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Christchurch's High Performance Rebuild

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Abstract

The devastating earthquake sequence in Christchurch and Canterbury has resulted in the removal of over 1200 buildings in the former Christchurch CBD. Add to this the damage to over 100,000 homes and the impact on the lives of the 436,000 residents of Greater Christchurch.

The Canterbury Earthquakes have provided an unprecedented opportunity to rethink, revitalise and renew Central Christchurch. Aided by an investment of greater than NZ$40bn, sourced via insurance, central and local government contributions and topped up by commercial and private investment, with construction at its peak, we are experiencing a spend rate exceeding NZ$100M per week.

Out of the rubble is emerging a well-formed and vibrant city centre that produces economic and social benefits by bringing together people for business, cultural or social activities. The "new Christchurch" is being built upon the principles of resilience, sustainability and connectedness, whilst also reflecting our history through the retention and enhancement of key heritage buildings and infrastructure assets framed by green spaces and accessible pathways.

This paper introduces some of the initiatives put in place as building blocks to drive the recovery of the new City Core, and indeed greater Christchurch and Canterbury Area. These initiatives range from improved building structural standards and codes, to 'Green' building rating tools, to Energy Design Advice Grants and "Smart City" development principles.

The new Christchurch can be (and is being) defined by its accessible, connected, resilient and high performing building stock. Only time will be the ultimate judge, however after just over 5 years, the city is going from strength to strength and Christchurch continues to provide a significant contribution to the national economy.

Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords: Christchurch; Earthquake; Rebuild; High Performance; Smart; Resilient; Sustainability; Green Building; Energy Efficiency; Smart City.

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1. Introduction

At 4:35am on September 4 2010, a magnitude 7.1 earthquake struck approximately 38km west of Christchurch. This event initiated the devastating sequence of earthquakes that has resulted in significant damage and destruction of the city of Christchurch and the greater Canterbury area. The city and surrounding landscape has changed forever as a result. Despite the devastation however, the Canterbury Earthquakes have provided an unprecedented opportunity to rethink, revitalise and renew Central Christchurch and create a future-proofed city that is smart, resilient as well as energy and resource efficient.

The total rebuild investment of greater than NZ$40bn is being sourced via insurance, central and local government contributions and topped up by commercial and private investment. It is nearly six years since the initial earthquake. The rebuild has progressively ramped up to a level where the peak of construction activity is currently being experienced, corresponding to a spend rate exceeding NZ$100M per week. The streetscape is rapidly changing as new buildings and infrastructure developments take shape both within the CBD and across the city.

This paper introduces some of the initiatives put in place as building blocks to drive the recovery of the new City Core, and indeed greater Christchurch and Canterbury Area. These initiatives range from improved building structural standards and codes, to ‘Green’ building rating tools, to Energy Design Advice Grants and “Smart City” development principles.

2. Impact of the Earthquakes

2.1. Largest earthquakes and damage

The number of individual quakes occurring between 4 September 2010 and mid 2016 has surpassed 17,500, with nearly 600 at magnitude 4 or greater [1]. The largest events are presented in Table 1. See Appendix 1.

Table 1. Summary of largest earthquakes that occurred in Christchurch 2010/2011.

Date	Time	Depth	Magnitude	Intensity	Energy
4 Sep 2010	4:35am	11.04	7.10	Intensive	671 kilo tonnes
22 Feb 2011	12:51pm	5.95	6.34	Destructive	49 kilo tonnes
13 Jun 2011	2:20pm	6.92	6.41	Destructive	62 kilo tonnes
23 Dec 2011	3:18pm	6.95	6.00	Very Strong	15 kilo tonnes

The most devastating impact on the city occurred at 12:51pm on 22 February 2011 when the magnitude 6.34 quake occurred only 6.7km from the CBD. 185 lives were lost with 115 people dying due to the collapse of a single six story building in the CBD. The February earthquake is noted as New Zealand’s most significant natural disaster with the government declaring a state of national emergency which remained in force until 30 April 2011. The Peak Ground Acceleration (PGA) on 22 February of 1.8g (1.8 times the force of gravity) in Central Christchurch and 2.2g at Heathcote Valley, only a few kilometres from the epicentre, was the highest PGA every recorded in NZ and further, was one of the greatest ever recorded worldwide, and unusually high for a 6.3 earthquake [2].

