Strategies for Sustainability and Resilience After Earthquakes

Ensuring Food Security in the Chirstchurch city case

Chalmers University of Technology
Design for Sustainable Development
Daniela Francisca González
Master of Science Thesis

Strategies for Sustainability and Resilience After Earthquakes
Ensuring Food Security in the Chirstchurch City Case
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A 30 credit thesis submitted to the Department of Architecture, Chalmers University of Technology, in partial fulfilment of the requirements for the degree Master of Science in Design for Sustainable Development

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Abstract

This thesis shows that sustainability meets resilience when applicable to places with earthquakes issues, and perhaps be adaptable to other situations around the world.

Understanding causes and consequences of earthquakes worldwide, and specifically in the Christchurch city-New Zealand case, as well as their recovery program, this document has led to propose a set of “strategies for sustainability and resilience” to be added to the “Christchurch recovery plan” which should be applicable along the different phases of the plan.

To prove this point of view it has been chosen one strategy among others that were found during this research; “Resources Decentralization” and a sub-strategy called “Systems Isolation”. The first one looked in a macro or general view and the second one in a micro or more individual way.

From a list established in this investigation of important resources, four were chosen (food, water, waste and energy) as the most essential resources for human survival. Understanding that they all are interconnected with each other, the proposed planning and design solutions place a greater emphasis in the resource Food.

To show tangible examples of the investigation the ideas of “Resources Decentralization” and “Systems Isolation” were applied in the neighborhood of Saint Albans in the Christchurch city context; a city in New Zealand badly affected by earthquakes during 2010 and 2011.

With these two examples it is vital to understand how important can be the decentralization of basic resources (structure, ownership and management), spread them among the community, encouraging social participation and responsibility sharing in order to achieve resiliency.

Foreword

Daniela Francisca González is a qualified architect from Central University of Chile, B.Arch. 2003 and registered architect 2006, with former experience as designer, construction monitor and quantity surveyor manager in Chile.

With a passion for traveling Daniela has been working in New Zealand for the last four years collaborating in two engineering consultancies and lately in the Christchurch Earthquake Recovery Program with repairing projects.

Within a compulsory background in earthquakes and structural education coming from her studies in Chile and lately, the earthquakes experiences in the city of Christchurch - New Zealand, Daniela has also an underlying interest in sustainable development. For this reason she enrolled in the master course at Chalmers University called Design for Sustainable Development. Her future aim is to work actively and professionaly towards sustainability and resilience.

Contents

1. Introduction

"Resilience is defined as the capacity for collective action in the face of unexpected extreme events that shatter infrastructure and disrupt normal operating conditions"…

Designing Resilience
by L.K. Comfort, A.
Boin & C.C. Demchak.

The earth is in constant movement and has always been changing. Today these changes are going in a worrying and faster way than we, the Humanity, were expecting.

Natural disasters are manifesting more often in the last 100 years, but also human's activities are contributing and triggering this rapidness. Earthquakes are one of those phenomenons; when the earth's tectonic plates shake they are releasing its accumulated energy too often now, destroying everything around and taking lives away.

The impact of earthquakes is huge and the time to recover from these disasters is too long. Understanding that humanity can't avoid or totally prevent these issues is how this master thesis started, wondering how can people create more resilient cities. What is needed to go towards this direction?
The case of Christchurch city in New Zealand was chosen in this work investigation for further analysis having as references the Christchurch earthquakes in 4 September 2010 and 22 February 2011 among other aftershock.

Those two events have completely changed the city's aspect and also their people's mood.

But even if New Zealand is considered a seismic country most of the earthquakes have occurred outside in the forest or in the sea far from cities and few events in some towns within hundreds of years ago. The newer buildings were structurally prone but not the old ones, among other circumstances, therefore Christchurch wasn't totally prepared for those events.

Coming back to the questions on how to create more resilient cities and how we can go towards this direction, the subject of earthquakes and its consequences worldwide with a special focus to Christchurch city were studied to figure out which elements did work and which did not with the idea to add strategies for sustainability and resilience to the Christchurch recovery program when realized that some elements were missing in the stages of the recovering program.

Understanding this, the idea of that we can't keep developing as we do; that we have to improve even more our systems, the professions and the communication in a more holistic way did came up.

Delimitations of this report

These strategies for sustainability and resilience are vast and there is more than enough material to be continued in a longer research. Therefore, this report has concentrated on resources decentralization hosted in a combined network structure when realized as a very resilient to disaster events.

Finally this investigation focused only on the resource called Food, because it is interconnected with all other resources and it is the most important of all of them since it ensures survival, which it is shown in the context of Saint Albans, a residential neighborhood in Christchurch out of the city center.

The ideas and solutions hosted in Strategy Resources Decentralization and Sub-strategy Isolated Systems shown in the area of Saint Albans are based on technical and technological point of view. The social aspects of those ideas and solutions have not being considered in this report.

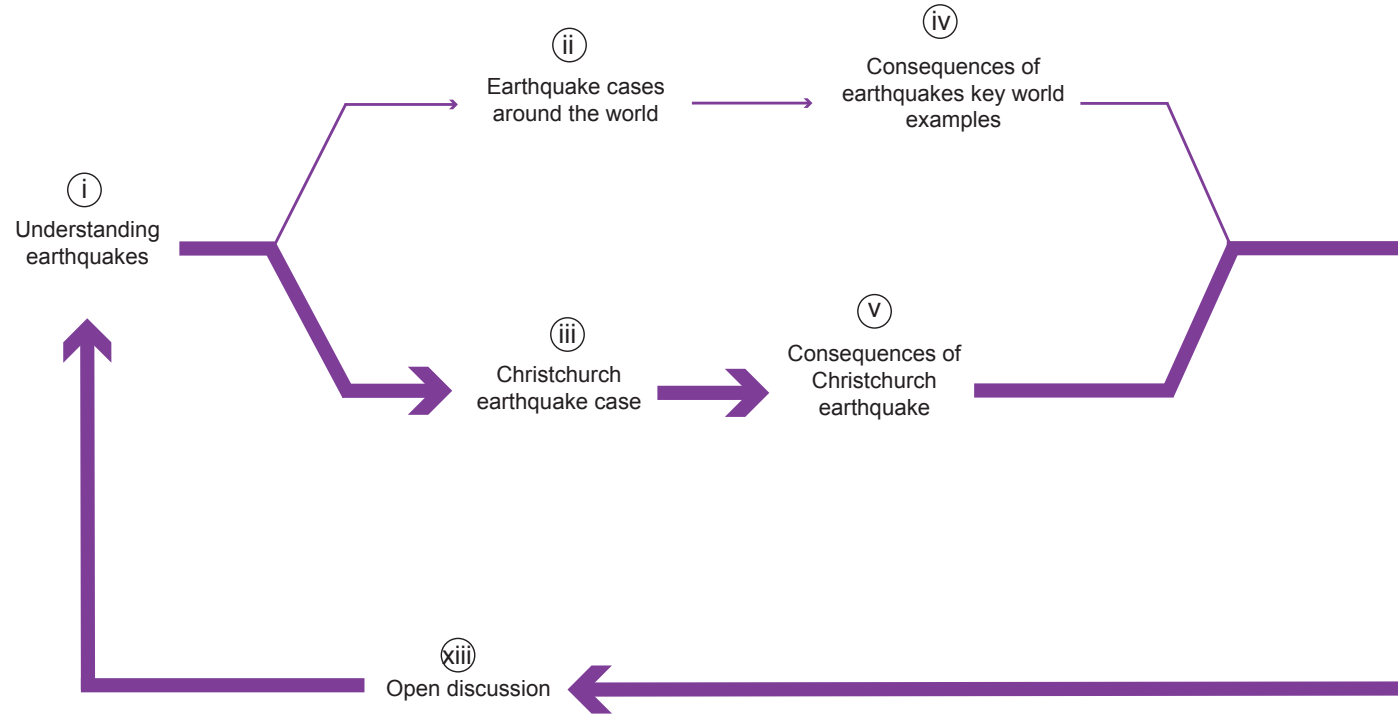
1.1 Working Method

The lay-out at the left represents the working pathways that I have made during this research process.

Although all these phases have contributed to this report, the topic and material is so vast and broad that could feed a bigger work investigation beyond this master thesis.

Understanding that I have chosen to narrow this report and concentrate in one key case and few strategies.

The direction of this report can be followed by the primary arrows from beginning to the end of the work.



Working method mind map

i) This phase consisted of an investigation of earthquakes understanding for example what they are, how they work, where they occur, how to measure the level or frequencies and damage perceptions.

ii) What happened in different countries around the world, which were the strongest and more damaging earthquakes and the frequency differences between each of them. Where occur the earthquakes and where have they the strongest impacts and consequences?

iii) The case of Christchurch city in new Zealand, their public data, thoughts of my own experience there and how it has been affected since the two main earthquakes happened in 09/10 and 02/11.

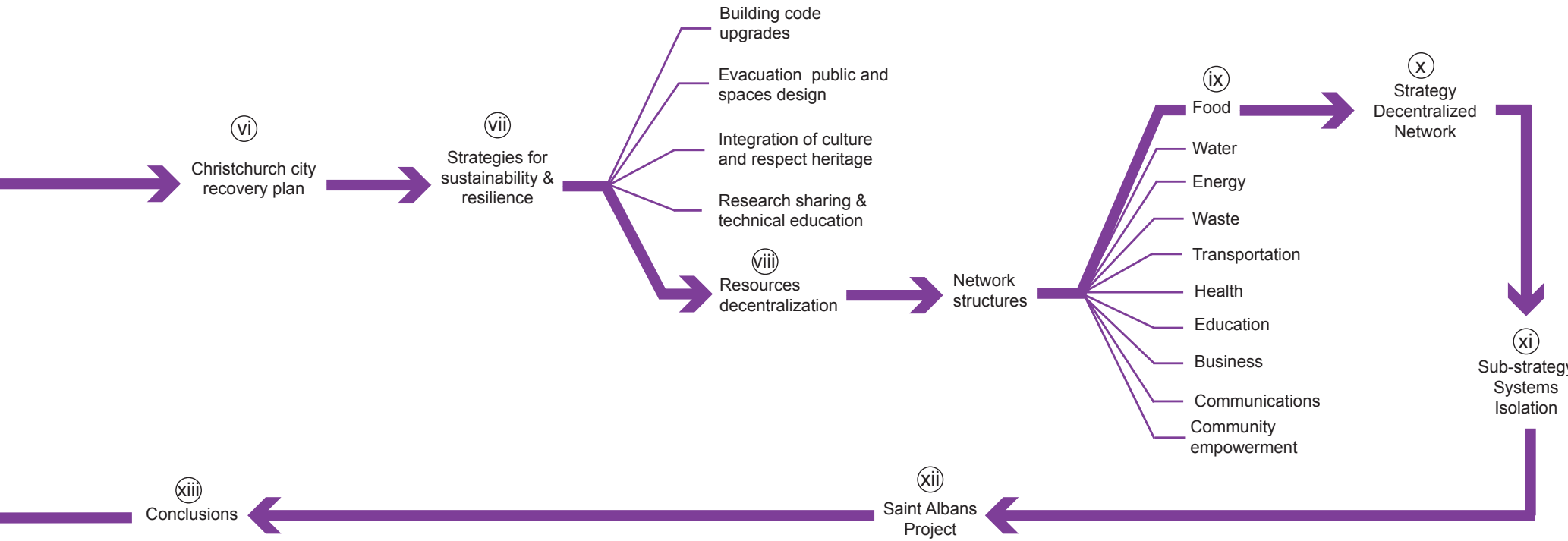
iv) What were the main and common consequences of most of them subjected to their different contexts?

v) What were the main problems after each event, which things did work well and which did not.

vi) The Christchurch recovery plan and key projects for the city's rebuild.

vii) Analyzing Christchurch, the main problems after the earthquakes and their recovery program is when I have realized that some strategies should be added within the recovery phases of the program.

Because the earthquake's consequences other references and ideas, the strategies became very



large for a master program development. Lots of things to look after and all of them too important, they may give the chance for a further research, perhaps in a PHD program:

Building code upgrades
Evacuation and public space Culture + Heritage
Research + Technical Education
Resources Decentralization: Food - Water - Energy - Waste -Transportation - Health - Education - Business - Communication - Community Empowerment

viii) Decided to explore resources decentralization strategy and their network structures until I found a structure system that can be resilient in case of an earthquake event.

