

# 41 Exemplar case study

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## ABSTRACT

Having outgrown its old Melbourne headquarters, the Australian Institute of Architects decided to rebuild on its blue-chip piece of Melbourne CBD real estate. The brief to designers Lyons Architects was to conceive and construct a building that embodies the values of sustainable architecture in a modern multi-storey commercial office building.

This note discusses the notion of the Total Carbon Metric, a quantitative tool used for the building's design that measures carbon emissions brought about by embodied energy (materials), operational energy, transport and waste over a 30-year total lifecycle.

## Introduction

41 Exemplar – 41X for short – will be the new Melbourne home of the Victorian division of the Australian Institute of Architects (the Institute). Located at 41 Exhibition Street, Melbourne, the 21 storey strata-title commercial office building is due for completion in late 2013.

The Institute initiated the project through a design competition which was won by Melbourne's Lyons Architects in conjunction with AECOM.

The Institute's inspiring vision for the project is an exemplar case study in sustainable design and a new direction in Australian building design. In response to this vision, AECOM, the project's integrated sustainability and building engineering services consultant, proposed a carbon-centred design approach focussed not just on operational energy, but also encompassing the embodied energy within the materials, waste and transport. This approach utilised AECOM's Total Carbon Metric (TCM) methodology. Subsequently, the TCM has been used as a key driver in the design and construction of 41X, and will continue to underpin the management and operation of the new building to reduce the carbon impact of 41X.

One of the project's innovative and far reaching initiatives is a Sustainability Charter for all building tenants. The Sustainability Charter binds tenants to the sustainability agenda for the building to monitor and, where needed, change behaviours. On an annual basis, the measured operational carbon footprint of the building's tenants will be independently assessed. Combined with the quantified embodied carbon of the physical building, the operational carbon will be offset annually.

This case study describes how the project team has delivered the Institute's vision for 41X and steps through AECOM's TCM. It presents the quantity of carbon generated by the building's embodied material emissions, operational energy, transport and waste. It then looks at how the TCM tool influenced the building's design and explores the role the TCM had on the building's unique Sustainability Charter.

## The building

The inception of 41X dates back to 2006 when the Institute commissioned a detailed feasibility study for the site. The standard of the previous premises at 41 Exhibition Street was the lowest of any Institute accommodation in the country. It needed a complete refurbishment, rebuild, or sale and relocation to achieve an appropriate standard. Having reviewed all

these options, the feasibility study concluded that the current site provided an excellent prime city location which was popular and convenient for both staff and members, and therefore the best option would be to rebuild on the site.

Through a design competition held in 2009, Lyons and their consulting team (including AECOM) were awarded the project.

### Building stats

5 Star NABERS Energy – Base Building

5 Star Green Star

occupied floors: 21

NLA: 5585m<sup>2</sup>

GFA: 8554m<sup>2</sup>

office floor plate: 285m<sup>2</sup> NLA

Institute staff: 72 people

In 2011, a contract for the construction of the new building was agreed with Hickory, with the project scheduled to be completed in late 2013.

Functional space types include basement back-of-house, ground floor retail and 21 levels of commercial office space including Institute offices.

The building is targeting a 5 Star NABERS (National Australian Built Environment Rating System) Energy Base Building rating and 5 Star Green Star Office v3 Design rating.

