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Environmental evaluation of energy efficiency refurbishment in New Zealand's commercial office buildings

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Executive summary

In New Zealand, 80 % of existing commercial office buildings are more than 20 years old and consume approximately 40 % more energy than newer counterparts. Moreover, nearly 38 % of the energy-related emissions in New Zealand's cities are due to the heating and cooling requirements of commercial office buildings. Therefore, energy efficiency measures in office buildings are recommended to reduce operational energy related costs, provide better working conditions, and enhance business value. An energy efficiency refurbishment which involves adoption of multiple energy saving measures such as thermal insulation, improved glazing, air conditioning and lighting systems, can reduce the energy consumption of existing buildings by nearly 60 %. However, such a refurbishment also involves substantial construction work associated with the demolition and replacement of several building components, and this is associated with additional environmental impacts. It is therefore important to evaluate if the environmental benefits associated with reductions in energy demand can outweigh the environmental impacts of refurbishment.

This research investigated the comprehensive environmental impacts of energy efficiency refurbishments in New Zealand's office buildings using Life Cycle Assessment (LCA). The research used existing data collected for Building Energy End-use Study (BEES) by the Building Research Association of New Zealand (BRANZ). In particular, this research used the information on building design and annual energy consumption of existing and refurbished building prototypes. These building prototypes provided - construction details adopted in buildings of different sizes; and the operational energy performance based on typical climatic conditions found in New Zealand. The environmental performance of the buildings was calculated for Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Photo-chemical Oxidation Potential (PCOP), Acidification Potential (AP), Eutrophication Potential (EP), Abiotic Depletion of resources (AD_r), Abiotic Depletion of fossil fuels (AD_{ff}), Human toxicity carcinogenic (HT-carc), Human toxicity non-carcinogenic (HT-non care), Eco-toxicity freshwater ($ET_{freshwater}$), Particulate Matter Formation (PMF), and Ionizing Radiation (IR).

A series of studies were performed to: (i) assess the environmental impacts and identify the environmental hot-spots of energy efficiency refurbishment, (ii) assess the influence of building's service life, energy, resource and waste management on the environmental performance of energy efficiency refurbishment, (iii) assess the influence of building size, design and location on the environmental performance of energy efficiency refurbishment, and (iv) to evaluate the contribution of energy efficiency refurbishment to New Zealand's 2050 climate change mitigation target compared to the environmental performance of existing office building stock.

The results showed that at energy efficiency refurbishments can reduce emissions for environmental impact categories affected by energy demand particularly for global warming, acidification and photochemical oxidation. However, the refurbishment is also associated with increase in environmental impacts affected by resource demand such ozone depletion potential, abiotic depletion of resources, human toxicity (carcinogenic) and ionizing radiation. Service life of over 25 years is required to compensate the embodied environmental impacts of refurbishment for most of the impact categories, particularly if the electricity is sourced from renewable energy sources.

Refurbished components such as- on-site photovoltaic (PV), aluminium framed windows, façade components and heat pumps were identified as the major environmental hot-spots for most impact categories. The embodied environmental impacts to most categories could be reduced by 20 - 40 % if the waste recovery and recycling at construction site is improved. However, the overall environmental impacts of refurbished office buildings are highly sensitive to the choice of energy supply.

Energy supply from grid electricity generated from renewable resources should be prioritised over the use of on- site PV. Benefits from on-site PV is limited if the grid electricity supply is mainly from renewable sources; moreover, the production of photovoltaic panels is energy and resource intensive. It can increase nearly 50 - 100 % of the embodied environmental associated with building refurbishment. If on- site photovoltaic is installed, it should be prioritised in buildings with large roof area located in regions with long sunshine hours. The results also show that in large buildings- efficient heating, ventilation and lighting equipment; and smaller wall to window ratios should be prioritised to reduce environmental impacts. In small buildings, the choice of façade materials with low embodied impacts should be prioritised to reduce environmental impacts.

With respect to New Zealand's 2050 target for the existing office building sector 60 - 90 % greenhouse gas emissions reductions is possible only if the office building stock refurbishment is combined with a renewable energy supply. Nearly 60 – 70 % of the greenhouse gas emissions can be reduced if the refurbishment of the existing office building stock is limited to existing large office building stock (>3500 m²) or to buildings in Auckland and Wellington.

The main conclusions based on the results of this research are to prioritise better resource and waste management, to prioritise strategies for maintenance of refurbished buildings to promote longer service life, to support national level policies on increased use of renewable sources for grid electricity generation, and to prioritise refurbishment for a share of the building stock based on size and location which contributes to maximum energy reduction and minimal environmental impacts. The outcomes of this research can support national policy makers and independent building stakeholders (e.g. architects, owners, and engineers) who are keen on promoting energy efficiency refurbishments in New Zealand's office buildings.

