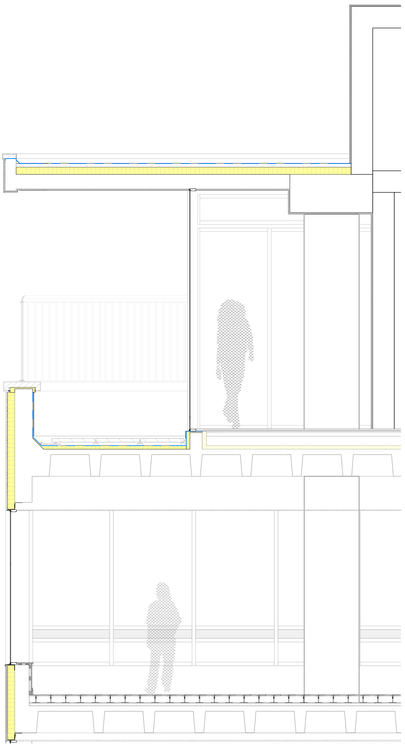
1:20 Existing Section



1:20 Proposed Retrofit Section

Key Section

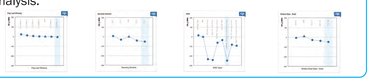




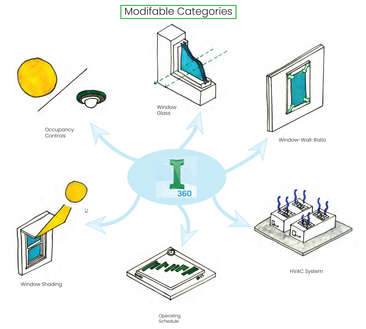
Can Pre-Regulation Office Buildings be retrofitted to current NZEB standards in order to reduce its Net Carbon Output?

Insight 360 Preliminary Results

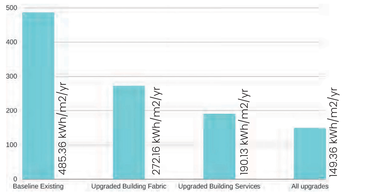
Insight 360 is an Energy Simulation software that produces very early stage energy results from the inputted BIM model. Different properties of the building are able to be adjusted and thus changes the outcome of the results, allowing in preliminary comparative analysis.



Modifable Categories



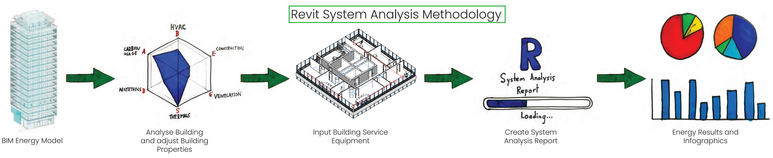
Experiment Results



These preliminary results show the huge potential in saving energy in the existing Liberty Hall if the correct areas are retrofit. A 69.2 percentage decrease in energy use is estimated to be achieved if all aspects of the building are upgraded.

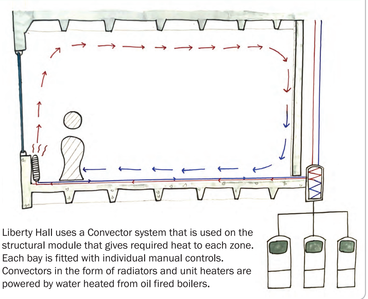
Existing Liberty Hall Building Service Analysis

Revit System Analysis Methodology



BIM Energy Model | Analyse Building and adjust Building Properties | Input Building Service Equipment | Create System Analysis Report | Energy Results and Infographics

Heating System



Liberty Hall uses a Convector system that is used on the structural module that gives required heat to each zone. Each bay is fitted with individual manual controls. Convectors in the form of radiators and unit heaters are powered by water heated from oil fired boilers.