The extremely high PGA, and simultaneous vertical and horizontal ground movement was "almost impossible" for buildings to survive intact. Liquefaction was significant, causing the upwelling of more than 200,000 tonnes of silt which needed to be cleared. The liquefaction caused significant ground movement, undermining many foundations and destroying infrastructure, damage which "may be the greatest ever recorded anywhere in a modern city". 80% of the water and sewerage system was severely damaged and over 1200 buildings in the former CBD received irreparable damage and have had to be removed. Damage to over 100,000 homes occurred and the lives of 436,000 residents of greater Christchurch have been impacted. Nearly 10,000 homes have been deemed uninhabitable due to major land movement, increased flooding risk and/or rock fall hazard – as a result the government declared significant portions of land to be “red zone” and embarked on a land acquisition process which has resulted in these owners/residents having to relocate to other parts of the city, or further afield. The damaged houses were demolished and the land cleared to be left as vacant park area for the foreseeable future. Prior to any subsequent redevelopment at a later date, this land will need to undergo substantial remediation in order to mitigate the risk of flooding, liquefaction or land deformation.

2.2. Broader impacts

The broader impacts of the earthquake sequence have been more far reaching than one might imagine and, apart from the changes to the natural environment) including liquefaction, lateral spreading near waterways, land level changes and numerous rock falls and landslides), air and water quality were also impacted, largely caused by silt and suspended sediment washed into streams and waterways via storm water infrastructure. This, coupled with effluent contamination from damaged sewer pipework has also impacted on ecology and biodiversity across the city.

The impacts on the built and social environment involved a variety of buildings and infrastructure ranging from residential housing, healthcare and schooling facilities, central business district (commercial, retail and hospitality), to iconic landmarks and heritage buildings. The nature and scale of the physical impacts are able to be readily identified/quantified, however the varied social and environmental effects on individuals, whanau, social networks and communities are complex and often interrelated, and may manifest in a number of different ways.

Aside from the 185 deaths, over 7170 injuries were caused by both the primary shaking and were thus unavoidable, however many related to actions taken during the shaking (moving and taking cover) or subsequent earthquake related actions (undertaking cleanup). Some 250 elderly residents required temporary evacuation to other regions due to damage caused to their primary accommodation. Medical admissions were abundant during the recovery phase with many issues or ailments being symptomatic of overcrowding of homes, schools and office spaces or damaged, damp and cold homes. The impacts on health and mental wellbeing affected significantly on many people’s quality of life with symptoms of stress, hyper-vigilance, anxiety, sleep deprivation and fatigue, as well as people being forgetful, preoccupied and irritable [3].

3. Rebuild Issues and Challenges

3.1. Business Continuity

Of immediate concern post-quake was the focus on maintaining business operations. Because of the state of emergency and cordoning off of a significant portion of the Christchurch CBD after the February earthquake, many businesses were severely impacted and took some time to resume operations. Immediate support was provided for many businesses from central government and the Inland Revenue Department (IRD) which enabled business continuity for a great many companies.

3.2. Insurance

Insurance is often cited as a top-of mind issue right across the city – challenges ranging from validity of policies, to level of insurance cover, to the ability to agree and obtain an adequate settlement/payout, to reduced ability to obtain reinsurance and, even if this was possible, the substantial premium increases that resulted. Many of these issues remain ongoing, particularly for residents however, those that secured early payouts were quickly able to take the initiative and begin their rebuild in earnest. The insurance industry has again settled down and the building construction industry is responding to any newly imposed parameters – in particular the previous “full replacement” policy (with building size limits) is now replaced with a “sum insured” policy.

3.3. Resilience

Resilience can be considered in two ways:

1. The resilience of the people of Christchurch, the businesses that they work for and run and,
2. The physical (structural) robustness of the buildings and infrastructure that were either damaged in the earthquakes and required some form of repair/reinstatement, or the robust designs that emerged for new buildings and infrastructure.

Both of the above have been extensively tested since September 2010 with variable outcomes based on particular geographies and demography across the city. In the context of this paper however, the focus remains on more resilient building standards in order to ensure improved structural performance in future earthquake events.

3.4. Other

Many other issues and impacts can be identified however these fall outside the focus of this paper and for this reason they are not discussed further.

4. The Rebuild Vision

In late March 2011, in response to the February 2011 Christchurch Earthquake, the NZ Government announced the establishment of the "Canterbury Earthquake Recovery Authority" (CERA). This new entity had wide-ranging powers and could suspend laws and regulations for the purpose of earthquake recovery. The initial focus of CERA was to develop the Christchurch Central Recovery Plan (CCRP), a "masterplan" or blueprint for the rebuild of the central city area. Published in July 2012, the CCRP captured the vision and defined the objectives for the rebuild and regeneration of greater Christchurch. Refer to figure 1.