Realizing that all these structures are connected I have decided to look the importance for survival of: Food-Water-Energy-Waste

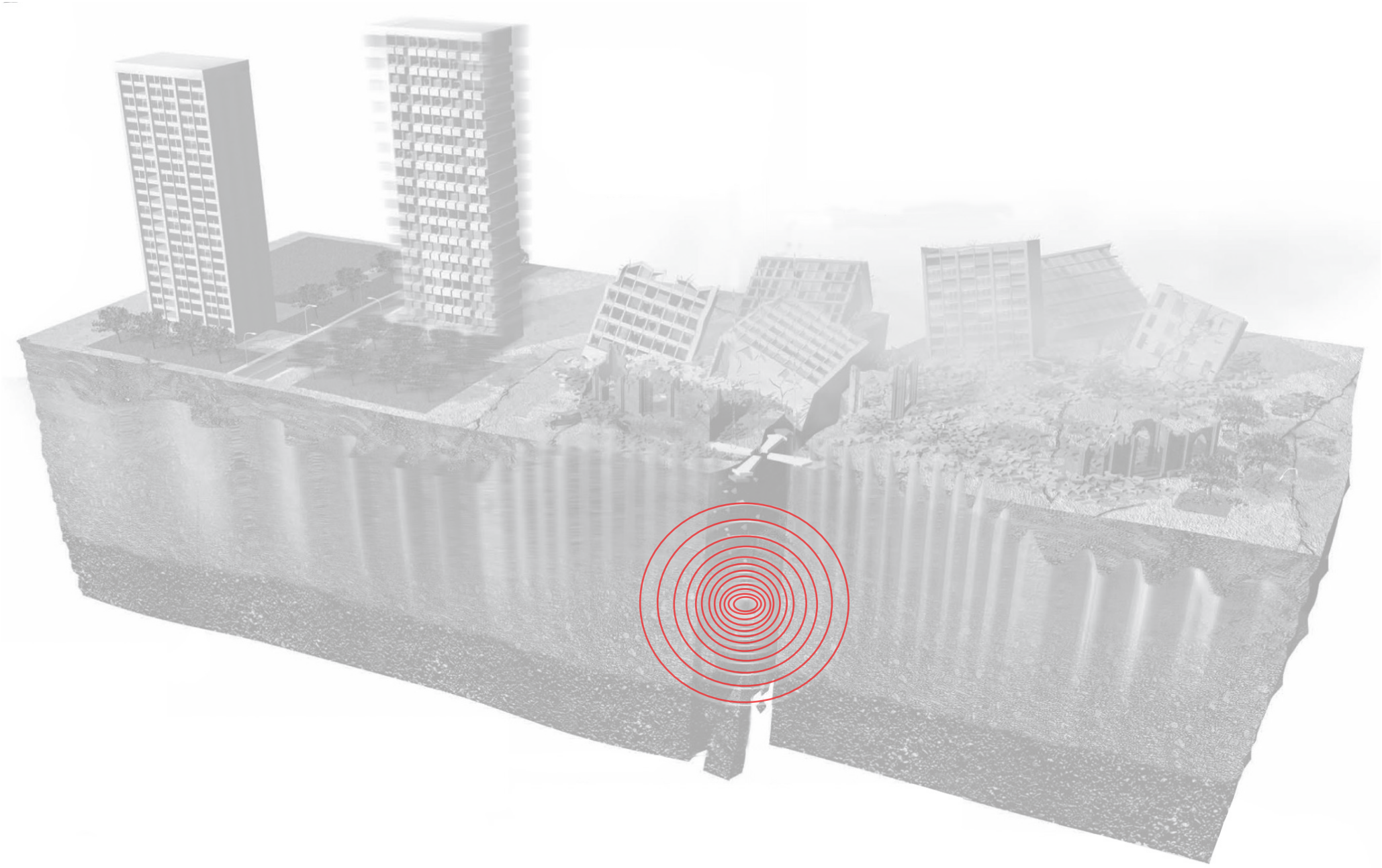
ix) Finally I have chosen FOOD as the most important subject of the resources decentralization, because in some way, it is interrelated to all other structures.

x) To see in a more general view how food structure can be applied I have created the Strategy called Decentralized Network and have it applied to Christchurch city context.

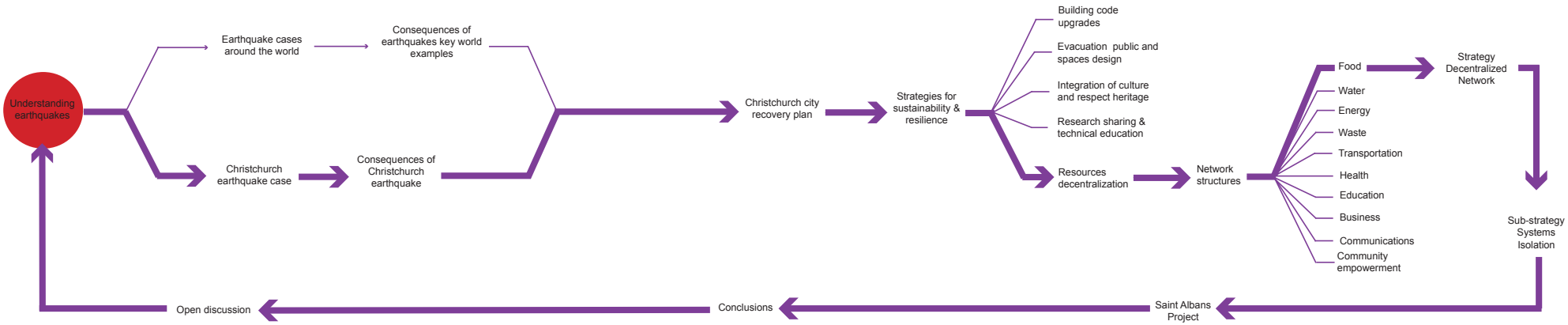
xi) Then I decided to look it in a closer point of view so at thinking how can be an element in this network I created the Sub-strategy called Systems Isolation, were the element can stand alone and at the same time could be connected to the decentralized network.

xii) Strategy and sub-strategy are shown in a small context area in Christchurch called Saint Albans. There I have exposed in one block the Strategy and in an isolated home the sub-strategy.

xiii) The result of this work has led to conclusions and perhaps it can perform in other countries with other background and issues, so an open public discussion is crucial to provide feedback to this research.



2. Understanding Earthquakes

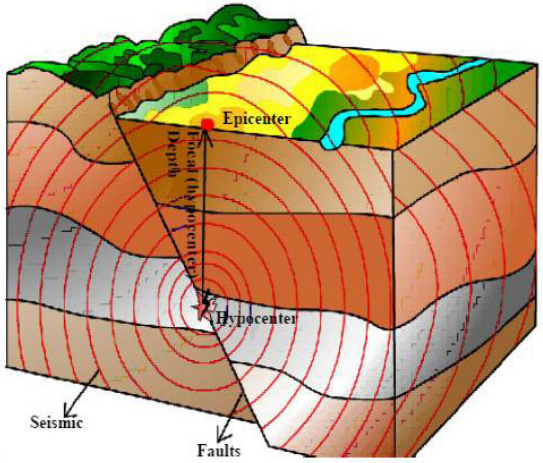


2.1 What is an earthquake?

Earth – quake: is an unexpected movement of the earth's surface. This movement is caused by the friction of earth blocks called tectonic plates. [Earthquake induced disasters, NATO]

The tectonic plates are the earth's crust and they are almost hundred kilometers in thickness. These plates are always moving slightly, but when they move against each other this pressure accumulates for some time and is released ramdomly.

Naturally occurring earthquakes: The tectonic plates are marked by fault or fissures along the borders; when the tectonic plates slide past each other or crash with each other is when the earthquakes occur.



Earthquake example
Source: scweb.cwb.gov.tw

2.2 Comparison of recent earthquakes by energy release

How can we compare for example the magnitude 9.0 earthquake in Japan with the magnitude 6.3 quake that struck New Zealand?

The magnitude **(M)** measures shaking force in the Richter scale. To understand it easily we take the Richter scale from 1 to 10 where one degree above means 10 times stronger than the degree below.

For example an earthquake of magnitude 6 shakes 10 times stronger than an earthquake of magnitude 5; a magnitude 7 shakes 10 times tougher as a magnitude 6, and subsequently.

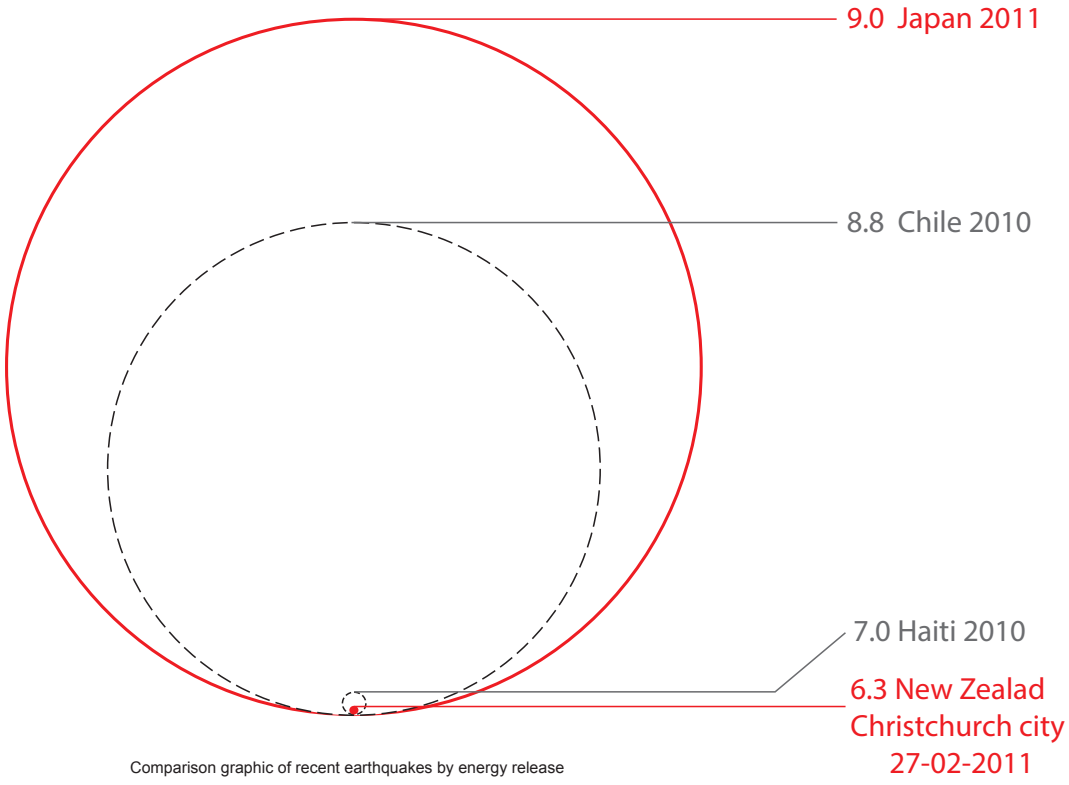
So, to compare two earthquakes we have to deduct one magnitude from the other and raise 10 to that number using the following comparison formula:

$$10^{(M1-M2)}$$

For example, if the magnitude of one quake is 6 and another is 8, then the difference in magnitudes is 2, so the stronger earthquake shakes 10^2 or 100 times stronger or weaker than the other one.

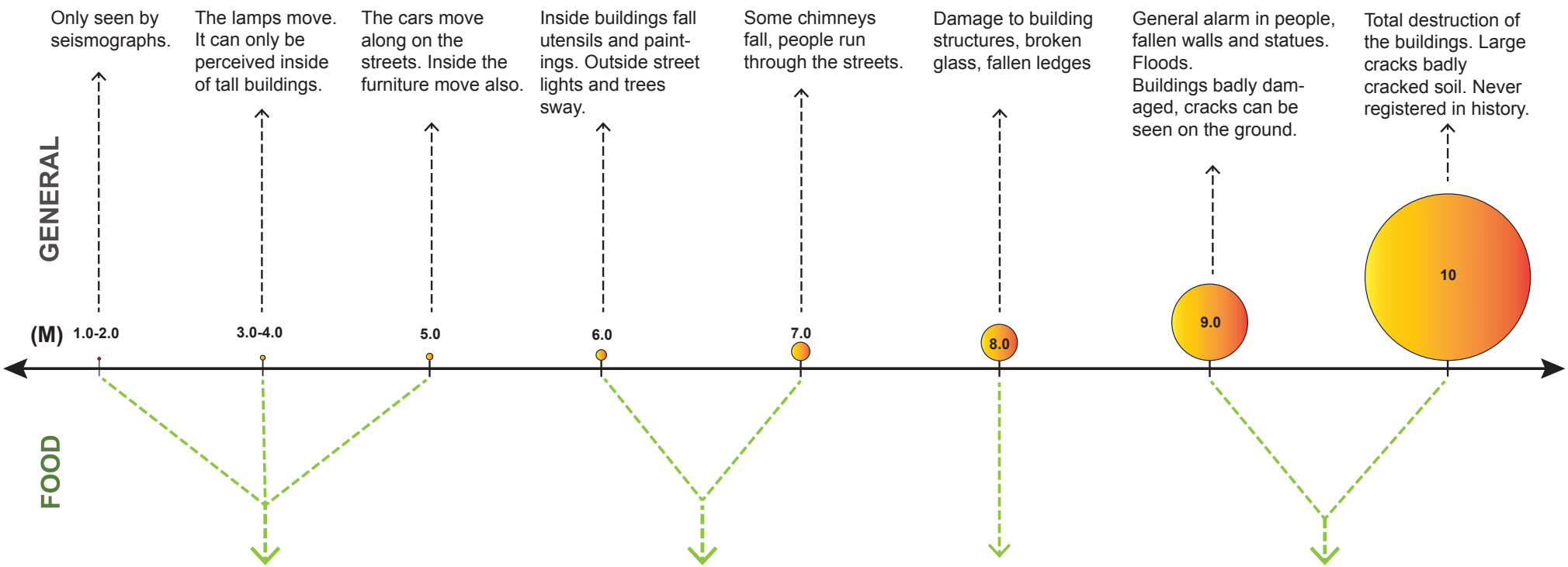
Comparing the earthquake in Japan of magnitude 9.0 with the New Zealand earthquake in February 2011 of magnitude 6.3 the difference in magnitudes is 2.7 and using the formula the difference in magnitude is:

$10^{2.7}$ = 501,18 times stronger.



Comparison graphic of recent earthquakes by energy release

2.3 Understanding magnitudes in terms of perception and damage



MINOR

There are not considerable issues at this level.
No food is visible affected.

DESTRUCTIVE

Depending on the terrain conditions and characteristics the ground surface can break. If the terrain is close to water areas liquefaction might come up, then food supply can be affected.