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“It is not the mountain we conquer, but ourselves.”- Sir Edmund Hillary

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I dedicate this work to Michele and my family.

List of Abbreviations

AD _{ff}	Abiotic Depletion (fossil fuels)
AD _r	Abiotic Depletion (resources)
AP	Acidification Potential
AISI	American Iron and Steel Institute
BAU	Business As Usual
BRANZ	Building Research Association of New Zealand
CCANZ	Cement and Concrete Association of New Zealand
CIS Russia	Commonwealth of Independent States (Russia)
EP	Eutrophication Potential
ET _{freshwater}	Eco-toxicity (freshwater)
FAO	Food and Agriculture Association
GWP	Global Warming Potential
GHG	Greenhouse gas emissions
HT carc	Human Toxicity (carcinogenic)
HT non carc	Human Toxicity (non- carcinogenic)
IAI	International Aluminium Institute
IEA	International Energy Agency
IR	Ionizing Radiation
LCA	Life Cycle Assessment
LED	Light Emitting Diode
MBIE	Ministry of Business, Innovation and Employment
NZ	New Zealand
ODP	Ozone Depletion Potential
OECD	Organization for Economic Cooperation and Development
PCOP	Photochemical Oxidation Potential
PET	Polyethylene Terephthalate
PMF	Particulate Matter Formation
RoW	Rest of the World
REBRI	Resource Efficiency in the Building and Related Industries
UNCOMTRADE	United Nations international COMmercial TRADE statistics
UN FCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environmental Program
USGS	United States Geological Survey

Table of Contents

Executive summary	iii
Acknowledgements	iv
List of Abbreviations	vii
List of Figures.....	xiii
List of Tables.....	xiv
1.1 Energy efficiency refurbishments - a strategy to improve environmental performance of commercial buildings	2
1.2 Relevance of energy efficiency refurbishment for commercial buildings in New Zealand	3
1.3 Assessment methods to evaluate energy efficiency refurbishments.....	6
1.4 Relevance of LCA to evaluate the environmental effects of energy efficiency refurbishment in New Zealand’s commercial buildings.....	8
1.5 Research aim and objectives.....	9
1.5.1 Research aim and questions.....	9
1.5.2 Materials and Methods	10
1.5.3 Structure of the thesis	12
1.6 List of publications	13
2.1 Introduction	19
2.2 LCA standards for the building sector.....	21
2.2.1 Goal and Scope.....	21
2.2.2 Inventory analysis in building LCA	22
2.2.3 Impact assessment and Interpretation of building LCA	24
2.3 Definition of building refurbishment in LCA.....	25
2.4 Methodology.....	27
2.5 Discussion on methodological approaches.....	31
2.5.1 Scope	31
2.5.2 Inventory Analysis.....	32
2.5.3 Impact Assessment	33
2.5.4 Number and Location.....	34
2.6 LCA of whole office buildings.....	35
2.6.1 Energy conservation in operation.....	38
2.6.2 Environmental improvement in material production.....	39
2.6.3 Material recycling.....	40
2.7 LCA of refurbishment for energy efficiency in office buildings.....	41
2.7.1 Environmental impacts of multiple refurbishment measures	41

2.7.2 Environmental impacts of single building component refurbishment.....	42
2.8 Conclusion.....	45
3.1 Introduction	52
3.2 Methodology	55
3.2.1 Case study description.....	55
3.2.2 Functional unit and system boundaries	56
3.2.3 Data acquisition for inventory analysis	58
3.2.3.1 Building façade elements	59
3.2.3.2 Technical components	60
3.2.3.3 Construction activities related to refurbishment.....	61
3.2.3.4 Inventory for construction materials and energy	61
3.2.3.5 Building operation.....	63
3.2.3.6 Inventory for electricity mix and potential scenarios	63
3.3 Results	66
3.3.1 Environmental impacts of refurbishment	66
3.3.2 Cumulative environmental impact	67
3.3.3 Environmental Payback.....	70
3.4 Discussion	71
3.4.1 Environmental hotspots in building refurbishment	71
3.4.2 Relevance of deep energy refurbishment in offsetting environmental impacts from New Zealand’s electricity grid mix	73
3.4.3 Comparison of results with existing studies.....	74
3.4.4 Limitations and Future Work	76
3.5 Conclusion.....	77
4.1 Introduction	86
4.1.1 Use of Consequential LCA modelling in the building sector.....	87
4.2 Methodology	89
4.2.1 Base case and scenarios.....	90
4.2.2 Inventory analysis.....	94
4.2.2.1 Identification of marginal suppliers.....	94
4.2.2.2 Substitution and avoided burdens.....	97
4.2.3 Impact Assessment	99
4.2.4 Sensitivity analysis	99
4.3 Results	100
4.3.1 Contribution analysis.....	100
4.3.2 Scenario analysis	100