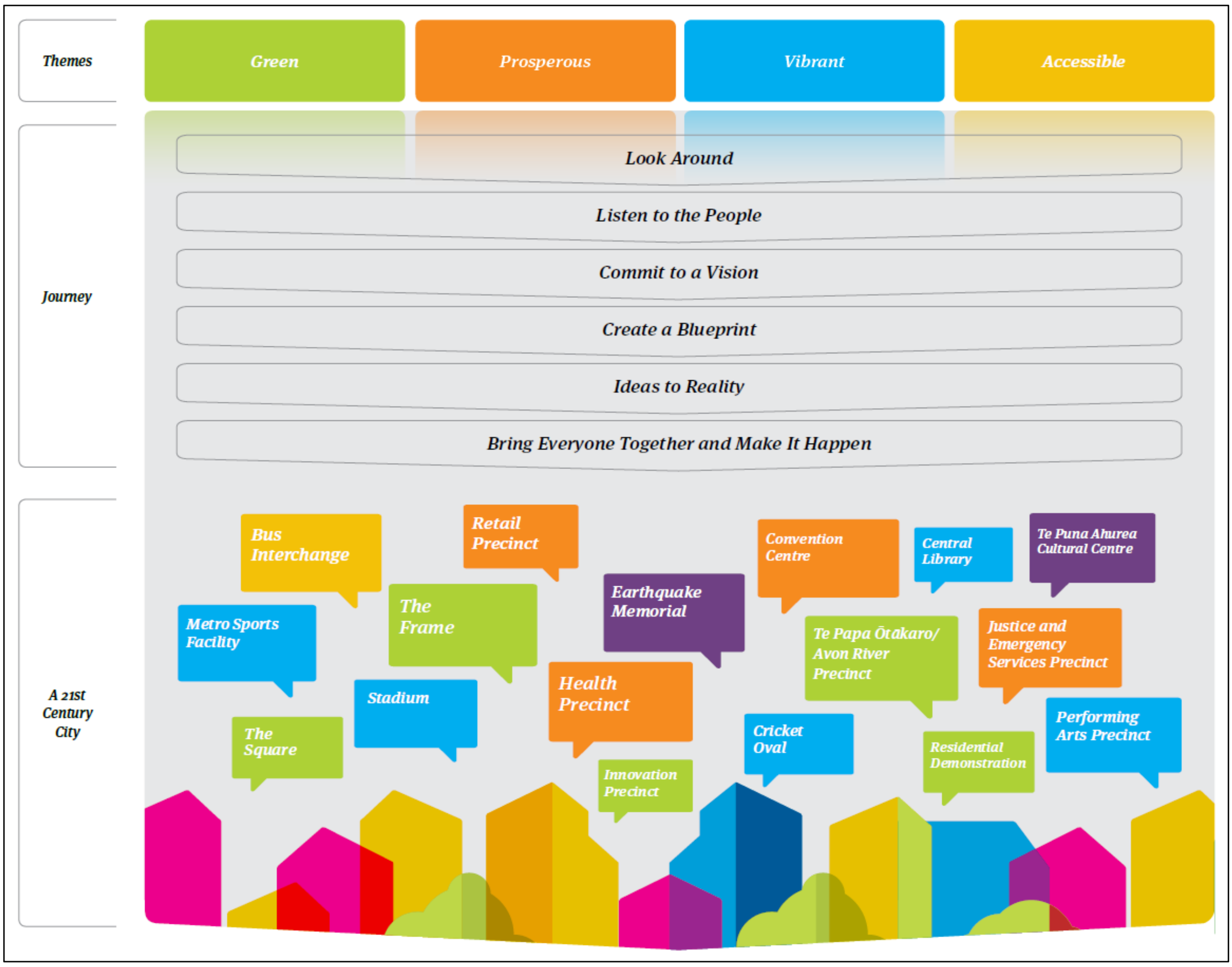


Fig. 1. Key Themes, Journey and 21st Century City Vision for the CCRP [4].

The CCRP is focused on four key themes that were captured from the people of Christchurch during the consultation phase. These themes then feed into the journey of creating the blueprint and then driving the rebuild of a 21st century city based around 17 Anchor projects which would ignite the redevelopment of the central city and stimulate parallel public and private investment into the rebuild.