DISASTROUS

Depending on the terrain conditions and characteristics the ground surface can break. If the terrain is close to water areas liquefaction might destroy crops and food securi-ty can be in high risk.

CATASTROPHIC

The ground surface breaks. Food supply is interrupted.

2.4 Consequences of earthquakes

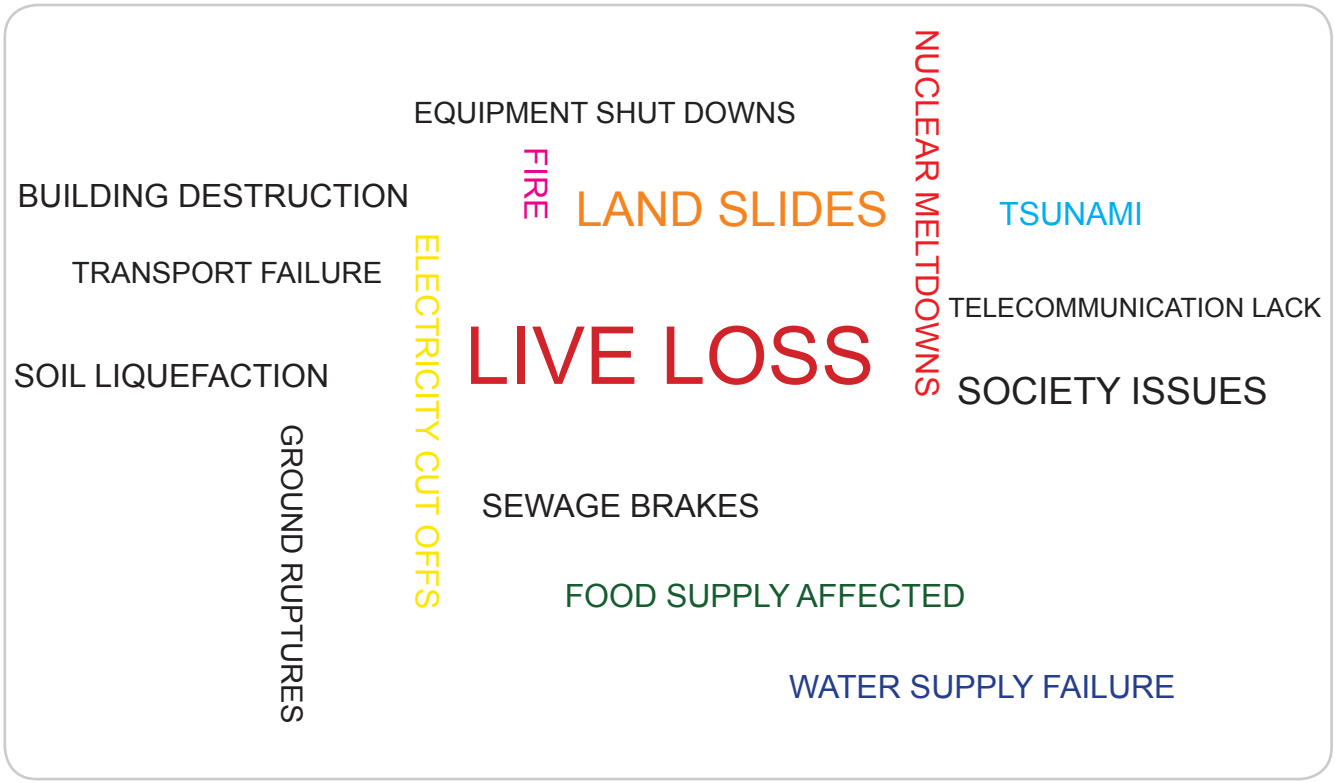
It is not possible to prevent an earthquake, because the tectonic plates are always moving slightly until in some opportunities the energy released is too high. Their consequences depend of the country's context;

A more industrialized country may have greater financial losses, but a less industrialized country would have more injuries and deaths. [Urban earthquake Disaster mitigation through architectural design and urban planning - Ye Yaoxian]

Injuries and deaths can vary according to the building type and their conditions, time of the day of occurrence, population density whether if the earthquake is followed by other disaster like tsunamis, lands slides, floods among others. [Shelter after disaster, UN/OCHA, 2010]

We have for example the case of Haiti, a less industrialized country with high level of poverty and in very dense area in comparison with their population over 10.000.000, struck by an earthquake of magnitude 7.0 in January 2010 causing over 200.000 deaths. [World Bank 2012]

Then the case of Chile, an industrialized country with larger area in comparison with their population over 16.000.000, which had an earthquake of magnitude 8.8 in February 2010 followed by a tsunami causing around 550 deaths mainly by the tsunami. [USGS Earthquake Hazards Program, Largest earthquakes in the world]



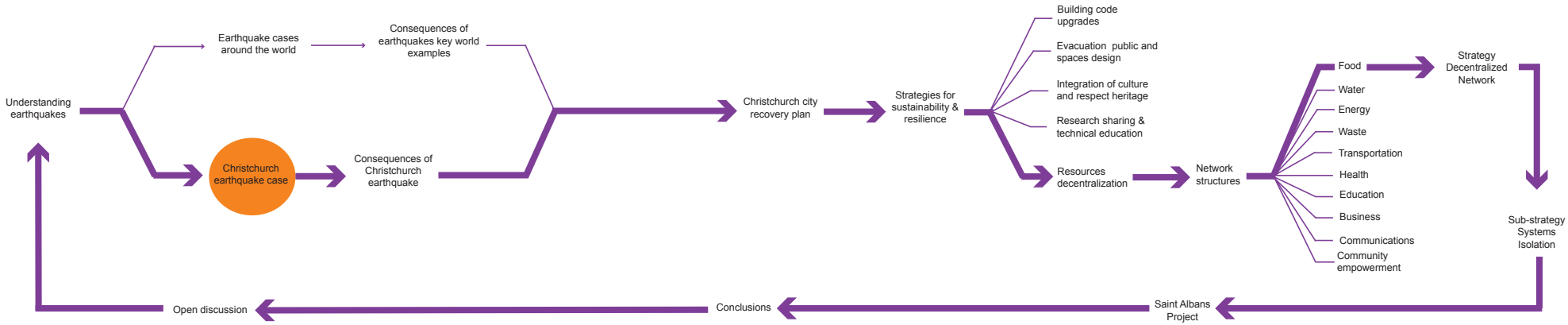
Chaotic Dynamics of earthquake's consequences

And a third case is Japan, a highly industrialized country with smaller area in comparison with their population over 126.000.000, struck by and earthquake of magnitude 9.0 in March 2011 followed by a tsunami and a nuclear meltdown causing around 15.884 deaths mainly by the tsunami. [USGS Earthquake Hazards Program, Earthquakes in the world since 1900]

The image above represents a chaotic list of consequences after earthquakes. [City of Portland Earthquake Response Appendix- Sam adams, Carmen Merlo, April 2012]

It is impossible to make a clear order or prioritization [Edward Lorenz] of consequences since they are all interconnected and sensitive to their local conditions and events but, which highlights more and should be place above all the rest is Live Loss.

3. Study Case: Christchurch - New Zealand




New Zealand

New Zealand is an island country in the south-western Pacific Ocean. The country geographically comprises two main landmasses the North Island and the South Island mainly and few other smaller islands, hosting about 4.530.134 million [Statistics New Zealand, 2014] population being Christchurch the largest city in the South Island and the country's third largest urban populated city with around 341,469 people [CCC Population Summary 2013]

3.1 The Christchurch context

Christchurch represents the business hub for the South Island with about 70 percent of the region's economic production coming from activities that occur within the city and the major transport connection with a port and airport that handles over $5 billion of exports per year [CERA, Christchurch Central Recovery Plan, 2012].

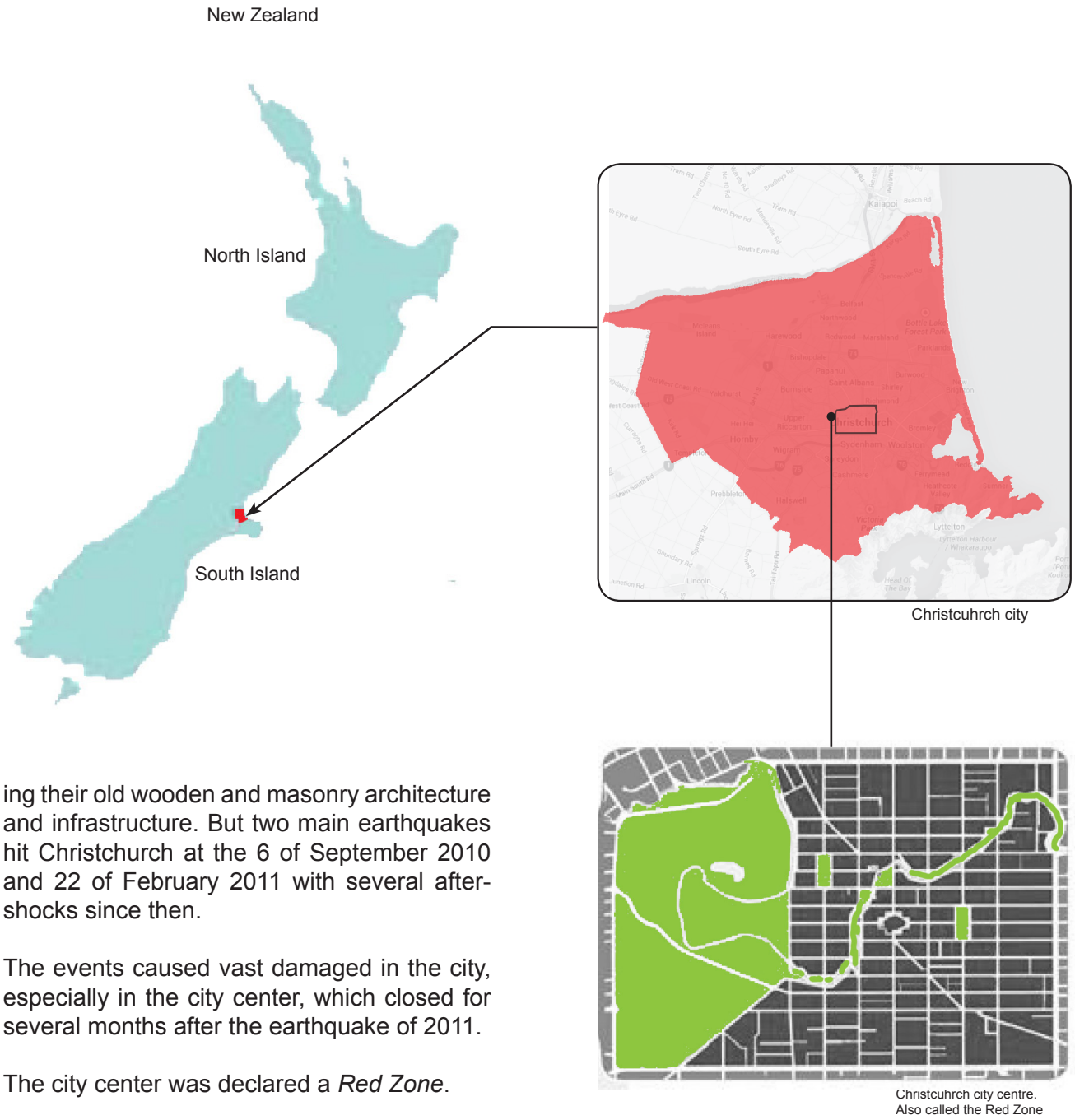
The city is the main door to the tourism in the South Island receiving more than 1.8 million visitors yearly. (Before the earthquakes of 2010 and 2011)

It is also the health and educational center with one tertiary hospital and two universities.

The city center developed only over 160 years and it had the characteristic of being the most British looking city in New Zealand conserving their old wooden and masonry architecture and infrastructure. But two main earthquakes hit Christchurch at the 6 of September 2010 and 22 of February 2011 with several aftershocks since then.

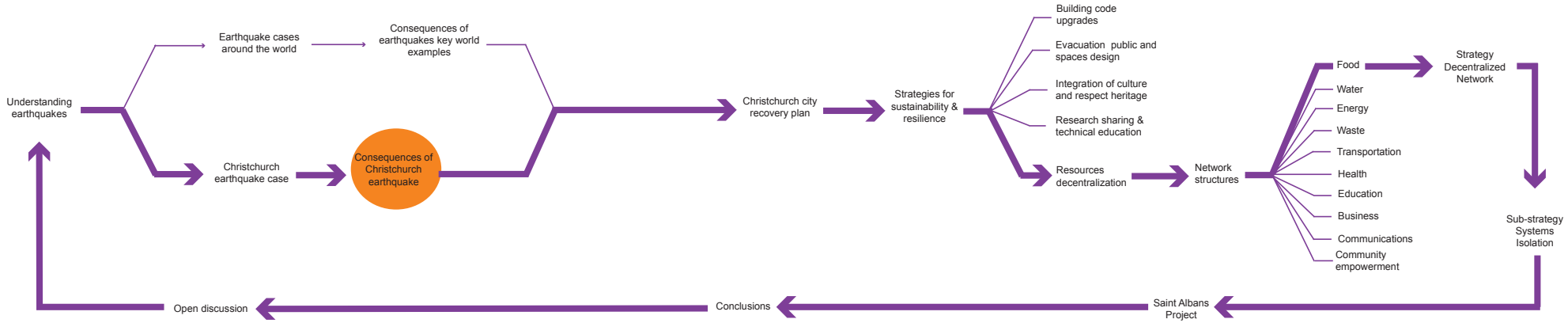
The events caused vast damaged in the city, especially in the city center, which closed for several months after the earthquake of 2011.