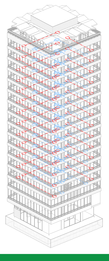
Ventilation System

In the Summer, the ventilation strategy mainly consisted of natural flow through the use of top-hung opening windows

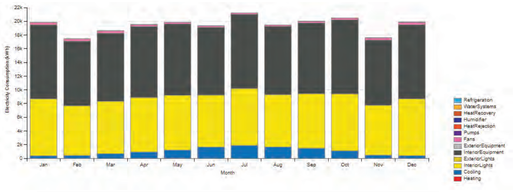
In the Winter, finely controllable metal slits at the top of window frames allowed air to enter without disrupting thermal comfort

Mechanical ventilation was rarely used due to limiting budget. Was installed in central core rooms and lower floor Commercial Meeting Rooms

BIM Model System Zone Layout



Annual Electricity Consumption (kWh)

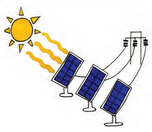


From the Revit System Analysis Report, the existing Liberty Hall building was found to consume 314533 kWh per annum. This figure is reflective on the heating equipment, ventilation systems, pumps, interior lighting and fans. This figure is to be compared to the retrofit building proposal outlined further in this research paper.

Renewable Energy Study

Renewable Energy Options

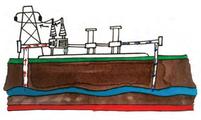
Solar Photovoltaic Energy



- The conversion of solar energy directly into electricity in a solid-state device
- Clean and silent energy production method
- Can take advantage of unused spaces in the roof.
- Locally available
- Variable energy source, dependent on the sun

Easy and Practical to implement to our building

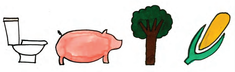
Geothermal Energy



- The use of heat energy from deep within the earth's crust
- Consistent source of energy, can produce regardless of weather condition
- Life cycle emissions 4 times lower than solar PV Panels
- Difficultt and expensive to implement in our building's location

Difficult and expensive to implement in our building's location

Biomass Energy



- The use of heat energy from deep within the earth's crust
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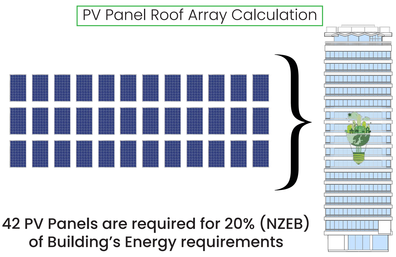
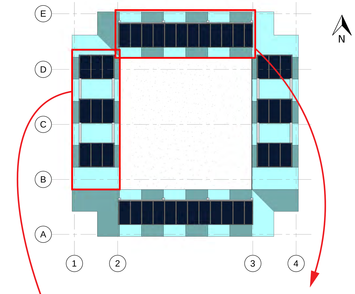
Difficult and expensive to implement in our building's location