Following the ratification of the CCRP, CERA embarked on an extensive land acquisition campaign in order to pave the way for the anchor projects to get underway in earnest. Each anchor project has then progressed using a myriad of procurement models and funding initiatives. Progress has been swift and dramatic for some of the projects while others remain on the roadmap to be initiated in future years when funding or design and construction resources can be allocated.

5. Rebuild Initiatives

Many opportunities and initiatives already existed prior, or were established post-earthquake to drive the rebuild of Christchurch in line with the vision captured within the CCRP. The following section captures each initiative and has been categorised to provide context as to which stakeholder(s) championed the initiative.

5.1. Central Government

5.1.1. Canterbury Earthquake Recovery Authority (CERA)

As described in section 4, CERA was established as a government department to lead and coordinate the Government's response and recovery efforts following the earthquakes of 2010 and 2011 in Canterbury. CERA was disestablished on 18 April 2016 as the Government transitions from leading the recovery, to establishing long-term, locally-led recovery and regeneration arrangements. During its period of existence however, CERA has produced a series of design guides to drive the approach to rebuild [5].

5.1.2. Energy Efficiency and Conservation Authority (EECA)

- **Energy Design Advice Grants** - The Commercial Building Design Advice programme supports property owners and developers to optimise each stage in the design of a new commercial building. Access to technical experts, practical advice and financial assistance is provided. The programme covers all commercial buildings including offices, retail outlets, supermarkets, schools, universities and hospitals [6].
- **Project Grants and Crown Loans** - EECA Business supports publicly funded organisations big and small to make good energy choices. The Crown loans scheme is one way we do this. The scheme offers interest-free loans to fund energy efficiency and renewable energy projects for publicly funded organisations. These include schools, hospitals, local councils, and government departments [7].

5.1.3. Ministry of Business, Innovation and Employment (MBIE)

- **Seismic hazard factor** - Since 2011, structural design in the Canterbury region has been significantly impacted by the change in the seismic hazard factor (from 0.22 to 0.3) for the region off the back of increased seismic activity. Increased public awareness of building performance and methods of construction has focused attention on understanding and reducing non-structural damage and life safety risk alongside the clarification of requirement under local authority Earthquake Prone Building Policies to ensure that EQPBs are strengthened to remove such risks to the public [8].
- **Seismic Performance of Non Structural Elements –** MBIE has commissioned of a review of the performance and economic benefits arising from the installation of code compliant non structural elements (suspended ceilings, partition walls, HVAC equipment and ducting, pipework, plumbing and sprinkler systems) across a representative range of medium to high occupancy buildings. This review includes identifying the responsibilities and roles for the design and construction of seismic restraints for non-structural elements across other jurisdictions (including the USA) as well as investigations into the maintenance and lifecycle costs associated with the seismic restraints for non-structural elements. The review is currently underway with findings expected to be published later in 2016.

5.2. Local Government

5.2.1. Christchurch City Council (CCC)

- **Target Sustainability -** Target Sustainability provides free support to help Christchurch businesses become more resource efficient through reducing waste and being energy and water efficient. The type of support provided depends on the business and its requirements – The focus on improving resource efficiency saves money, helps the environment plus provides the business with a point of difference and adds value to its brand equity [9].

5.3. Industry Bodies

5.3.1. New Zealand Green Building Council (NZGBC)

- **Green Star** - A rating tool used to evaluate the green credentials of buildings in NZ. It awards points for energy, water, materials, management, innovation and indoor environment quality etc. Rating levels are 4 star (best practice), 5 star (NZ excellence), 6 star (world leadership). Support and points are administrated by architects, engineers and designers who are specially qualified to assess and deliver Green Star projects. The certification process may be for either the building's "Design", or "Build" and fit-out period. It is a one-off process and certification lasts for the building's lifetime [10].
- **Homestar** - An independent tool that rates and communicates the sustainability and performance of New Zealand homes. Homestar was developed from successful international rating tools and adapted for NZ's specific conditions. It can be used on any residential building, from stand-alone homes to multi-unit dwellings. A home is rated on a scale from 1 to 10: 1 means it needs significant work, and 10 indicates international best practice. Most new homes built to Building Code achieve a 3-4 Homestar rating, and most existing NZ homes only achieve a 2-3 Homestar rating [11].
- **NABERSNZ** - A tool for rating the energy efficiency of buildings. Its focus is on ensuring they are cost efficient to operate. Meters are installed to measure energy efficiency performance and the first assessment can be made 12 months after the building is in-use. The meters separate out the base building energy (lifts, stairwell lighting, common toilets, air conditioning, ventilation) from the tenancy energy (computers, lighting, data centres, staff kitchens in areas occupied by tenants). It has a free self-assessment component and star ratings range from 0 to 6. NABERSNZ can be repeatedly used to track and improve energy efficiency for little cost. It can be applied in both a new build and retrofit [12].