The city center was declared a *Red Zone*.



Christchurch Cathedral Square
Source: Flickr - Roger T Wong

3.2 Consequences of Christchurch Earthquake



Christchurch Earthquake
Source: NZ4

Consequences of Christchurch Earthquake

Christchurch had several shakes, but two of them were considerable bigger; the first at 6 September 2010, a 7.3 magnitude during the late night with epicenter a few kilometers out of the city causing mainly building and little infrastructure damage.

Christchurch was settled on a swamp area, has old infrastructure and the buildings in the city center in their majority were between 160 years old. The unreinforced buildings were old enough to fall down with the first earthquake.

But, they reminded there waiting for the insurance companies to solve with the owners what to do, if they were going for repair or demolition.

The second earthquake in 22 February 2011 had 6.3 magnitude, struck in the noon of a working day with epicenter in the city center. Unlikely, this event caused vast damaged in the city and the remaining damaged buildings collapsed causing thousands injuries and taking several lives away.

Apart of that there were two not so old buildings collapsed with the second earthquake; The Pyne Gould was a 5 storey building from 1963 and met the standards on that time [NZSS 95], but they were too low in comparison with now. [Collapse of the Pyne Gould, DBH September 2011]

The second building Canterbury Television CTV with six-storey was made of weak columns and concrete and did not meet standards when it was built in 1986. [The Press, Christchurch]

Based on the New Zealand's news, New Zealand Government, Christchurch City Council, my own experience working for Aurecon NZ in projects related to the Christchurch Recovery Program, site inspections and finally, my personal life experience as a Christchurch resident is how this report came out with a list of consequences related to earthquakes in Christchurch city:

Live loss

The most damaging earthquake was on 22 February and happened in a working day around noon in a busy city center.

Unlucky Christchurch's old buildings and few other no so old fell down injuring thousands of people and taking with them the total of 154 lives.

Only collapse of the Canterbury Television building took away 115 people's lives with it. About 2/3 of the total deaths. Among them were New Zealand residents, international students and tourists.

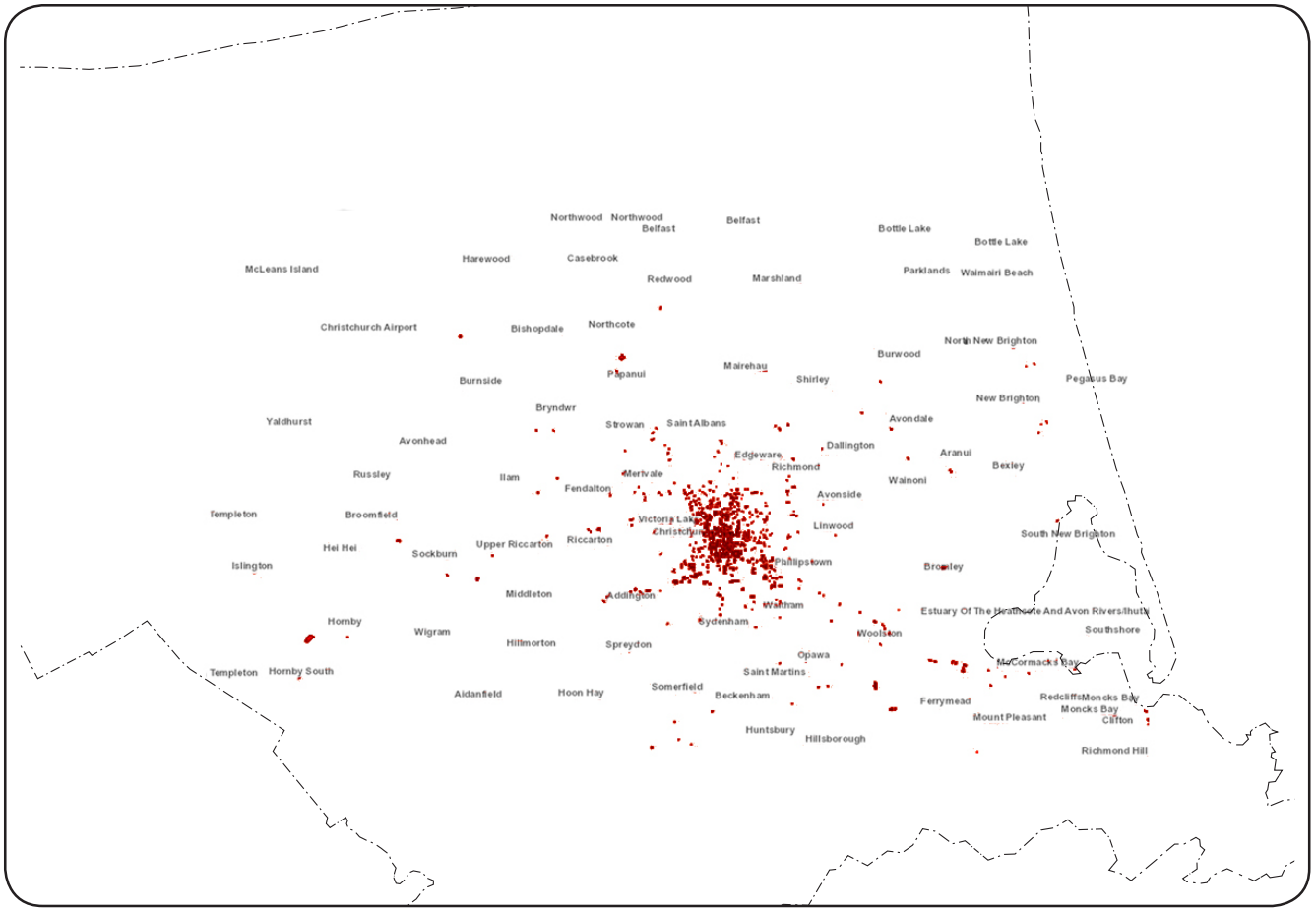
There is no need to explain how families and the whole community were affected...

Oklahoma City Memorial, Field of Empty Chairs
Source: Oklahoma City National Memorial and Museum

Building destruction

Many of the older buildings consisted in unreinforced masonry walls and wood. Also they were not upgraded to the current seismic standards.

The collapse of buildings has forced people to move out of their homes finding their own solutions or moving to emergency camps.



Christchurch demolition plan

Christchurch residential
Source: blogs.wsj.com

Christchurch City Centre, multy-storey building
Source: photosfan.com

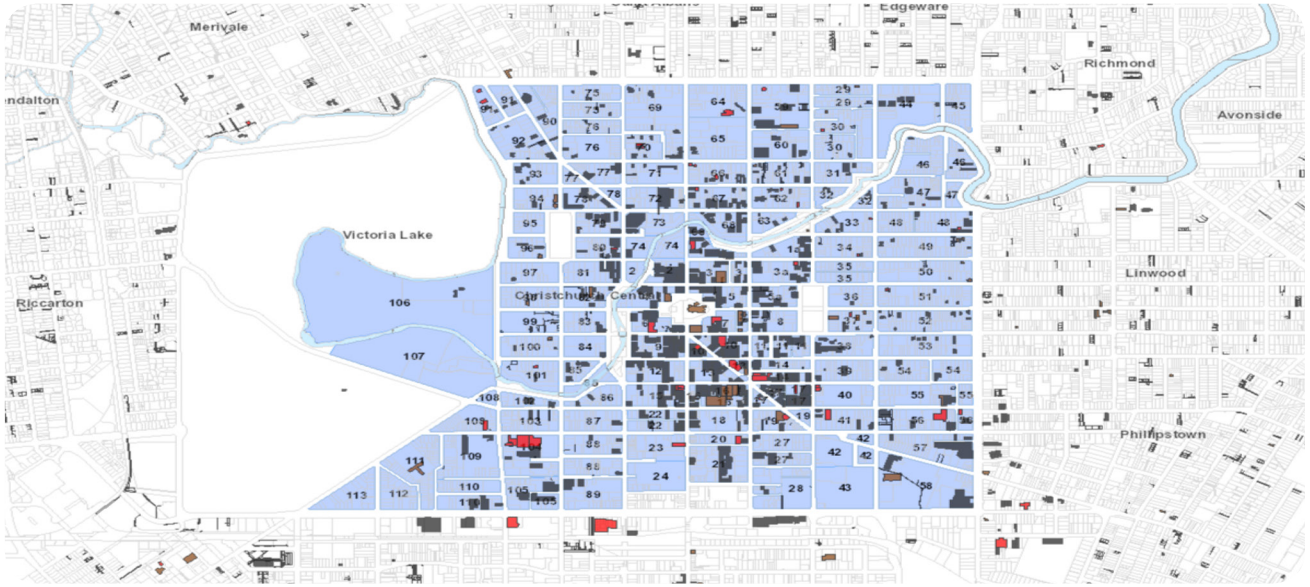
Christchurch City Centre
Source: news.com.au

The plan at the left shows the city center. The grey and red shades represent the demolition program from the council. Today those areas are empty.

The blue shades represent the called “red zone”. A zone that was closed for several months declared unsafe and guarded by military forces.

This “red zone” hosted activities for the 70% of the financial output of Canterbury region.

Businesses were force to move out of the center to the suburbs to keep operating. Some other got bankrupted forcing people to move out of the city and in some cases out of the country.



Christchurch city centre demolition plan
Source: Christchurch City Council

Ground ruptures

The ground shakes and this ruptures causes damages to buildings and other structures.

The severity of destruction depends on how close the area is to the epicenter. Ground rupture means the breakage and displacement of the earth’s surface. It is a major threat to huge structures like bridges, dams and nuclear power plants.

Source: otagocdem.govt.nz

Source: surveying.net.nz

Landslides

Other major threats that occur due to an earthquake are landslides. When the earthquake is accompanied by other major threats like wildfires, volcanic activity or storms, landslides may occur.

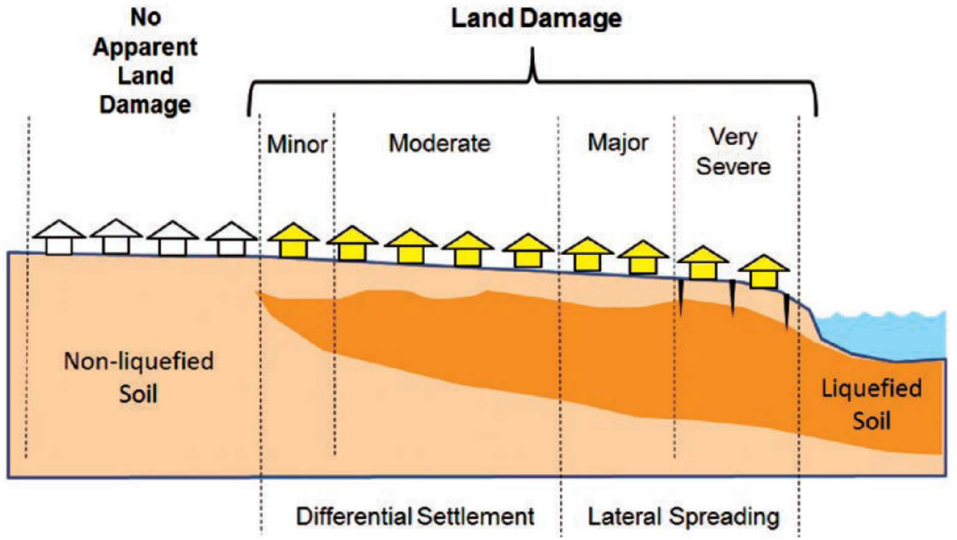
Landslide in Sumner area
Source: nz.news.yahoo.com/.nz

Soil liquefaction

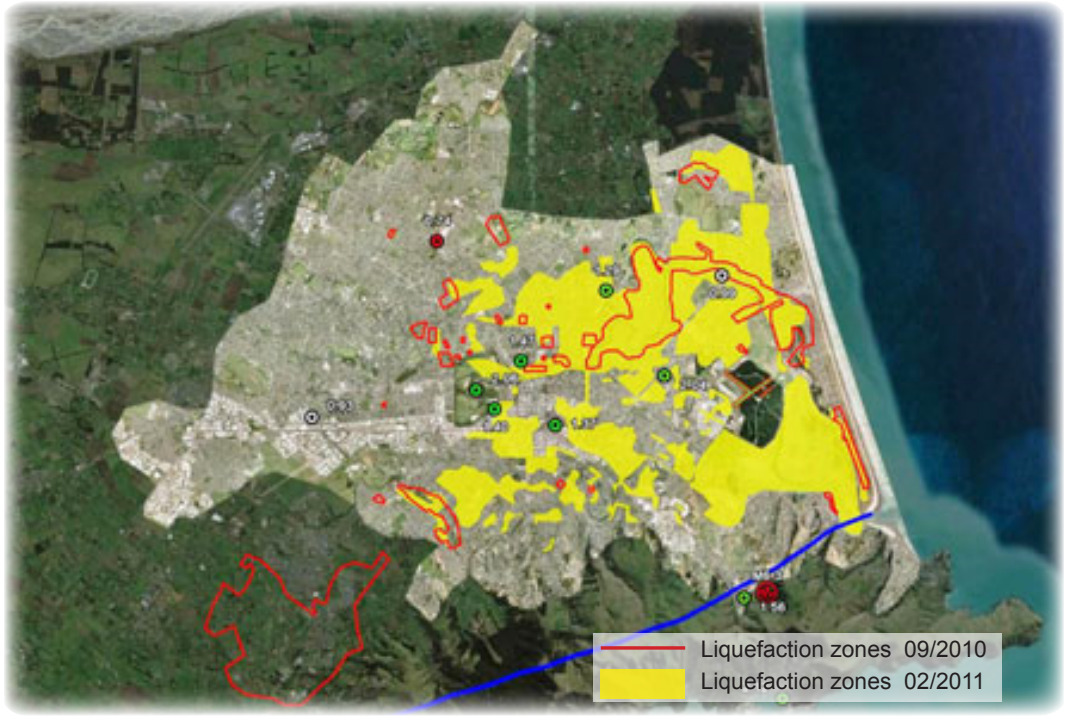
When water saturated granular material like sand loses its strength due to earthquake it gets modified into a liquid. This process caused damage to bridges and buildings. There was a chance of these structures getting collapsed to the ground.