4.3.3 Sensitivity analysis	104
4.4 Discussion.....	107
4.4.1 Contribution Analysis.....	107
4.4.2 Scenario Analysis	108
4.4.3 Sensitivity Analysis	109
4.4.4 Limitations.....	110
4.5 Conclusion.....	111
5.1. Introduction	125
5.2. Methodology.....	127
5.2.1 LCA modelling.....	129
5.2.2 Statistical Analysis	133
5.2.2.1 Model selection.....	134
5.3 Results	136
5.3.1 Kruskal-Wallis and post hoc Dunn test results.....	136
5.3.1.1 Buildings in BAU compared to other scenarios	136
5.3.1.2 Comparison of buildings in RE, PV and BCP scenarios	136
5.3.2 GAM results	138
5.4 Discussion.....	140
5.4.1 Refurbished buildings in the BAU scenario	140
5.4.2 Refurbished buildings in the PV scenario	142
5.4.3 Refurbished buildings in RE scenario	143
5.4.4 Refurbished buildings in the BCP scenario	144
5.4.5 Limitations and future work	144
5.5 Conclusion.....	145
Abstract	153
6.1 Introduction	154
6.2 Methodology.....	158
6.2.1 New Zealand specific office building prototypes	158
6.2.1.1 Building characteristics and Energy simulation	158
6.2.1.2 Life cycle assessment of building prototypes	159
6.2.1.3 New Zealand’s Electricity grid scenarios	160
6.2.1.4 Environmental impact of building prototypes up to 2050	161
6.2.2 New Zealand’s office building stock.....	162
6.2.2.1 Stock Aggregation Analysis	163
6.2.2.2 Accounting for New Zealand’s 2050 GHG emission target.....	164
6.3 Results	167

6.3.1 Environmental performance of New Zealand’s office building stock.....	167
6.3.2 Environmental performance based on building location and building size groups	168
6.3.3 Target 2050 - New Zealand’s office building stock	171
6.3.4 Targeting refurbishment towards specific building stock	173
6.4 Discussion	176
6.4.1 Role of electricity supply.....	176
6.4.2 Impacts embodied in refurbishment	177
6.4.3 Refurbishment and 2050 GHG mitigation target	178
6.4.3.1 Targeting GHG mitigation with specific location	179
6.4.3.2 Targeting GHG mitigation towards buildings of specific sizes.....	179
6.4.4 Limitations and future work	180
6.5 Conclusion.....	182
7.1 Introduction	188
7.2 Influence of study design	188
7.2.1. Inventory modelling	190
7.2.2 Life Cycle Stages.....	191
7.2.3 Analytical approaches adopted to strengthen LCA results.....	192
7.3 Key findings	195
7.3.1. Environmental Hotspots	195
7.3.2. Influence of electricity supply	196
7.3.3. Influence of waste and resource management	197
7.3.4 Influence of building characteristics	199
7.3.4.1 Building Lifetime	199
7.3.4.2 Building size.....	200
7.3.4.3 Buildings in different location.....	200
7.3.5 Maximizing net environmental benefits.....	201
7.4 Applicability of results to policy makers.....	205
7.4.1 National policy: prioritise renewable grid electricity generation	205
7.4.2 National policy: prioritise deep energy refurbishment of existing building stock as an immediate climate change mitigation strategy.....	205
7.4.3 National policy: prioritise services that support segregation and recycling of construction wastes	206
7.4.4 National policy: prioritise refurbishment strategies based on building size and location	206
7.4.5 Building Level: prioritise construction waste and resource management	206

7.4.6 Building Level: prioritise longer operational period of refurbished buildings with maintenance	207
7.4.7 Building Level: prioritise refurbishment strategies based on building design, size and location.....	207
7.5 Limitations and future work	207
7.5.1 Limitations - case studies	207
7.5.2 Limitations - methodology	209
7.6 Conclusions	212
Supporting Information - 1	233
Supporting Information - 2	237
Supporting Information - 3	246
Supporting Information - 4	261
Appendix	267