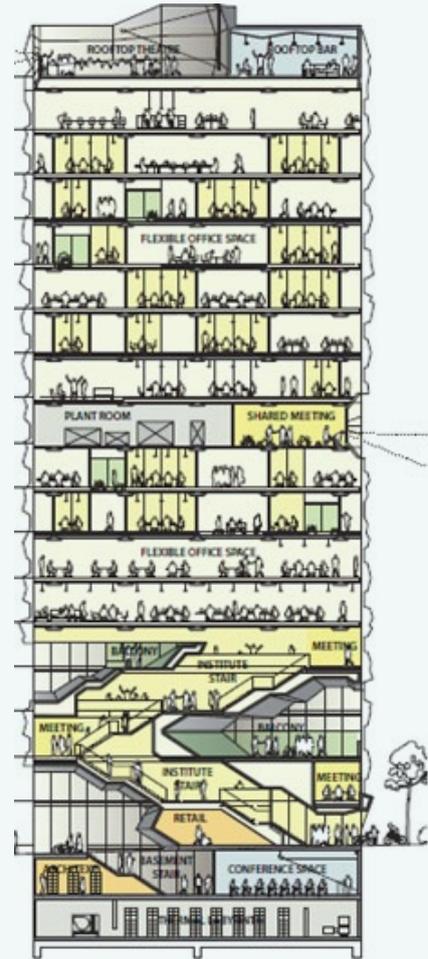
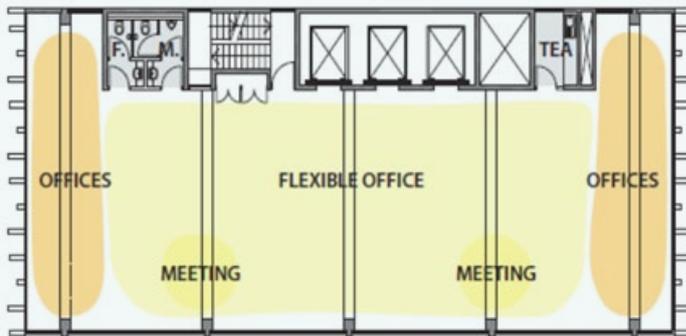
### Thermal performance

Building perimeter to internal zone ratio is 65%, which led to a high performance building envelope. The east/west facade U-value 2.50 W/m<sup>2</sup>K, 0.25 SHGC

The south facade U-value 2.50 W/m<sup>2</sup>K, 0.33 SHGC

HVAC strategy is a floor-by-floor variable volume low temperature system with demand control ventilation and 50% increase in outside air rate.

Thermal plant comprises roof top air cooled chiller, tenancy closed circuit heat rejection plant and a forced draft boiler.



## The concept

The Institute's design competition brief called for 6 Star Green Star Office v3 Design and As Built ratings. During the competition phase, the Lyons/AECOM design team explored opportunities to meet this requirement but the unusual physical parameters of the redevelopment with its small site footprint made it extraordinarily difficult to achieve within the commercial parameters of the project.

To counter the challenges confronting the delivery of a 6 Star Green Star building, the design team formulated an alternative environmental solution with a more holistic approach to a building's carbon cycle. The design team considered that a building, through its construction and operation, builds up a balance sheet of CO<sub>2</sub> that is displaced to the environment. Carbon is embedded in the building's construction and then continually emitted through its operation. The new approach comprehensively considers the quantity of carbon that a building generates, and then seeks to displace that carbon through design methods in the first instance and then, if required, offsite displacement – the Total Carbon Metric.

The Institute embraced the proposed carbon-centred approach and included emissions reduction analysis in the brief as a requirement to complement the revised target of a 5 Star Green Star Office v3 Design rating, whilst maintaining the original 5 Star NABERS Energy Base Building rating target.

## Total Carbon Metric

The TCM is an analytical process to quantify the environmental impact of a development. The TCM tool involves the collation of data from embodied carbon metric calculations, AECOM-developed waste and transport models, and a dynamic 3D energy simulation model.

The TCM is not a Life Cycle Analysis (LCA) tool but rather a comparative analysis tool. It enables the assessment of a design's carbon objective in conjunction with the functional project requirements and financial constraints. Data from the tool quantifies the opportunities for carbon mitigation and, thus, the potential impact of design initiatives on a building's carbon footprint.

The TCM quantifies data for four critical carbon sectors:

- operational energy
- materials
- transport
- waste

## TCM applied to 41X

The Institute determined that the TCM study would assess the feasibility of the proposed design achieving at least a 60% reduction in greenhouse gas emissions compared to a typical Business As Usual (BAU) base case commercial office development.