Liquefaction in on the road
Source: fmkorea.net

Liquefaction in Kilmore St
Source: keithwoodford.wordpress.com



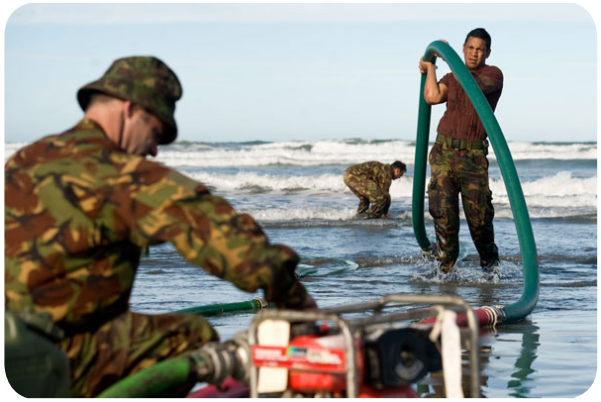
Schematic section of liquefaction-induced land damage
Source: New Zeland Department of Builgind and Housing



Christchurch liquefaction from ground shaking map
Source: R. Green, GEER

Water supply failure

District water systems fail and get contaminated being unable to drink and use for hygienically purposes.

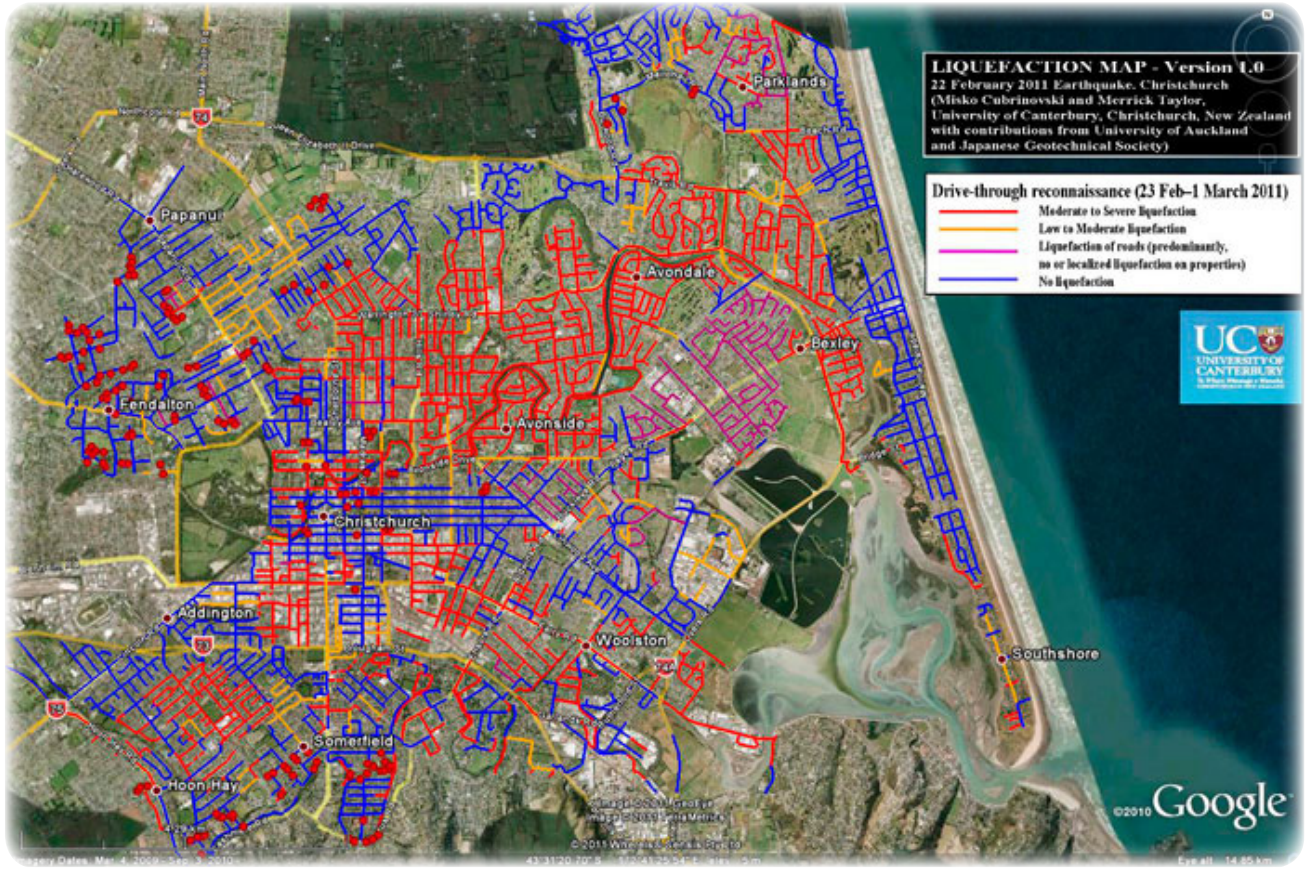


The army provided desalinated water to the residents
Source: stuff.co.nz

Water tanks were placed at the affected areas
Source: wozawanderer.blogspot.com

Sewage piping brakes

Or doesn't work contaminating the area and forcing people to find other non-technical



Liquefaction affecting pipes
Source: planetearth.nerc.ac.uk

Electricity cut offs and fire

Also being unable to cook, powered appliances, heat and cool down homes and keeping food fresh.

Due to the damage of electrical power and gas lines chances of fire eruption were high due to the earthquake.

Fire in Worcester St, city centre
Source: stuff.co.nz

Equipment shutdown

Education, hospitals and other institutions and services stopped and in some cases got over saturated.

The city center was closed on a string guarded by military, the area inside the string is called the Red Zone and the access was restricted to only authorized personnel, demolition companies, engineers, insurances, among others.

Christchurch Red Zone

Transport paralyzed

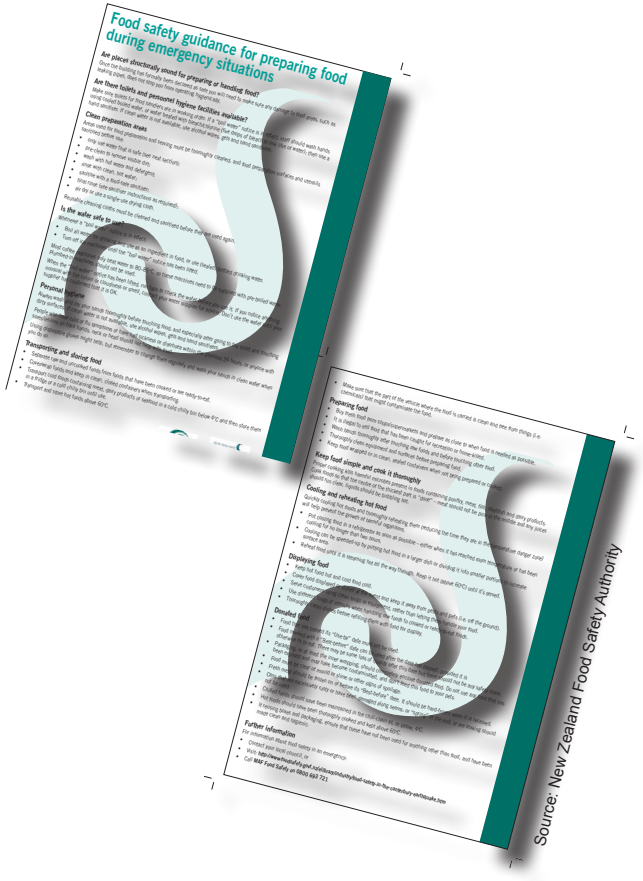
After disasters occur the main transportation systems brakes down public and private, roads, bridges, traffic lights having the local residents disconnected.

Source: earthquake-report.com

Christchurch City center
Source: hoteliermiddleeast.com

Food safety

The 22 February 2011 earthquake disrupted the city power supply for several days, sewers were damaged and water lines were broken due to the liquefaction pumping and pushing the buried infrastructures up to the surface, the city water were contaminated and food safety became an issue to address, the risk of gastroenteritis and foodborne illness were eminent.



Houses and food businesses were unable to prepare and keep fresh food in fridges and freezers, also most of the cooking devices in the city are electrical.

The daily situation was difficult. [New Zealand Food Safety Authority]

Food security

Because of the 22 February 2011 earthquake the food supply got affected.

The local crops got buried by liquefaction, supermarkets and other shops were closed, and several suburbs had restricted road access which makes communications and aids difficult.

Source: ruralagriculturefoodsecurity.wordpress.com

Telecommunication lack

Internet cut off, local telephony cuts and surrounded saturated, being impossible to contact victims and search of their situation.

Community problems

After February 2011 the community had to deal with a wide range of earthquake related issues like general stress and dangerous scapes such a drug and alchohol abuse, gambling, domestic violence, anxiety and depression, also issues such as unemployment, debt increase, immigration rejection, pregnancy increase, robbery, among others.

Conclusions

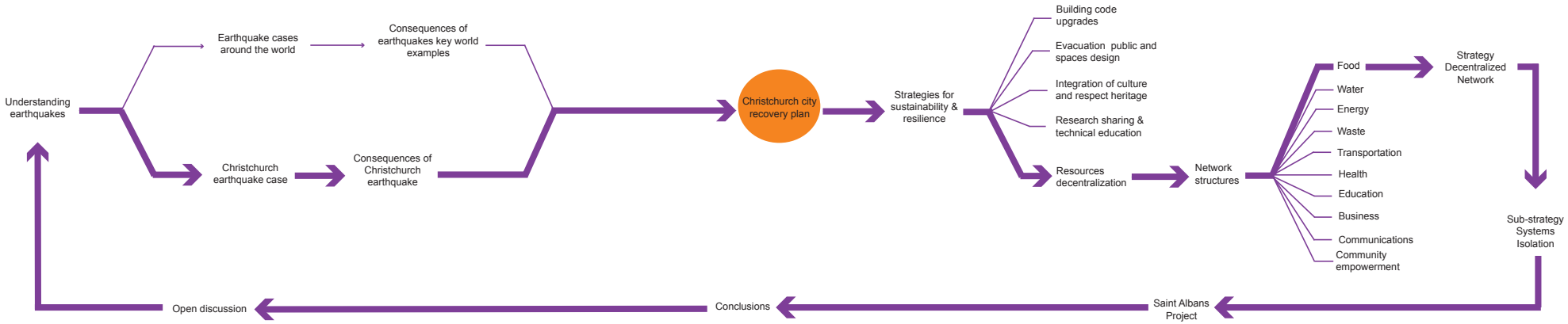
The consequences listed above are giving us a lesson.

It is telling us that our way of planning and building cities are too vulnerable for the present problems.

They are not resilient enough to survive earthquakes.

It is crucial to define stronger strategies in order safe lives and to keep the cities infrastructures working back as soon as possible after each upcoming event.

3.3 Christchurch City Recovery Plan



Paths to Recovery

Christchurch is located in the Canterbury region which generates around 12% of the country's national gross domestic product (GDP). Despite the heritage and historical background there are enough economic reasons to invest in the recover and improvement of a better central city.

As it is mentioned before, the 70% of Canterbury's economic output comes from activities inside Christchurch. The city has the only tertiary hospital in South Island, two universities, 24 hours airport, a sea port connecting it within the country and internationally. Then recovery after earthquake is crucial for the community to come back to a normal condition and life standards.

Prior to the creation of the Christchurch Recovery Plan several speakers from all around the world involved in disaster recovery were invited to Christchurch to explain and share their experiences and knowledge in redeveloping cities affected by natural and manmade disasters. From that meeting the Christchurch City Council (CCC) took the most common stages in the recovery to be applied to Christchurch city.

Christchurch city few minutes after earthquake 2011, dust from falling debris.
Source: Chrisrtchurch City Council

Christchurch Central Recovery Plan

The graphic bellow shows the four stages of the Christchurch City Paths to Recovery Plan; emergency, restoration, reconstruction and improvement.
After emergency response (evacuation, search and rescue) all the work for recovery starts.