List of Figures

Chapter 1

Figure 1.1 Energy Performance Indicators (EnPI) of different commercial premises based on their use.....5

Chapter 2

Figure 2.1 Life cycle stages of a building represented as adapted from building LCA standard EN 15978 (2011)).....22

Figure 2.2 Building performance with predicted modifications in its functional timeframe.....26

Chapter 3

Figure 3.1 Activities and flows associated with materials and energy modelled in this study for building refurbishment and subsequent operational use.....58

Figure 3.2 The impact assessment results for refurbished building and the relative contributions of the different refurbished components, construction activities and waste treatment.....67

Figure 3.2.(a and b) Cumulative impact assessment results for the refurbished and existing building operating for 25 or 50 years using different electricity grid mix scenarios.....68

Chapter 4

Figure 4.1 System boundary, base case and the three scenarios on share of materials recycled or re-used assessed.....94

Figure 4.2 (a and b) Impact assessment results for the building refurbishment in Business As Usual scenario, waste minimization scenario, alternative material procurement scenario, and combination of waste minimization and alternative material procurement scenario.....103

Figure 4.3 (a and b) Net impact results (per functional unit) in each scenario for sensitivity analysis of a) recycling efficiency, b) specific marginal suppliers and c) potential change in electricity grid mix of specific marginal suppliers106

Chapter 5

Figure 5.1 Representative office building prototypes and seven regions across New Zealand. Schematic representation of data and methodology used in chapter 5.....132

Figure 5.2 (a and b) The comparative results per functional unit for the four scenarios on energy and resource management138

Chapter 6

Figure 6.1 Representative office building prototypes and seven regions across New Zealand. Schematic representation of data used in chapter 6.....160

Figure 6.2 (a and b) The stock aggregated impact assessment results from 2017 - 2050 for buildings in four different refurbished or non-refurbished conditions (nRb, Rb, Rb BCP, Rb PV) and two scenarios on NZ grid electricity generation.....171

Figure 6.3 Cumulative GWP between 2017 to 2050 for buildings in in four different refurbished or non-refurbished conditions (nRb, Rb, Rb BCP, Rb PV) and two scenarios on NZ grid electricity generation.....174

Chapter 7

Figure 7.1 Heat map built to represent the influence of building condition and strategies for building refurbishment on the overall environmental performance of New Zealand’s existing office building stock.....205

List of Tables

Chapter 1

Table 1.1 Energy Performance Indicators (EnPIs) for electricity use by commercial buildings in New Zealand.....4

Chapter 2

Table 2.1 Whole building Life cycle assessment studies on office buildings.....29

Table 2.2 Life cycle assessment studies on refurbishment in office buildings.....30

Chapter 3

Table 3.1 Building Characteristics - existing and refurbished building.....56

Table 3.2 Scenarios used to represent the New Zealand Grid electricity mix.....64

Table 3.3 Inventory data for refurbishment activities and annual building operation for case study building.....65

Table 3.4 Payback period of the deep energy refurbishment for the case study using different electricity grid mix scenarios.....71

Chapter 4

Table 4.1 Specifications of the existing and refurbished building and related refurbishment measures91

Table. 4.2 Marginal suppliers of construction materials and products.....97

Table 4.3 Marginal electricity supply of identified material and product suppliers.....	98
---	----

Table 4.4 Modelling assumptions for secondary materials produced from the recovery of demolition waste or used to substitute primary materials during refurbishment and associated avoided burdens.....	99
---	----

Chapter 5

Table 5.1 Summary of building characteristics which were considered as predictor variables in the GAM modelling to test their influence on the environmental impact.....	133
--	-----

Chapter 6

Table 6.1 Environmental impact categories and related impact assessment methods.....	161
--	-----

Table 6.2 Marginal sources of electricity production in New Zealand and the environmental impacts associated with 1 kWh of low voltage electricity produced.....	162
--	-----

Table 6.3 Total floor area of office buildings in New Zealand based on size and location.....	164
---	-----

Table 6.4 GWP in 2050 of whole office building stock with respect to New Zealand's 2050 target.....	175
---	-----

Table 6.5 GWP in 2050 of whole office building stock with respect to 2050 target-if buildings in specific regions are refurbished.....	175
--	-----

Table 6.6 GWP in 2050 of whole office building stock with respect to 2050 target-if buildings in two or more major cities and adjoining regions are refurbished...	175
--	-----

Table 6.7 GWP in 2050 of whole office building stock with respect to 2050 target-if buildings of specific sizes are refurbished.....	176
--	-----

Chapter 7

Table 7. 1 Summary and comparison of the study design.....	195
--	-----