5.4. Collaborations

5.4.1. Christchurch Agency for Energy Trust (CAfE)

A charitable trust established by the CCC on 13 July 2010, in collaboration with EECA. The primary purpose of the Trust is to promote energy efficiency initiatives and the use of renewable energy in Christchurch. A prime area of focus for CAfE was to provide advice on energy efficient design solutions and investigate the technical feasibility and financial viability of a Christchurch District Energy Scheme (DES) [13].

5.4.2. Christchurch Energy Grant

This grant is delivered in partnership between CCC and the EECA to explore the options for energy initiatives at the concept design stage. CAfE has established a $1.8 million fund to encourage the use of renewable energy and advanced energy efficiency measures in the city rebuild. Developers of buildings inside the four avenues can apply to the Grants Scheme to help meet the cost of technology to implement measures such as photovoltaic cells for electricity generation or drawing artesian water from beneath the city for heat exchange systems [14].

5.4.3. Building A Sustainable Environment (BASE)

A simple, introductory-level green building assessment for new office, retail and mixed use buildings to help the Greater Christchurch rebuild developed by the NZGBC in conjunction with CCC and property industry experts. BASE provides building owners and project teams with a tool to benchmark environmental features. The standards within the tool have been set to provide a moderate increase in green building practices over standard industry practice and Building Code requirements. The standard has been designed to be achievable for both small and large buildings and considers site management, services, facilities, comfort and materials [15].

5.5. Design Led Initiatives

Many consultants and suppliers are operating in this space, driving building performance improvements via:

- Utilising various structural systems to match the resilience requirements for the building - base isolation, engineered timber (pre-stressed laminated (PRES-Lam) or laminated veneer lumber (LVL)), structural steel solutions using a buckling restrained brace (BRB) or viscous damped moment frame (VDMF), or a hybrid combination of solutions.
- Incorporation of seismic monitoring system into the building – see section 6.2.
- Adoption of new technologies – including the rapid uptake of LED lighting or ground sourced heat pumps for HVAC systems (well proven technology overseas).
- Raising energy efficiency through optimized HVAC or lighting designs.
- High Performance Façade systems to reduce heat gains or heat loss and produce a higher indoor environment quality (IEQ).

6. Design Outcomes

6.1. Smart Cities

New, “smart” technologies and systems will undoubtedly be required in the complex built environment and infrastructure that will be required to meet the needs of society in the modern city of the future. It is expected that this need will be driven by the desire to optimise energy efficiency and resources, reduce or re-use waste, and will include resilient and sustainable design aspects. It is the convergence of the digital realm with networked technologies and how we interface with them that will define the increasing ‘intelligence’ of any truly global building strategy for future generations.

“Smart” cities and buildings use sensors and integrated real-time monitoring systems to gather data which is then processed and analysed to provide tools for improvement in either technical performance of quality of life objectives. In an Artificial Intelligence (AI) paradigm the city or building could eventually become sentient, mimicking the complex behaviours of a biological system that evaluates its environment and performance and then modifies parameters to improve outcomes. While this may seem futuristic many of the elements for Smart systems already exist in 2016. A good example is Arup’s ProjectOVE - BIM model of human body [16].

There is currently a strong focus on resilient design approach that is inherently part of a smart building philosophy to join sound design principles with considered application of smart technology. In this environment the ability for agile design is paramount to keep pace with technology development and applications, while managing long-term risks.

6.2. Seismic Sensors

Using accelerometers coupled with data loggers, Opus is now monitoring the seismic performance of buildings such as Trimble Technologies and Opus House in Christchurch. Basic data management and analytics is undertaken and displayed on a real-time dashboard to provide a user friendly interface to assess building performance and make any damage assessment quickly and efficiently after an earthquake event. A similar system is well developed in the state of California, USA, where a level of mandate applies in respect of monitoring building structural integrity and performance in a seismic event.

There are significant benefits in the building “state-of-health” being communicated to occupants/owners and/or emergency response teams to provide peace-of-mind around safety and integrity of the structure following an earthquake. These benefits relate to business continuity and damage identification/management and the flow on impacts of reduced insurance premiums and reinstatement or building maintenance costs. Improved knowledge over building performance over time will also inform future resilient design solutions and likely contribute to policy (building code) changes.