Restoration of basic services, clearing debris and pads and making the environment safe to public can take up to 10 months. Reconstruction begins after restoration, the infrastructure and buildings are repaired and this stage can take up to 8 years. Improvement is the longest stage and is related to make the city better than it was before the disaster happened. This can take another 10 years. [Christchurch Central Recovery Plan, CERA 2012]

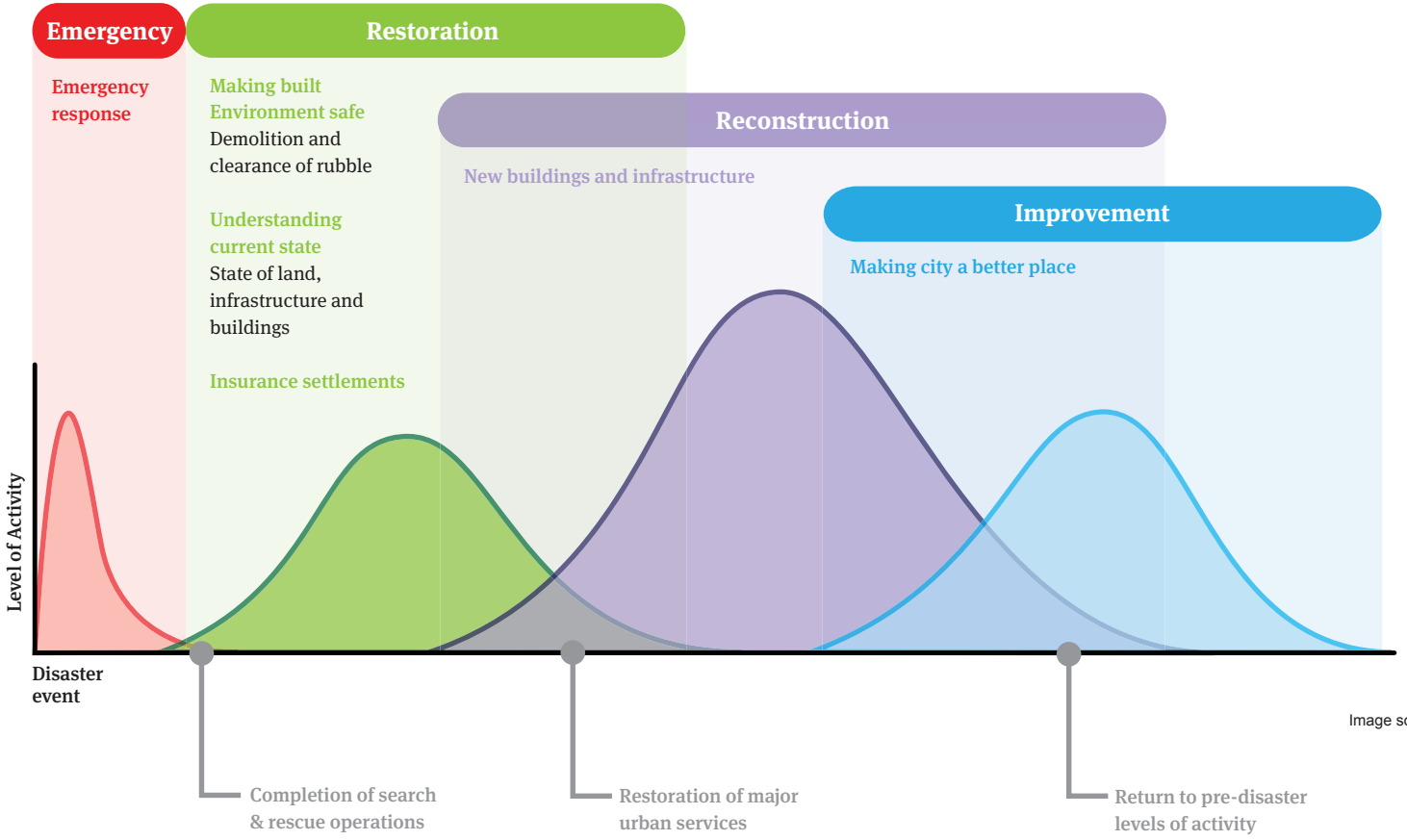
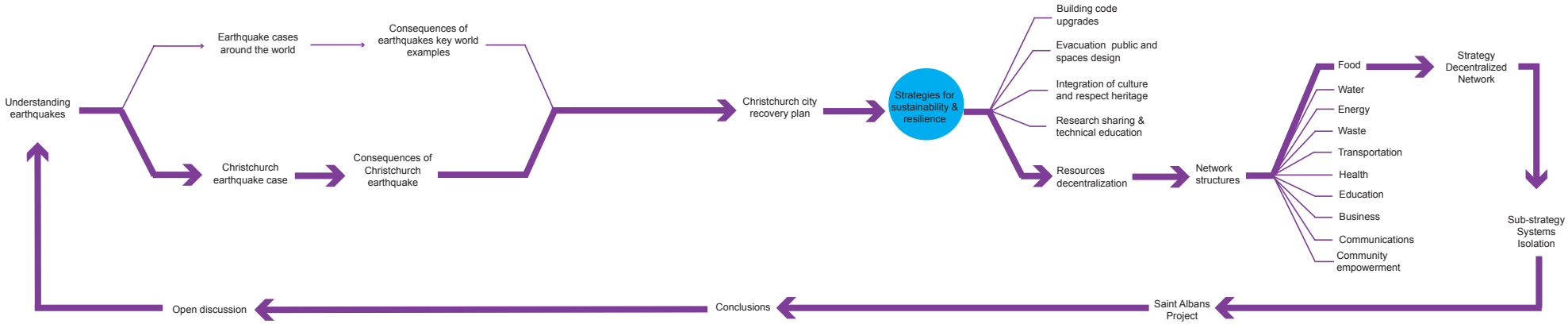


Image source: Christchurch City Plan

4. Strategies for Sustainability & Resilience



4.1 Why strategies?

The word “strategy” originate from the greek “στρατηγία” stratēgia, which literally means “art of troop leader; office of general, command, generalship”. It is a high level plan to achieve one or more goals under conditions of uncertainty. [Liddell, Henry & Scott, Robert. A Greek-English Lexicon, of Perseus]

Based on the consequences of earthquakes, what have been done so far and how are the stages of the Christchurch central recovery plan I got the idea that there is some inconsistencies in the time of the recovery plan’s phases versus the achievements once each phase is completed.

To explain this I have some questions, for example why begin the *Improvement phase* at the end of the recovery plan when it could begin straight forward after the *Emergency phase* until the end?

Why keep building in the same way it have done so far but with higher standards (after earthquakes events) when we could try new systems which can perform better under and earthquake and other events?

A consist example is why bring back the same sewage system in the areas badly affected by liquefaction during the *Restoration phase?* I believe that another and stronger earthquake can struck the city again and destroy the restored system again, and again, and again.

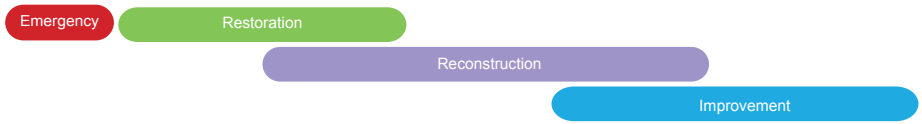
Why not try a new (and more sustainable and resilient) system in the destroyed areas from the beginning?

Because of that I have concluded that the commence of the *Improvement phase* is too late within the *Recovery plan* and this phase should start straight away after the emergency phase have finalized.

A part of that I have prepared a list of strategies as a plus that should be included into the *Recovery plan* to reinforce it.

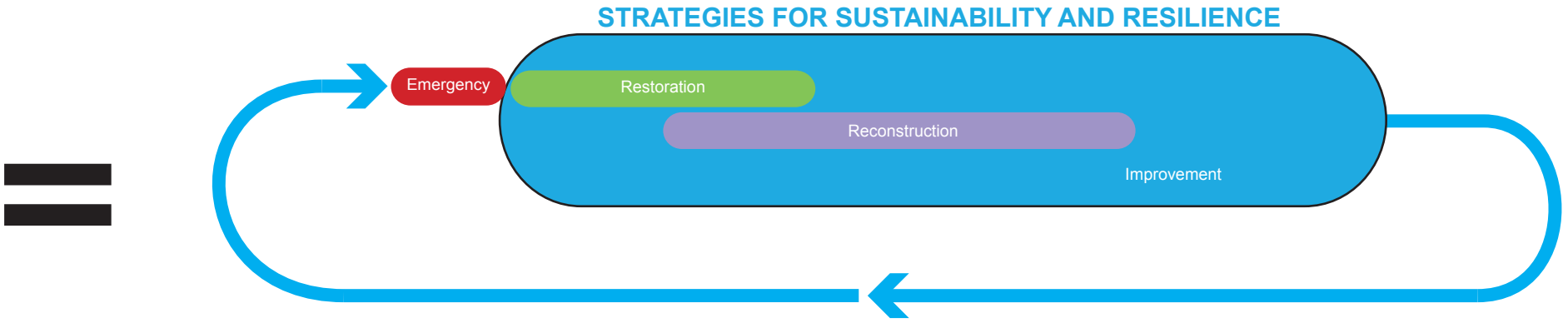
The strategies should complement transversely to the other three phases (restoration, reconstruction and improvement).

Christchurch Central Recovery Plan



STRATEGIES FOR SUSTAINABILITY AND RESILIENCE

The graphic below shows the *Christchurch City Paths to Recovery* with the proposed strategies additions and they should perform in a closed loop system, giving continuously feedback to the emergency phase.



Christchurch Central Recovery Plan adapted to proposal

4.2 List of Strategies_for sustainability and resilience

I have found five strategies that are applicable to the *Recovery plan*. The first four are currently undergoing in variable degrees, so this research concentrated towards the fifth strategy called *Resources Decentralization* to develop further in this research document.

i) Building code upgrades

Building codes are upgraded in seismic areas for any future building, but also older buildings should be compulsory prone in other to save lives. This part is not happening due to financial issues.

ii) Evacuation and public space

Design to keep main roads broad and clear to be used for accessing and as evacuation routes. This will facilitate the activities of diverse groups like rescue, provide help, aid and other guidance. The design of public spaces should also consider other uses in case of emergency such as safe areas to remain and meet with the others in case of an earthquake, temporary emergency camps and temporary basic services when is needed.

iii) Culture + Heritage

All new ideas and other world solution examples expecting to be implemented should consider and respect heritage and local culture. [Safer Homes, Stronger Communities, GFDRR 2010]

iv) Research + Technical Education

New research and technical education should be shared worldwide prioritizing seismic countries.

v) Resources Decentralization

Giving the chance to a variety of groups or individuals to decide how to manage, own and invest in resources. Spreading the control from few companies or institutions to the public will reinforce the network structure in case of an earthquake event (affecting potentially few areas and not the whole city)

Food: promoting and spreading variety of food production systems will perform better in emergency events when the cities are paralyzed.

Water: storing and recycling grey water systems will allow function in an earthquake event when the city pipes in some areas are broken.

Energy: offering different options of energy management also will perform better in emergency events when the cities are paralyzed.

Waste: recycle of organic waste into different production systems and sending the non-recyclable waste to the city energy plant.

Transportation: options using a variety of energy sources will remain working in case of emergency, a plan for transport through an emergency net (emergency streets and lanes) will keep connecting the whole city.

Health: each neighborhood in the city must have at least one health center so hospitals can delegate medical attention in case of emergency and evacuation.

Education: schools and other educational institutions should be involved in the emergency and recovery process giving to teachers and students responsibilities and the chance to collaborate in the community through civil defense, red cross and other associations.
Other civilians should also be trained for emergency and provide support to the institutions.

Business: local professionals and skilled companies should attend first the city recovery needs and then the other national and international companies should join after if it is required. In this way the local economy involved in the infrastructure can assure mobility and financial stability. For all general business their location should be diverse, not only in the city Centre, also in other alternative business areas within the city.
The creation of emergency employment can keep the local economy in balance and reduce resident's migration to other cities.

Communication: propose of community spokespersons in neighborhoods and municipalities so they can update to the government and other institutions with needs and news.

Community Empowerment: training workshops, psychological support, social activities, use of social centers, churches and schools available to host activities for the community specially in emergency situations to palliate social problems as consequences like stress, depression, domestic violence, robbery and to give a sense of warmth in difficult times when is most needed.

4.3 Resources Decentralization

Decentralization is the process of redistributing or dispersing functions, powers, people or things away from a central location or authority.

Some forms or characteristic of decentralization are;
- Devolution (at autonomous lower-level) when central authorities give back functions and decision making back to the locals for direct control.
- Delegation (at semi-autonomous lower-level) when central authorities give responsibilities to the local authorities, but still controlled by the central.
- Deconcentration (at sub-ordinate lower-level) limited transfer of authority. [UNDP-Government of Germany, 1999]

De idea of decentralize the basic resources came out of analyzing the main problems and consequences after the earthquake in Christchurch on 22 February 2011.

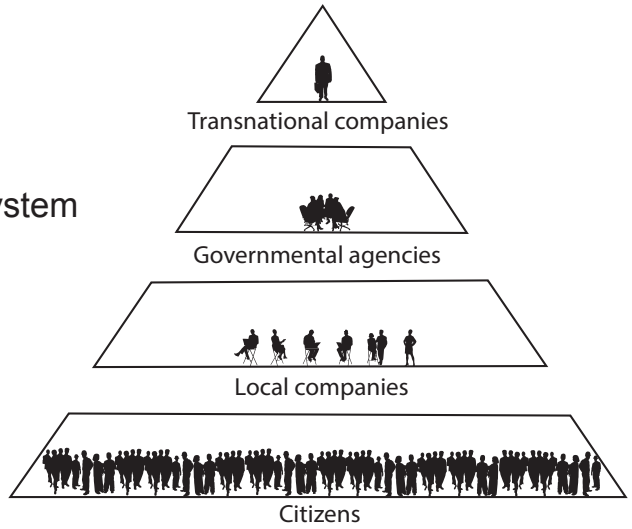
Have seen the city paralyzed and incapable to provide the most basic services needed to survive at the emergency stage was circulating in my mind for long time.

