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 carc), 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 m^2) 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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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

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