6.3. Integrated Design Approach

The earthquake rebuild of Christchurch is an unprecedented volume of work in the current NZ context. In order to future proof the new city, intelligent thinking and technology adoption is required to ensure that new buildings are energy smart, healthy and enduring. Integrating energy efficient and sustainable design practices in a new building project is sensible, doable and financially rewarding. A green building lasts longer and performs better.

A step change in both delivery (speed/efficiency/flexibility) and overall operational performance long term is necessary to ensure that these outcomes are achieved. Some of the challenges being addressed include:

- Demystifying industry jargon around green technology.
- Consultants, investors, developers, owners and tenants working more collaboratively to capture the sizeable benefits of high performing buildings – to embrace energy efficient design and green technology and improved structural resilience.
- Helping clients to understand that a green, healthy, resilient building is a wise investment:
  - It offers better value long-term and superior net operating income.
  - It is more energy efficient to run.
  - Buildings with environmental rating systems are well positioned to attract higher rentals, high quality tenants, and better occupancy rates.
- Encouraging clients to move from traditional thinking to fresh thinking and future trends in the development space.
- While a formal certification for Green Star or NABERSNZ rating may be off the agenda for a particular project, architects and engineers can communicate the key advantages of ensuring a building incorporates the Green Star design principles and is delivered on the basis of achieving a NABERSNZ rating in the future to prevent early obsolescence or avoid expensive post-build modifications.
- Despite the constant delivery pressure in the post-quake setting, it is important to allow within the design timeline to undertake energy modelling and allow for the investigation of different heating and cooling system technologies to reach optimum outcomes. The EECA Programme provides funds for energy modelling and, to date, some 50 percent of post-earthquake new build projects in Christchurch are utilising this offering.
- Develop project specific sustainability frameworks to help clients understand the best match.
- Ensure the consultant and construction team is totally aligned with the building's sustainable values to ensure nothing is lost in translation from the client's aspirations and brief to the final completed product.

7. Recognition of Progress and Achievement

Many well-established and annual award programmes continue to be run by national and international industry bodies. These programmes promote successful project outcomes and assist to further increase momentum for the increased innovation in building and infrastructure design, or the uptake of new technologies to improve performance. Some examples include:

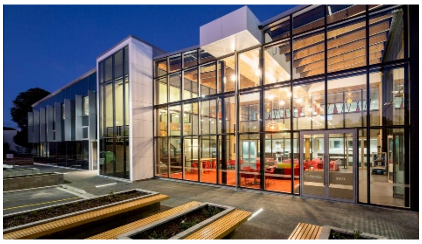
- EECA Awards – An ongoing biannual awards programme celebrating excellence and innovation in energy efficiency or renewable energy. In 2014, a special category was included to recognise excellence in Christchurch Rebuild = Christchurch Energy Champion [17].
- Innovate NZ Awards of Excellence and ACENZ Awards
- New Zealand Engineering Excellence Awards
- NZ Institute of Architects (NZIA) – Local and National Awards
- Architectural Designers New Zealand (ADNZ) – Design Awards
- Illumination Engineering Society (IES) – Lighting Design Awards
- Property Council New Zealand – Property Industry Awards
- NZ Institute of Building (NZIOB) – Awards for Excellence
- NZ Structural Engineering Society Awards
- Cement & Concrete Association of New Zealand (CCANZ) – Sustainability Awards
- Steel Construction New Zealand Incorporated (SCNZ) – Excellence in Steel Awards
- NZ Wood – Timber Design Awards

Many of these programs currently have an unprecedented number of entries from Christchurch due to the vast quantity and diverse range of buildings being constructed in and around the city.

8. Case Studies

Table 2 below presents are a few example projects where due consideration is being given to designing and constructing buildings that are both fit-for-purpose and encompass the key themes of smart/resilient/data in order to capture the essence of "Christchurch's High Performance Rebuild". There are other great examples popping up across the city including the redevelopment of the University of Canterbury, rebuild across several hospital campuses and central city commercial developments.

Table 2. Selection of Projects that Capture the Essence of "Christchurch's High Performance Rebuild".