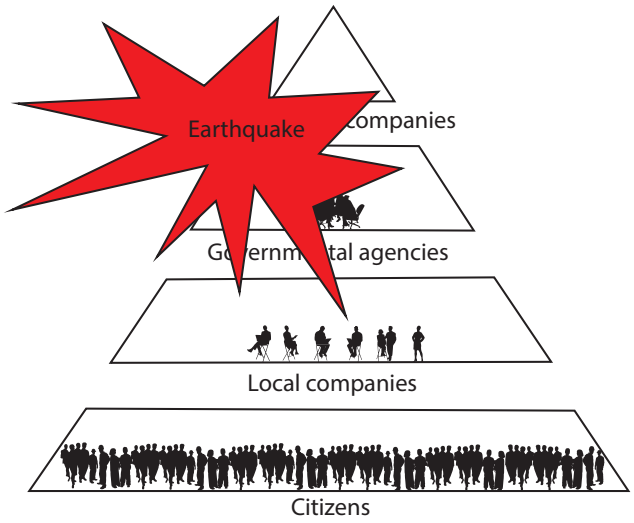
The graphics below show the common structure of resources systems which are either pyramidal or central, directed by governmental agencies, transnational companies or small group of trade's people.
Giving the chance to a variety of groups or individuals to decide how to manage, own and invest in resources.

Spreading the control from few companies or institutions to the public will reinforce the network structure in case of an earthquake event. (Affecting potentially few areas and not the whole city)

The decentralization system can provide more participation of individuals encouraging co-responsibility, diversity of groups, organizations or institutions instead of having only one characteristic type. Also efficiency due to failure of some responsible others can provide support and more tools for conflict resolution.

Piramidal system





6.4 Network structures

Network is a concrete pattern of relationships among entities in a social space. [Powell 1990]

Networks have been used in a variety of subjects such as graphs theory, mathematics, and social networks theory in sociology and computer sciences, physics, biology and economics.

The idea is understand that everything is interconnected.

For example, people are connected to social networks, connected to information, organizations, phases, transportation, among others.

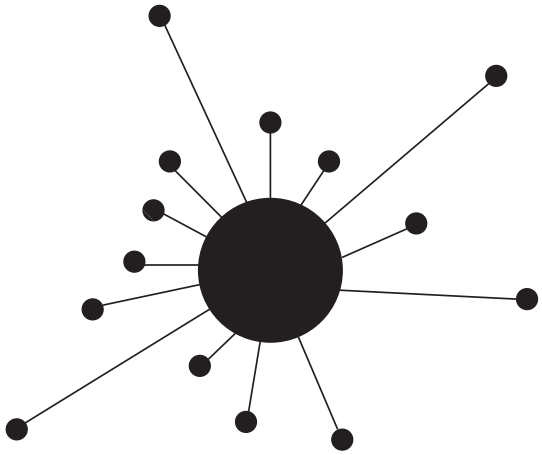
Then the spectrum of networks becomes very complex.
I have found three examples types of networks structures that can be tested with the *Resources Decentralization* strategy:

Types of network structures

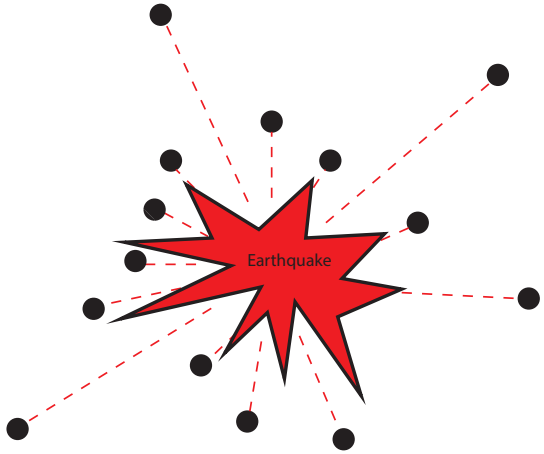
Centralized network

Directed by a central or hierarchical node.
The central node makes the decisions, contains all the power and distributes the resources to individuals.

If the central node struck by an earthquake event, the communication with individuals get interrupted.



Centralized network structure

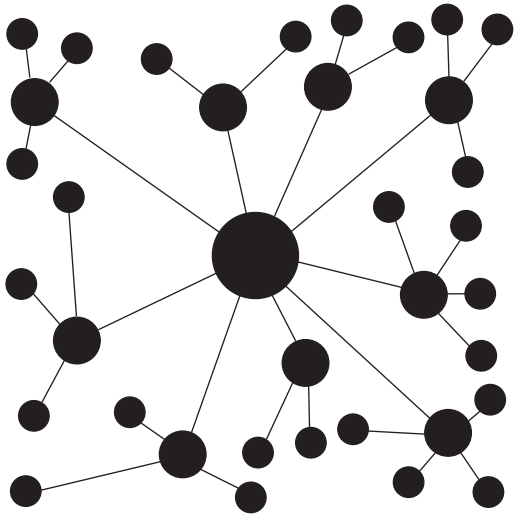


Fail

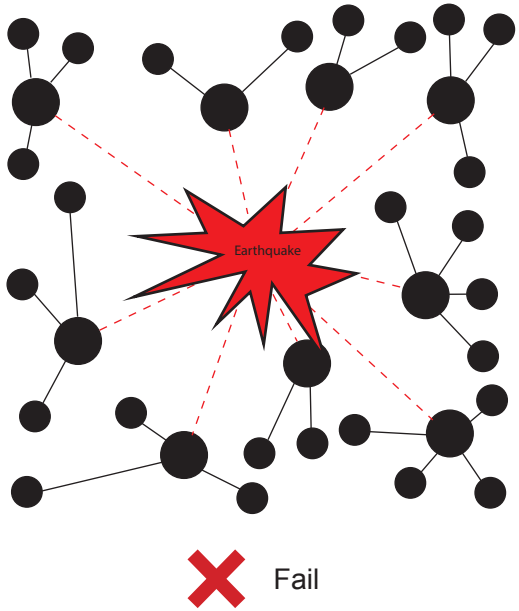
Decentralized network

Directed by a central or hierarchical node which delegates responsibilities and activities to secondary nodes. The secondary nodes distribute the resources to individuals.

If the central node struck by an earthquake event, the communication with secondary nodes and individuals get also interrupted.



Decentralized network structure

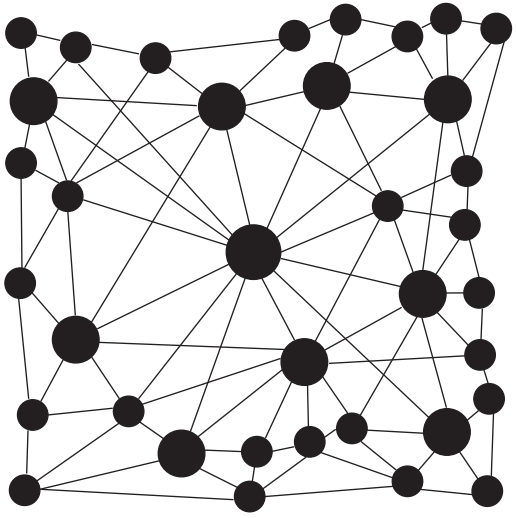


Fail

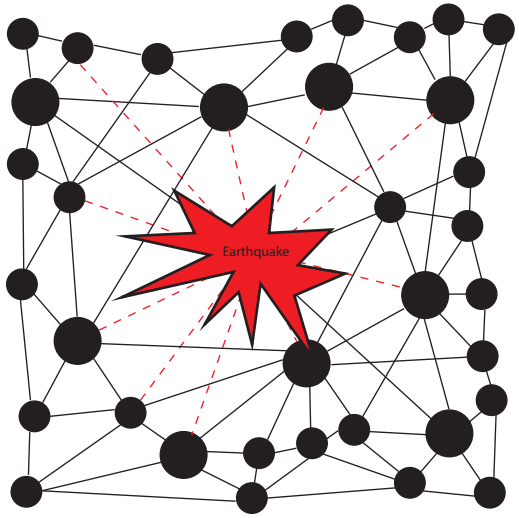
Combined and distributed network

Combined and distributed network can response to the problems of centralized systems when earthquakes events occur.

Non-hierarchical, flexible, efficient, robust and resilient.



Combined and distributed network structure



Resilient

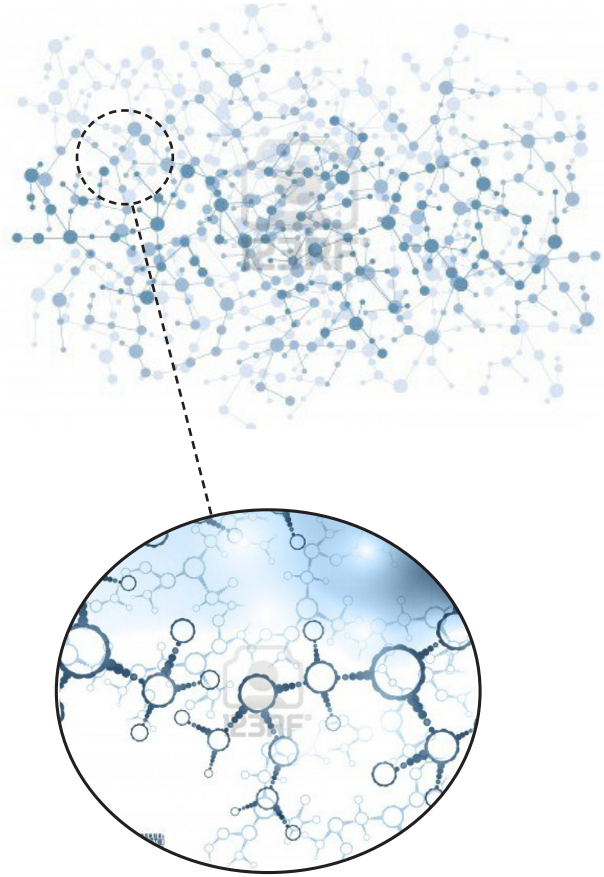
Samples of network structures found in nature

If we look how the nature have designed their systems, we can find vast examples of networks. The idea of seeking solutions by emulating nature's network structures is to test how nature can solve their needs and issues through design.

The examples beside show typologies of network structures with similar behavioral patterns; they are decentralized, combined and distributed. When an area get affected or partially destroyed the whole system can continuing performing for some time until the area is recovered or has mutated:

Molecular

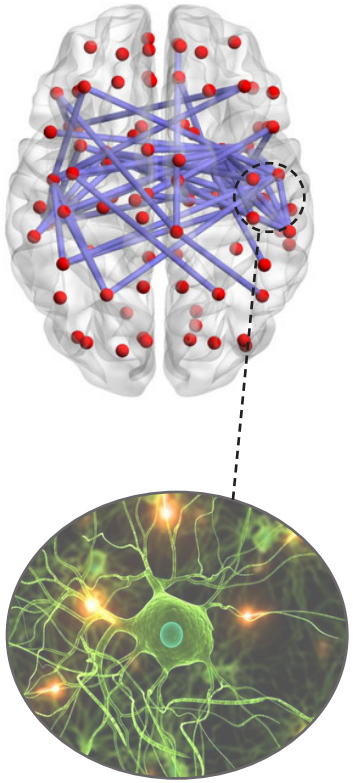
A molecule is a group of atoms held together by chemical bonds. The molecules are the components of the majority of the solid substances on Earth. [The Gold Book, 1997]



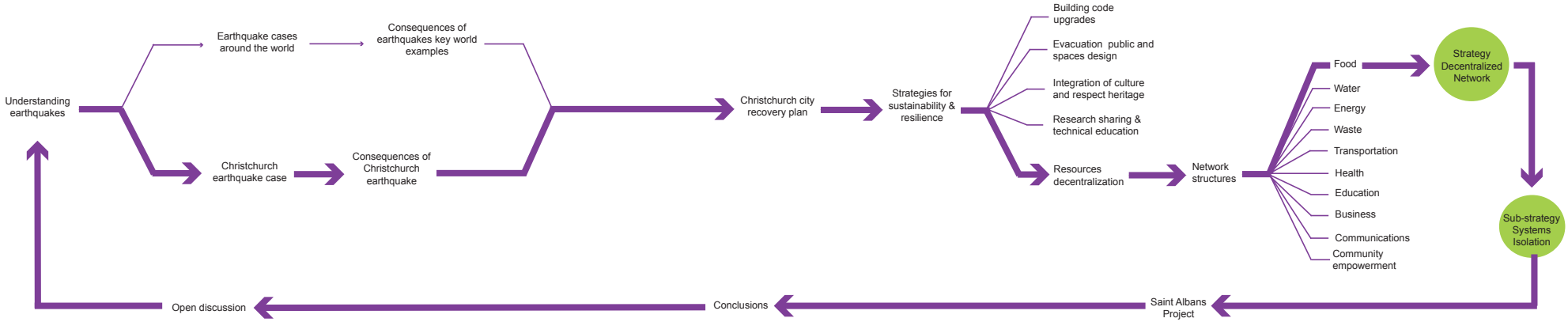
Neurons

Neurons are brain cells and they are interconnected each other by bridges or "axons" sending information through electricity.