For 41X, the specifics of the four carbon sectors are as follows:

**Operational Energy** – Grid electricity and natural gas provides energy for systems and services including air conditioning, lighting, general power requirements and vertical transportation.

Annual operational energy consumption was computed using dynamic energy modelling software. The simulation was completed in accordance with standard NABERS operational energy modelling methodology.

**Embodied energy of materials** – Applies to building materials used in construction. Low embodied energy is fundamental to reducing the building's carbon footprint.

The Embodied Carbon Metric (ECM) calculates material emissions based on Australia-specific emission factors derived using a cradle-to-site approach. This includes emissions from the extraction of raw materials, primary energy sources, manufacturing, on-site construction and transportation.

**Transport** – Carbon emissions generated by journeys to and from the building constitute an important aspect of the carbon footprint of any development. A focus area for behaviour change under this sector is staff travel to and from work.

The transport metric is based on the *Transport Demand Information Atlas for Victoria*, Volume 1 (Department of Transport 2008). Emission factors associated with transport modes were derived from the Australian Bureau of Statistics' *Survey of Motor Use and EPA Victoria's Greenhouse Inventory Management Plan 2007–2008*, in conjunction with the Department of Climate Change's *National Greenhouse Accounts* factors for transport (2008).

**Waste (operational)** – Generated through daily operations, waste is a significant aspect of the ongoing operational carbon emissions of the building. Operational waste includes organics, plastics, metal, glass, paper and general waste.

Waste produced during operation was estimated using benchmark waste generation rates from the City of Melbourne's *Guidelines for Preparing a Waste Management Plan* (2009). The generation rates for each individual waste stream and associated recycling rates were sourced from Ecocycle Victoria's *Understanding the Waste Stream* (2000).

The carbon emissions from landfill are associated with methane (CH<sub>4</sub>) production at landfill sites. Where the categorisation of waste streams is unknown, the *National Greenhouse Accounts* (DCC 2008) emissions factors for broad waste stream categories were used.

## 41X TCM scenarios

A TCM scenario was developed to represent the base case and the design decisions for 41X were translated into a TCM of the project's concept design.

### BAU – base case

The 41X analysis was founded on constructing a base case model consisting of business as usual (BAU) operation with respect to the use of energy, materials and transport usage patterns, as well as waste emissions.

**Energy** – The benchmark for comparison was intended to represent a minimum standard building, hence, a 3 Star NABERS Energy Base Building rating was nominated

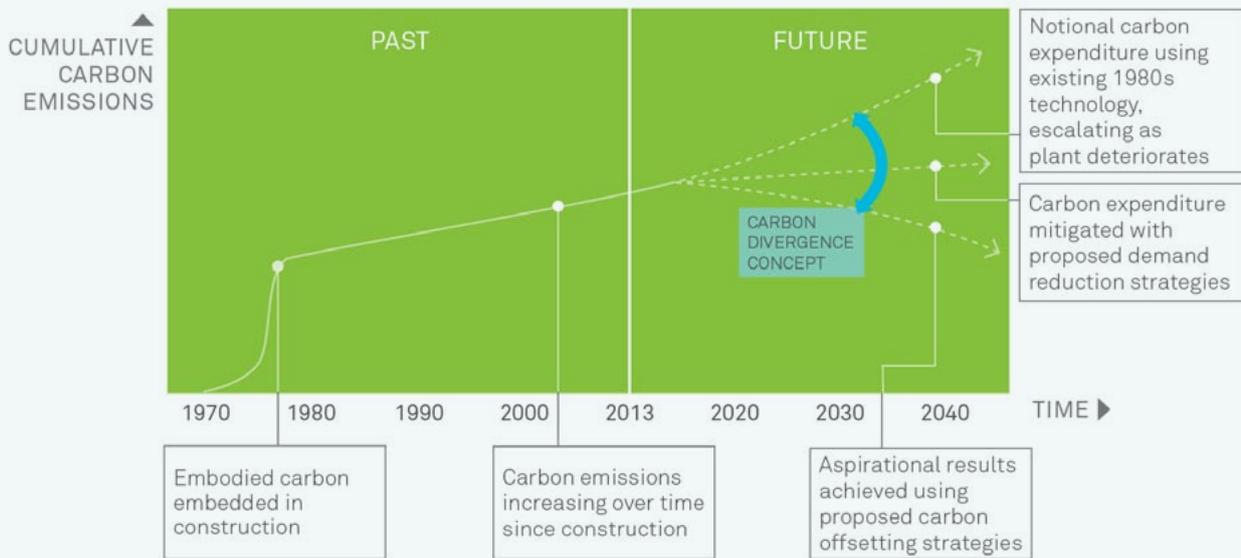
**Materials** – Minimum national construction code requirements for an office building in Melbourne CBD