BUILDING / PROJECT	KEY THEMES		
	SMART	RESILIENT	DATA
Trimble Navigation  Trimble Navigation's Christchurch Office was destroyed by a fire in May 2011 following the February earthquake. The 6000m^2 redevelopment incorporated the Architect's vision of using the latest timber engineering while incorporating additional floor area to address both their current and future needs.	Curtain wall façade system with insulation and double glazing to reduce glare and eliminate the need for external sun shading. Noise levels reduced through the use of timber-concrete composite floors. Integration of energy efficient technologies for HVAC to improve indoor environment quality (IEQ). Innovative lighting and features resulting in an installed lighting power density 50 per cent better building code requirements. Flexible yet simple controls which provide targeted zoning and daylight control.	Low-damage, resilient building that provides the owners and tenants with peace-of-mind in seismic events. Pioneering timber structure using pre-stressed laminated timber (PRES-Lam) building using both post-tensioned Laminated Veneer Lumber (LVL) frames and walls with energy dissipating devices for the lateral load resisting system Earthquake energy is absorbed with externally mounted "plug-and-play" energy dissipators, which are easily replaced following significant seismic events, providing economical repair alternatives.	Extensive instrumentation has been installed to monitor ongoing performance for both static and seismic loading. This monitoring will enable informed decisions on occupancy after a significant earthquake, and allow informed maintenance decisions when necessary.
Halswell Primary School  Halswell School was badly damaged in the 2010-11 Canterbury earthquakes, with ten classrooms needing to be demolished. The 600-pupil school was the first school to be fully rebuilt after the earthquakes, with the designs and methodologies setting a blueprint for future Greater Christchurch Education Renewal property programme (GCERP) projects in Canterbury.	The school was designed as a modern learning environment, with a series of teaching pods arranged around a central courtyard and play space, plus an administration block and school hall. The site maintained a high level of health and safety compliance throughout the project, and also achieved a 5 star rating from the New Zealand Green Building Council. NABERSNZ ready infrastructure (project designed ahead of NABERSNZ being launched).	Extensive Ground improvements to resolve liquefaction and land stabilization issues.	Site Wide Integration, using the schools existing IT infrastructure for communications and controls plus energy monitoring. Web-based graphical user interfaces providing visibility to classroom and real time data allowing integration into curriculum and student learning - stimulating energy efficient behavior and educating our future leaders.

Christchurch Justice and Emergency Services Precinct (CJESP)

One of the key “Anchor Projects”, This facility will bring together all justice and emergency services in one purpose-built, world class precinct in the heart of Christchurch. The facility will occupy some 40,000m^2 of floor area and will some 2000 people will work in or use the facility daily. At the peak of construction, some 400-500 people will be employed.

This project is being delivered by the Ministry of Justice as the lead agency and will, on completion, house representatives from nine government agencies making it a first of its kind in this part of the world. In order for this to be a world class facility the outcome needs to exemplify the design intent for the new Christchurch.

Unsurpassed level of design innovation on a large building project in NZ:

Chillers and reverse cycle heat pumps linked to aquifer as a heat source/sink.

Underfloor heating & cooling of atrium floor area to maximise occupant comfort and use energy most efficiently**.**

100% full fresh air capable air handling systems with full heat recovery with dedicated floor-by-floor and court-by-court plant. Low energy cost with high space comfort and free cooling when climatic conditions permit.

Selectable fresh air to maximise energy efficiency by using the source closest to the thermal conditions required for the courtrooms, override selectable by the Judge if fresh air flushing is required.

Hybrid Natural / Mechanical ventilation of suitable spaces such as Judges Chambers.

Larger open plan floor area of the Police Building uses highly efficient chilled beams with primary cooling from the aquifer – no costs of running a chiller.

Spaces are to be Naturally Ventilated as far as practicable, particularly the Atrium and Café in the Courts Complex and the car parking area of the Car Park Building.

Latest LED lighting technology, including active dimming controls to respond to actual lighting demands and integration with HVAC control systems.

Power over Ethernet (PoE) to low power devices (security cameras, etc).

High efficiency traction drive lifts, as well as turn-down escalators for when passenger volumes are low.

Extensive ground improvements upon which a 1.5m high strength concrete slab platform has been poured to deliver the importance level 4 design criteria.

Steel and concrete structure supported on Base Isolators using lead-rubber bearings and sliders. BI plane located between ground floor ceiling and first floor slab. BI to cater for up to 750mm movement in x and y direction with all building services infrastructure to remain intact and operational.

Robust and redundant mechanical and electrical design with backup systems provided to allow for 72 hours of autonomy post disaster.