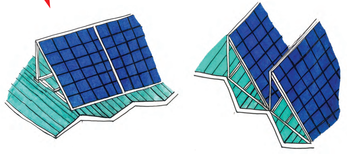
PV Panel Roof Array Calculation



42 PV Panels are required for 20% (NZEB) of Building's Energy requirements

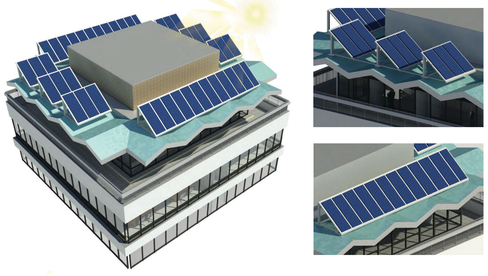
Liberty Hall Roof Plan



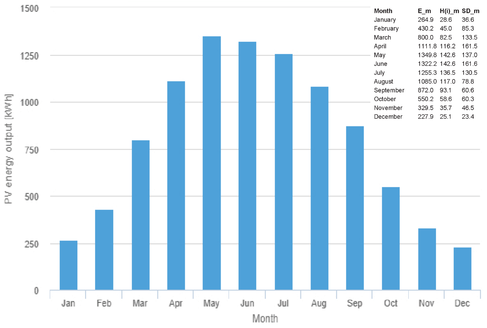


PV Array Orientation 1 | PV Array Orientation 2

PV Panel 3D Render



PVGIS Solar Calculator Results



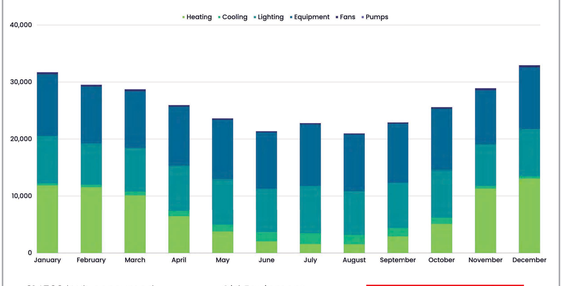
Month	E_m	H(i)_m	SD_m
January	264.9	28.6	36.6
February	430.2	45.0	85.3
March	800.0	82.5	139.5
April	1111.8	116.2	161.5
May	1349.8	142.6	137.0
June	1322.2	142.6	161.6
July	1255.3	136.5	130.5
August	1085.0	117.0	78.8
September	872.0	93.1	60.6
October	550.2	58.6	60.3
November	329.5	35.7	46.5
December	227.9	25.1	23.4

With the implementation of Solar PV Panels to the Retrofit scheme of Liberty Hall, a PV energy production of 9598.69 kWh is predicted per annum. This amount of energy that is being saved is equal to:

9598.69 kWh = **4152 kg of CO_2 equivalent** = **4651 lbs of coal burned**

Results and Conclusions

Existing Building Energy Consumption



314533 kWh consumed per annum × Old Equipment Factor of 2 = **629066 kWh/yr**

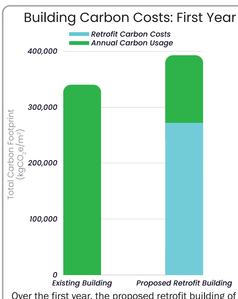
Retrofit Building Annual Energy Consumption

269536 kWh/yr

The Retrofit Proposal of Liberty Hall consumed 70% less energy per annum than the Existing Liberty Hall Building

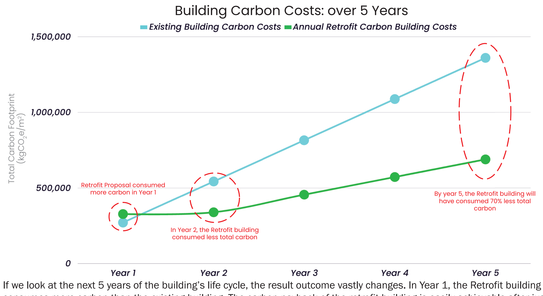
Key Findings and Conclusions

Building Carbon Costs: First Year



Over the first year, the proposed retrofit building of Liberty Hall is predicted to consume more carbon than the existing building. This is due to the high quality retrofit scheme applied to upgrade the building's thermal envelope construction. Looking at it this way means that the experiment concluded in a fail.

Building Carbon Costs: over 5 Years



If we look at the next 5 years of the building's life cycle, the result outcome vastly changes. In Year 1, the Retrofit building consumes more carbon than the existing building. The carbon payback of the retrofit building is easily achievable after just 2 years (seen in graph above). The retrofit building will continue to consume less carbon annually for the remainder of its life cycle in comparison to the existing building.

By the end of the proposed retrofit building's expected life cycle (approx. 30 years), it will have consumed 65% less carbon than the existing building at the end of it's life cycle

Limitations

A key limitation regarding this research project, was the inability to obtain access to the current Liberty hall as well as the its existing building service specification. The author resorted to educated guessing using information sourced from interviews of the building architect and structural engineer. Thus, the results shown may not be fully accurate to the true existing building of Liberty Hall, but as an experimental simulation instead.

Recommendations for Further Study

For any advice to continue this research study, the author recommends to the delve deeper into the specification of equipment maintenence culture. This was touched upon briefly in the Literature study done by the author. The methodology approached in this study could be also be applied to another building of similiar typology and the author recommends in doing so, with minor alterations were needed.