**Transport** – 2% cycling rate, 65% public transport, 25% car use

**Waste** – No recycling during demolition and construction, 37% general recycling rate during building operations

### BAU less 60%

The second TCM scenario was constructed based on the 41X design brief. During the early phases of design the project team predicted that environmental ratings alone could not meet the 60% carbon reduction target. Therefore a 'Green Plan' was developed for each of the four carbon sectors and analysed under the 'BAU less 60%' scenario.



## Achieving carbon reductions with Green Plans

**Energy Efficiency Plan** – The following three scenarios were nominated relative to the 3 Star NABERS BAU benchmark:

- 5 Star NABERS Energy Base Building
- 5 Star NABERS Energy Base Building and extension of the space temperature bandwidth (CB) to 20°C–25°C
- 5 Star NABERS Energy Base Building and extension of the space temperature bandwidth (CB) to 20°C–26°C

**Green Materials Plan** – The following carbon reduction element initiatives were identified within the materials sector:

- Steel reinforcing with 20% recycled content
- Fly ash in concrete 30%

**Green Transport Plan** – The proposed Green Transport Plan encourages tenant access to the site via public transport and bicycle transport. The car journeys avoided compared to the BAU benchmark were apportioned to public transport, walking and cycling.

The Green Transport Plan carbon reduction initiatives identified within the transport are:

- |   |              |
|---|--------------|
| 1. Walking increased from               | 5.5% to 7.7% |
| 2. Cycling increased from               | 2.3% to 6.7% |
| 3. Train and tram travel increased from | 51.8% to 61% |

- Bus travel increased from 12.9% to 14.6%
- Car travel decreased from 27.9% to 10%

**Green Waste Plan** – The Green Waste Plan encompassed both the office tenants and retail tenants in order to maximise its impact. Carbon reduction initiatives proposed for this scenario were:

- General recycling rate increased from BAU benchmark of 37% to 70%
- All residual garbage to landfill

## TCM Concept Design analysis

Findings for each carbon sector from the TCM Concept Design (presented in Figure 1) were as follows:

**Operational Energy** – The TCM comparative analysis of the Energy Base Case versus the Green Energy Efficiency Plan found:

- A 5 Star NABERS Energy Base Building achieves a 60% reduction in operational energy carbon emissions
- 20°C–25°C dB space temperature bandwidth achieves a 64% reduction
- A maximum sector reduction of 68% is possible with Option 'B' (20°C–26°C dB space temperature bandwidth) scenario. This final and endorsed Energy Efficiency Plan, Option 'C', equates to a reduction of 612 tonnes of CO<sub>2</sub>-e per annum

Under Energy Efficiency Plan Option 'C', the building will generate 293 tonnes of CO<sub>2</sub>-e per annum. Overall, the Energy Efficiency Plan reduces building carbon emission by 35%.

**Materials** – Two Green Materials Plan initiatives were assessed against the BAU benchmark. Under the Green Materials Plan, construction (demolition, site construction and product manufacture), is estimated to generate 7560 tonnes of CO<sub>2</sub>-e or the equivalent of 252 tonnes of CO<sub>2</sub>-e per annum distributed over a 30-year period. The Green Material Plan equates to a reduction of seven tonnes of CO<sub>2</sub>-e per annum, with a maximum sector reduction in embodied carbon emissions of 3%.