Defend-in-place operational philosophy employed on portions of precinct including Emergency Operations Centre (SOC), Fire, Police and Ambulance Communications Facility (South Comms) and Custodial facility. 2 hour fire rating provided plus a further 2 hour of backup to allow for safe evacuation after managed shut down in case of multiple failure scenarios associated with backup systems.

Electrical distribution incorporates energy metering and monitoring/management, integral with submain protection devices.

Integration of power and lighting systems, as well as security systems, with the Building Services BMS for lighting control and enterprise energy management.

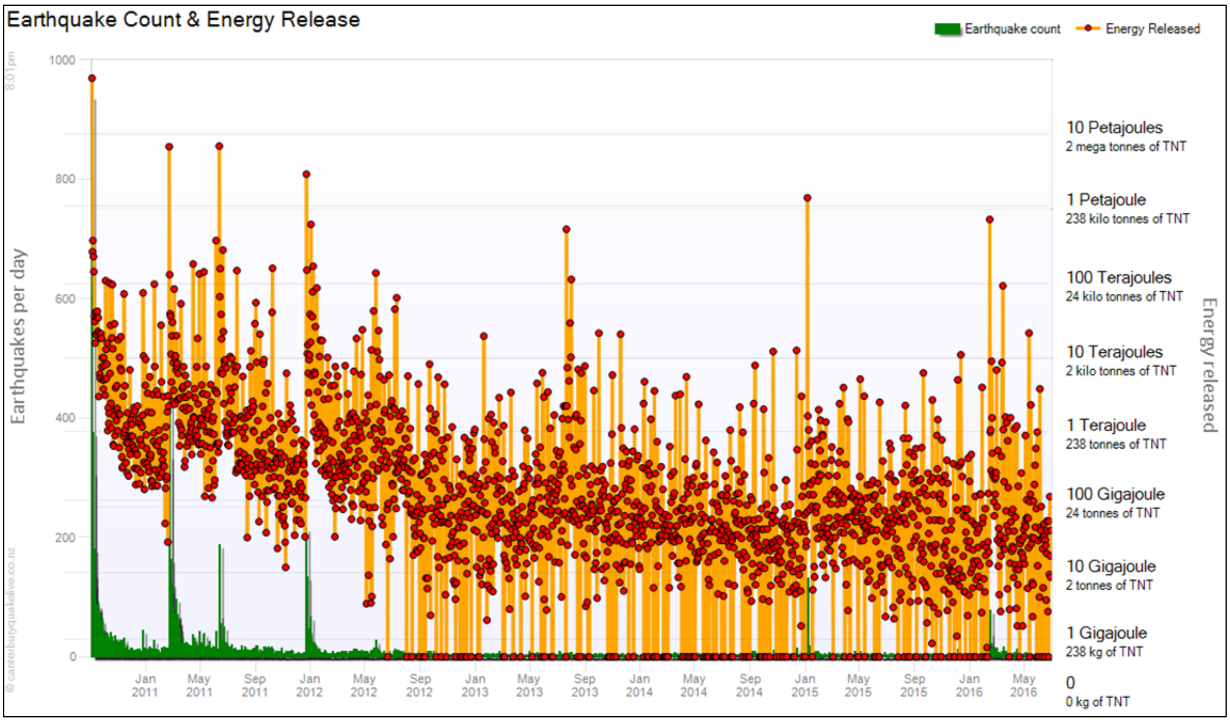
Peak power monitoring to determine when it is feasible to run the generators and export power back into the grid.

Extensive use of use of Wi-Fi technology will be used to maximise flexibility and future proofing of communication systems and reduce infrastructure cost.

9. Conclusion

1. Out of the rubble is emerging a well-formed and vibrant city centre that produces economic and social benefits by bringing together people for business, cultural or social activities. The "new Christchurch" is being built upon the principles of resilience, sustainability and connectedness, whilst also reflecting our history through the retention and enhancement of key heritage buildings and infrastructure assets framed by green spaces and accessible pathways.
2. Further, through the use of appropriate procurement approaches, allowing for full and proper engagement between the design and construction professionals and other stakeholders, plus with the appropriate utilization of the incentives presented within this paper will maximize the outcomes and deliver a better city for future generations.
3. Using the above case studies as representative examples, and with many more available across the city, the new Christchurch can be (and is being) defined by its accessible, connected, resilient and high performing building stock. Only time will be the ultimate judge, however after just over 5 years, the city is going from strength to strength and Christchurch continues to provide a significant contribution to the national economy.

Appendix A. Summary of Earthquakes (Count and Energy Released) [1].



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