The Green Materials Plan reduces total building carbon emissions by 1%.

**Transport** – Under the Green Transport Plan, transport is estimated to generate 376 tonnes of CO<sub>2</sub>-e per annum. This equates to a reduction of 94 tonnes of CO<sub>2</sub>-e per annum, a sector reduction in carbon emissions of 19%.

The Green Transport Plan reduces total building carbon emissions by 6%.

**Waste** – Under the Green Waste Plan, waste is estimated to generate 53 tonnes of CO<sub>2</sub>-e per annum. This equates to a reduction of 35 tonnes of CO<sub>2</sub>-e per annum, that is, 39% relative to BAU.

The Green Waste Plan reduces total building carbon emissions by 2%.

Overall, the accumulative benefits achieved from the Green Plans are estimated to be 44% when compared to BAU. This equates to a carbon emission saving each year of 706 tonnes (see Figure 1).

With the completion of the concept design, the TCM defined the possibility for 41X to achieve a 60% carbon reduction target and enabled qualified carbon emission data to form part of the building design decision-making process.

Findings from the TCM Concept Design analysis showed that the base building design had the potential to achieve a 44% reduction in carbon emissions and not the targeted 60%. To achieve 60% (or better), further initiatives or offsets would be required.

## Design changes

External factors played a role in the final building design. During the concept design period of, the economic conditions of the construction industry were not favourable, causing the viability of the project to be at risk. Hence, the Institute made the decision to place the project on hold for a period of time.

Upon the project's resumption, a Value Management (VM) process took place involving the Institute, the design team and the preferred builder, Hickory. As a result of the VM process, modifications to the overall building concept occurred, including discounting a number of proposed Green Plan initiatives.

The following is a summary of key changes that occurred during this time:

### General

- Number of occupied floors increased from 17 to 21
- Gross Floor Area (GFA) increased from 6550m<sup>2</sup> to 8554m<sup>2</sup>

### Energy efficiency plan

- The HVAC strategy moved from a central plant with chilled beam/under-floor air distribution (UFAD) to a floor-by-floor solution comprising a low temperature variable air volume system
- East/west glazing panel decreased in size while the glazing system performance increased

### Green materials plan

- The band beam structural floor configuration was replaced with a flat slab bubble deck solution
- Floor to floor height decreased
- Greater focus on a pre-cast solution
- Spacing and depth of east/west facade shading devices were rationalised

## REDUCTIONS CONCEPT DESIGN

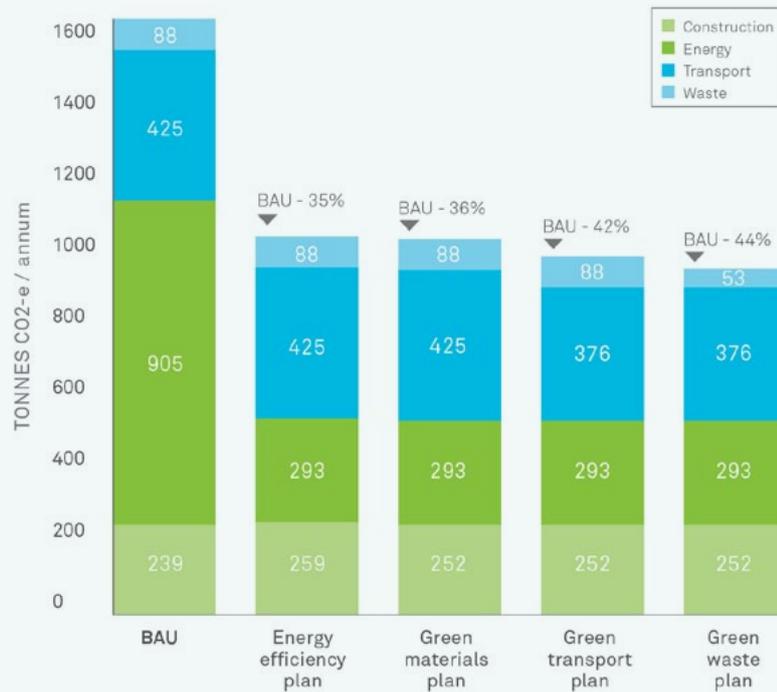


Figure 1: TCM Concept Design analysis

### Green transport plan

- Cycling 5%
- Public transport 75%
- Car travel 15%

### Green waste plan

- 80% construction recycling rate
- The TCM analysis of retail space was removed, therefore the volumetric estimate of waste generation focused only on office areas
- General recycling rate was reduced to 50%

### The revised project plan

While structural and building services changes occurred as a result of the VM process, the Institute remained steadfast on retaining a design capable of meeting the targeted 5 Star NABERS Energy Base Building rating and 5 Star Green Star Office v3 Design rating.

The Institute also continued to pursue its vision of an exemplar case study sustainable building design. Focusing on the carbon footprint, it still sought to meet and possibly exceed the project's environmental target of 60%, with the ultimate goal of achieving BAU-100% – carbon neutrality.

It was concluded that carbon neutrality could only be achieved through off-site carbon offsets, which led the Institute to develop a Sustainability Charter for the building.

### Sustainability Charter

Owners of commercial buildings do offset their electrical and gas-generated carbon emissions through the purchase of Green Power. While environmentally significant, this approach overlooks other sectors of carbon emissions: embodied energy, operational waste and occupant transport.

The project team revisited the project's carbon-centred philosophy, seeking lateral methods to displace the building's total carbon balance sheet. Through a series of workshops involving the project team, industry advisors, legal counsel and the Institute, the project team decided to create a Sustainability Charter for the development.

The objectives of the 41X Sustainability Charter are to:

- Minimise carbon emissions for the development through the integrated implementation of a range of environmentally sustainable systems
- Reduce all greenhouse gas emissions generated in construction and operation by 60% over 30 years when compared to a BAU commercial office building within Melbourne's central business district
- Achieve carbon neutrality by offsetting the remaining carbon emissions through an accredited program

The Sustainability Charter recognises both physical and economic constraints on the building's design and construction while still striving for opportunities in the building's operations – specifically occupant behaviour change – to reduce carbon emissions.

The Sustainability Charter states that:

1. An annual carbon report on 41X will be produced by an independent consulting agency that calculates the cost of carbon sequestration for the various tenant/owner occupier sector emissions.
2. The Owners Corporation will displace 100% of the carbon emissions from base building and tenant operational energy through government certified offsets.
3. Operational energy for each tenant or owner occupier will be separately metered. All carbon emissions will be offset through government certified offsets.
4. The embodied carbon emissions of materials used during the construction process will be quantified. All emissions will be offset over a 30-year period.
5. An annual transport study will be conducted by an independent consultant to calculate the carbon emissions associated with the transportation of building occupants between their place of residence to the building. This report becomes an input into the annual carbon report.
6. Each tenant will be responsible for segregating waste into appropriate streams: organics, plastics, glass, metals, cardboard/paper and general waste.
7. A waste contractor will be engaged to collect and dispose of building waste. All waste will be measured and quantities reported quarterly. These reports will form the basis of inputs into the annual carbon report.

**Post concept design changes to TCM** – Since completing the TCM Concept Design analysis in 2010, AECOM increased the sophistication of TCM through the inclusion of Davis Langdon's (an AECOM company) embodied carbon metric, which modifies each sector's input through feedback from other projects and adapted current *National Greenhouse Accounts* (Department of Climate Change) emission factors.

The 2012 version of the 41X TCM also improved the demolition and onsite construction input data as it included Hickory as the awarded builder. This enabled the 'For Construction' TCM demolition and onsite construction input data to be tailored to reflect Hickory's site management plan, including daily diary entries of demolition contractor work activities and approximated onsite work activities for the duration of the construction period.

**Modifications to TCM 'For Construction'** – By late 2011, the concept design TCM had served its purpose: to inform the project team of the base building's estimated carbon emissions and to provide a quantitative comparative analysis of a base case building versus a building with carbon reduction initiatives.

However, as a result of creating a Sustainability Charter, the concept design TCM required updating to reflect the final building design and to align the results from the TCM analysis with the protocols outlined under the charter including the addition of the tenancy operational energy consumption to capture the whole of building emissions. The revised TCM, a 'For Construction' version, was created. This served the purpose of:

- quantifying the constructed building's embodied carbon
- assisting in developing the initial carbon sequestration budget by calculating the totality of carbon emissions to be offset per annum
- assisting the Building Owners Corporation to develop a benchmark for a comparative performance analysis of the building's operational energy, waste and transportation usage

## GREENHOUSE GAS EMISSIONS BY SECTOR

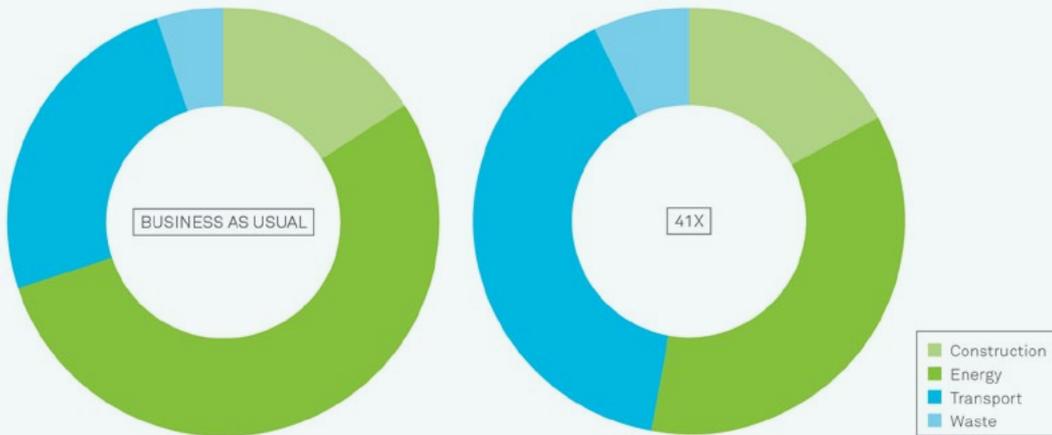


Figure 2: TCM 'For Construction' base building carbon emissions by sector

### 'For Construction' sector analysis

The TCM 'For Construction' analysis was based on the 'For Construction' set of documents issued to the builder. The findings for each sector were:

**Demolition & site construction** – From the demolition sub-contractor's collated data:

- The demolition and construction phase is estimated to generate 467 tonnes of CO<sub>2</sub>-e or the equivalent of 15.6 tonnes of CO<sub>2</sub>-e per annum (based on a 30-year period)
- The largest contributor is electricity (63%), the next largest contributor is fuel consumption by onsite generators and heavy machinery (22%)

**Embodied energy of materials** – The TCM analysis found:

- Aluminium represents 0.8% by weight, but its emissions contribute 33% of the sector's carbon emissions
- Concrete contributes 89% of total weight yet contributes the same amount (32%) of sector emissions as aluminium
- Building construction processes (demolition, site construction and product manufacture) achieve a 34% reduction across the construction sector under the Green Materials Plan

**Operational energy** – The TCM analysis found:

- 361 tonnes of CO<sub>2</sub>-e per annum will be emitted during the first year of building operation, or 65 kg CO<sub>2</sub>-e/m<sup>2</sup>
- With the Energy Efficiency Plan, a 60% reduction in sector carbon emissions or 544 tonnes of CO<sub>2</sub>-e per annum is saved when compared to BAU
- If tenancy energy consumption is included in the analysis, then the reduction in carbon emissions over the whole building has shifted from 60% to 32% when compared to BAU

**Transport** – The TCM analysis found:

- The Green Travel Plan equates to a 6% reduction in sector carbon emissions or approximately 24 tonnes CO<sub>2</sub>-e per annum
- Car trips only represent 15% of total journeys but emissions from cars will contribute 22% of the transport sector carbon emissions
- 60% of all journeys are train trips and contribute 60% of sector emissions

**Waste** – The TCM analysis found:

- Over 65% of waste will be generated from paper and cardboard products
- Waste sent to landfill will release approximately 74 tonnes of CO<sub>2</sub>-e into the atmosphere throughout the year
- Implementation of the Green Waste Plan equates to a 15% reduction in sector carbon emissions or approximately 14 tonnes of CO<sub>2</sub>-e per annum

## TCM 'For Construction' analysis

The project confronted site and economic challenges and the earlier design suggested a 44% reduction of carbon emissions over BAU. However, TCM 'For Construction' analysis found that the final design presented a 40% reduction of carbon emissions for the base building, or from the Owners Corporation/ Sustainability Charter perspective a facility capable of 27% less carbon emissions than a standard commercial office building inclusive of the tenancy operational energy. The contribution from each sector is shown in Figure 2.

The following are key findings from the TCM 'For Construction' base building analysis:

- The overall contribution to emissions reduction by the Energy Efficiency Plan is estimated to be 32%
- Building construction processes (demolition, site construction and product manufacture) achieve a 34% reduction within the Materials sector however it is a small contributor (5%) to the overall emissions savings
- The Green Transport Plan achieves an overall reduction of 2%
- The Green Waste Plan achieves an 15% reduction with its sector from a total carbon perspective, however this plan only provides a 1% reduction to the total building emissions
- The accumulative benefits from the Green Plans are an estimated overall carbon reduction of 40% for the base building or 27% for the whole building when compared to the BAU scenario – this equates to a saving each year of 670 tonnes of CO<sub>2</sub>-e

## Conclusion

As society becomes increasingly more carbon conscious, it is critical that designers of the built environment have access to a simple, creditable carbon measurement tool that captures at least the main carbon emitting elements of a building. The tool must ensure that, as building designers make key decisions about a building's design, they are kept informed of the design's impact on the environment.

41X's TCM was an essential tool in quantifying the building's ability to achieve the whole-of-building carbon emission reduction target. The tool's quantitative data for each sector provided insight into the magnitude of carbon generated per sector, their dominant elements, sector limitations and the influence carbon reduction strategies such as Green Plans can have on the design.

The TCM analysis also assisted in advancing the Institute's vision for designing sustainable buildings. The Institute formed a building performance accountability protocol known as the Sustainability Charter to ensure all strata-title owners adhere to the building's carbon neutrality target for embodied energy, operational energy, waste and transport. The TCM's role within the Sustainability Charter quantified the building's embodied carbon emissions and provided a benchmark to reference against the building's performance.

41X's carbon-centred approach has enabled stakeholders, designers and builders to understand the scale of the environmental impact the development could have had if minimum code requirement standards were implemented, or the design remained within the boundaries of the Green Star and NABERS rating tools. It also provided a mechanism to enable informed decisions during tough economic times. Ultimately, it led to the design of a building that is predicted to save 670 tonnes of CO<sub>2</sub>-e per annum over a typical commercial office building. This also equates to the removal of 7000 vehicles off our roads over a 30-year period.

## About the author

Russell Evans is the Victorian/Tasmanian Manager of the Applied Research and Sustainability Group at AECOM, a global provider of professional technical and management support services to markets including transportation, facilities, environmental, energy, water and government.

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## References

Department of Climate Change 2008, *National Greenhouse Accounts (NGA) Factors*

Australian Building Codes Board 2009 and 2011, *Building Code of Australia (BCA)*

Victorian Department of Transport 2008, *Transport Demand Atlas for Victoria*, Volume I

Environment Protection Authority Victoria 2007–2008, *Greenhouse Inventory Management Plan*

City of Melbourne 2009, *Guidelines for Preparing a Waste Management Plan*

Ecocycle Victoria 2000, *Understanding the Waste Stream*

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