The group of interconnected neurons is called in neuroscience "biological neural network". [Wade Nicholas, 1999]



5. Proposal

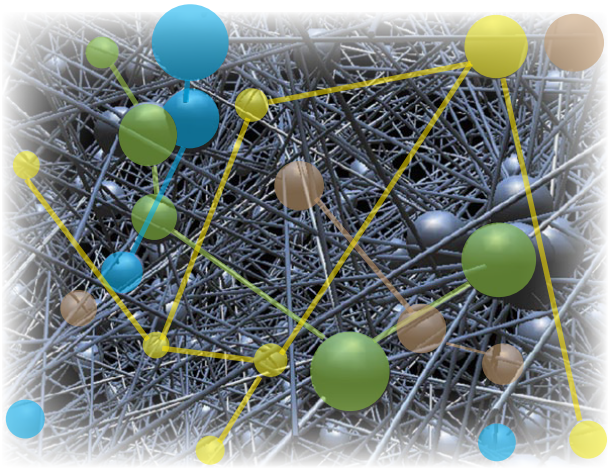

Understanding earthquakes
Earthquake cases around the world
Consequences of earthquakes key world examples
Christchurch earthquake case
Consequences of Christchurch earthquake
Christchurch city recovery plan
Strategies for sustainability & resilience
Building code upgrades
Evacuation public and spaces design
Integration of culture and respect heritage
Research sharing & technical education
Resources decentralization
Network structures
Food
Water
Energy
Waste
Transportation
Health
Education
Business
Communications
Community empowerment
Strategy Decentralized Network
Sub-strategy Systems Isolation
Saint Albans Project
Conclusions
Open discussion

5.1 Strategy: Food decentralization

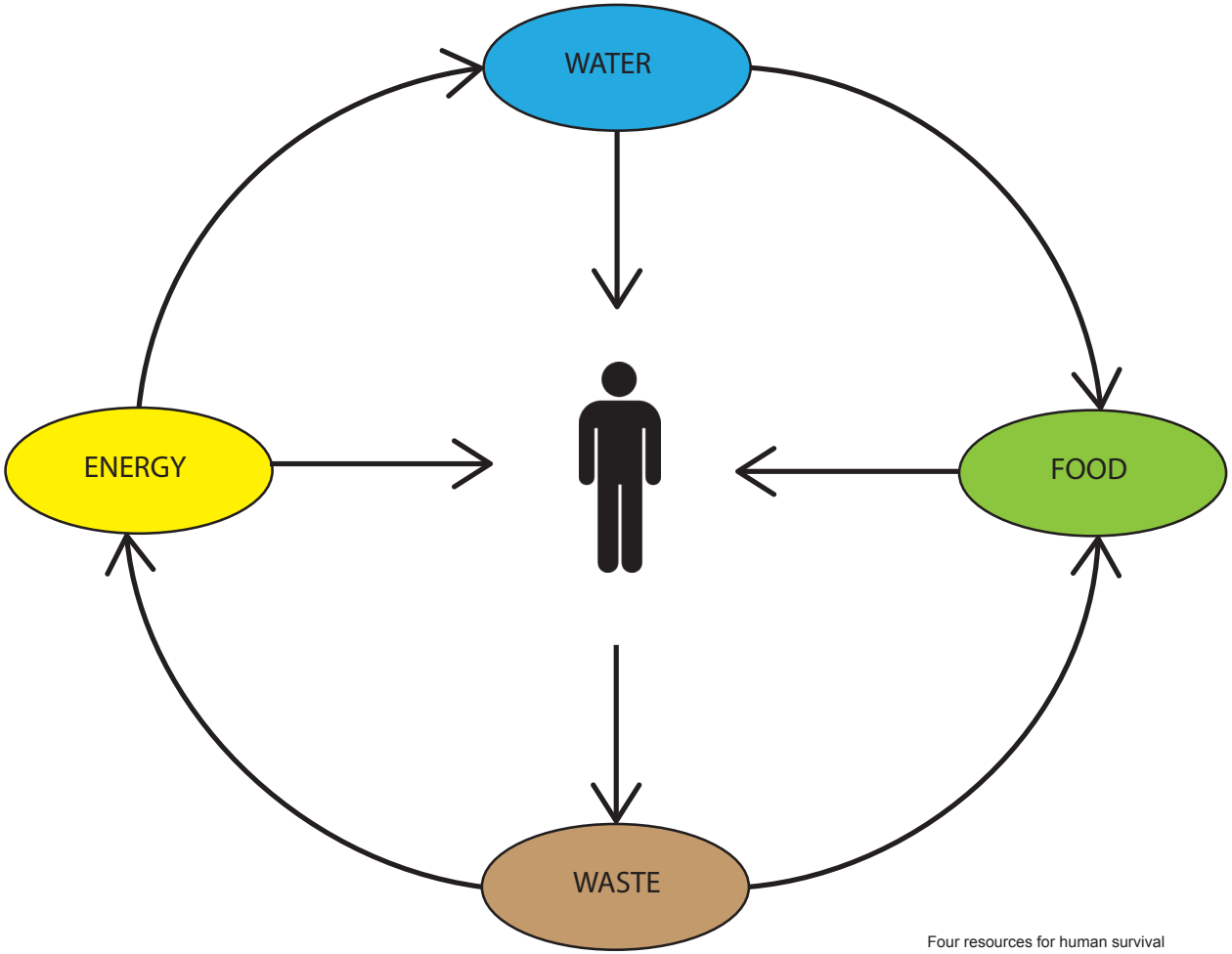
Having a look to the decentralization strategy and the list of resources, I realized that they are quite vast and the whole topic can lead to further academic work beyond this thesis. Then I decided to analyze the most important resources to people. Then, here is presented the four most essential for human survival.

FOOD - WATER - ENERGY - WASTE

Understanding that all of them are important and need each other to perform, they can be placed in the city or town area, overlap and interact with each other like layers.



Resources in network structures



Four resources for human survival

A human being needs food and water for survival.
At the same time produces waste that can be used to produce energy and feed the food production process.

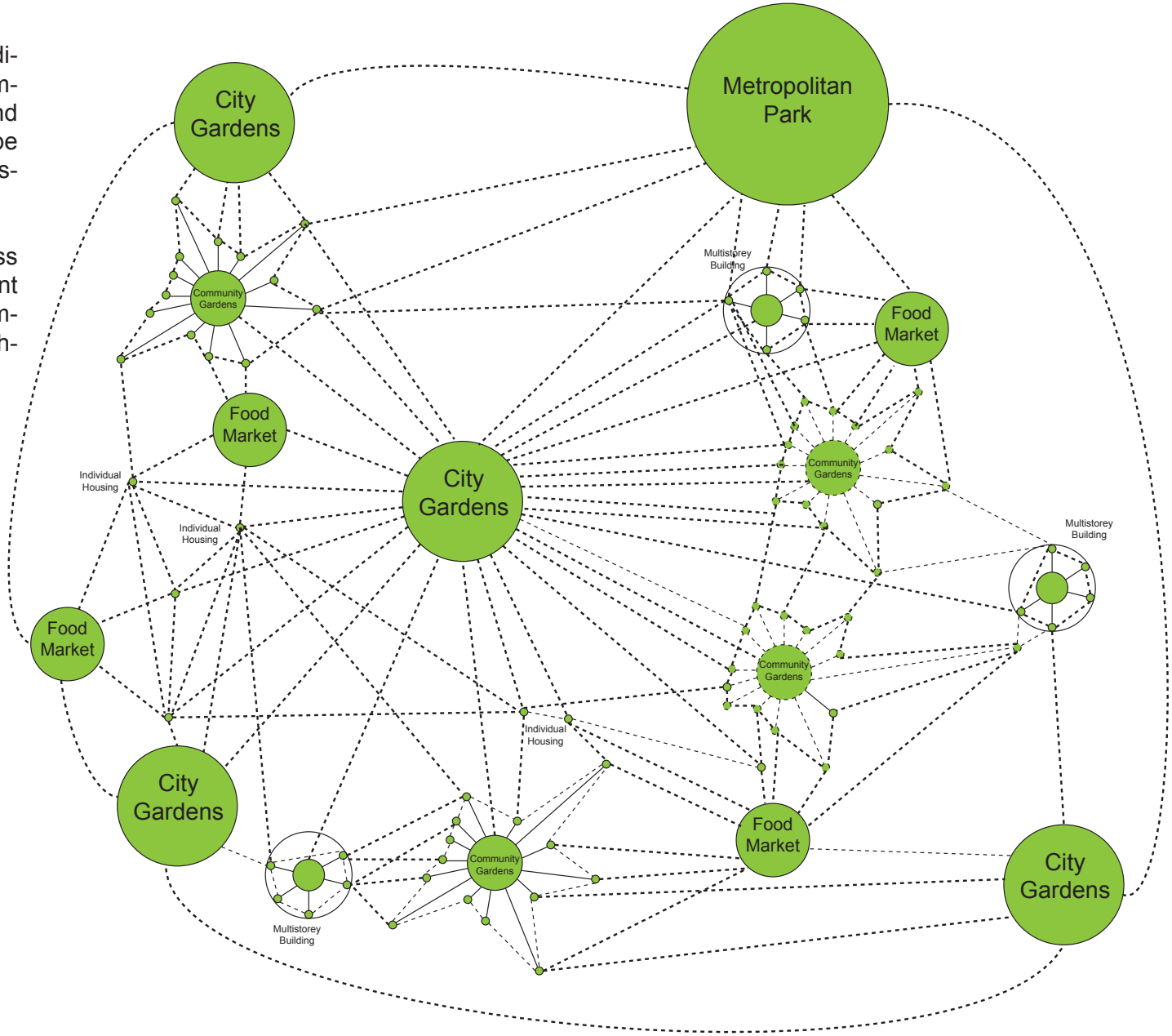
Also humans need energy for other processes and for water manipulation.

*Food is in my opinion the most crucial and I have chosen it for further development.

Food Network

Combined and distributed network were individual houses with gardens, allotments, community gardens, multi-storey buildings and city parks can host food production and be shared, swap or sold between their city's residents.

This system can provide benefits like less transportation expenses, ecological foot print decrease, local community and business empowerment, resources efficiency, among others.



Symbology

Public Gardens

Multi-storey Building

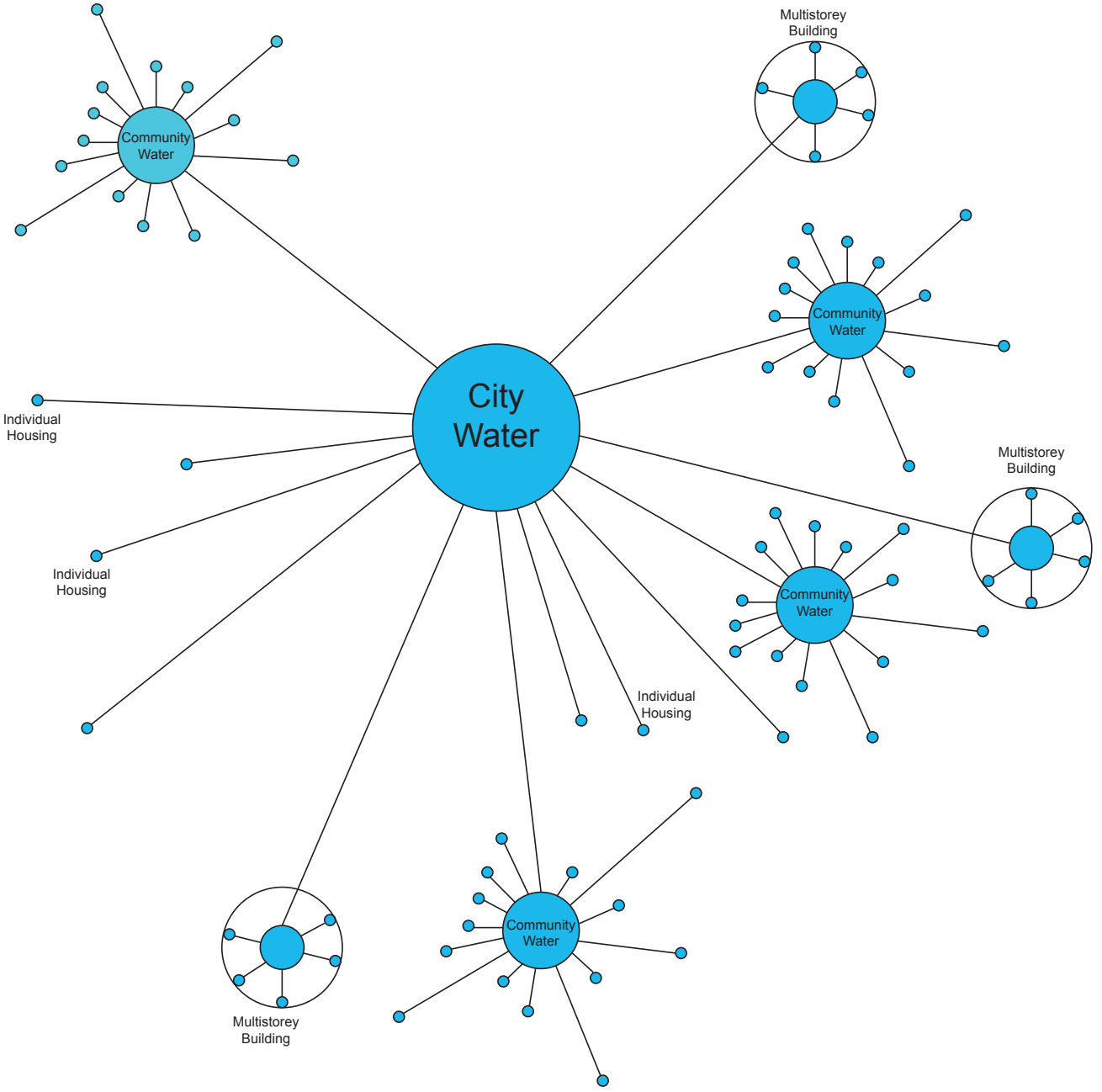
Community Gardens

Individual Housing

Connection

Water Network

Where individual houses with tanks, community water tanks, multi-storey buildings with water store capacity and city tanks can store water coming from the water company, but **also from rain,** and be distributed among their city's residents. The water tanks can have filters to purify water when needed.



Symbology

City Water

Multi-storey Building Water

Community Water Tanks

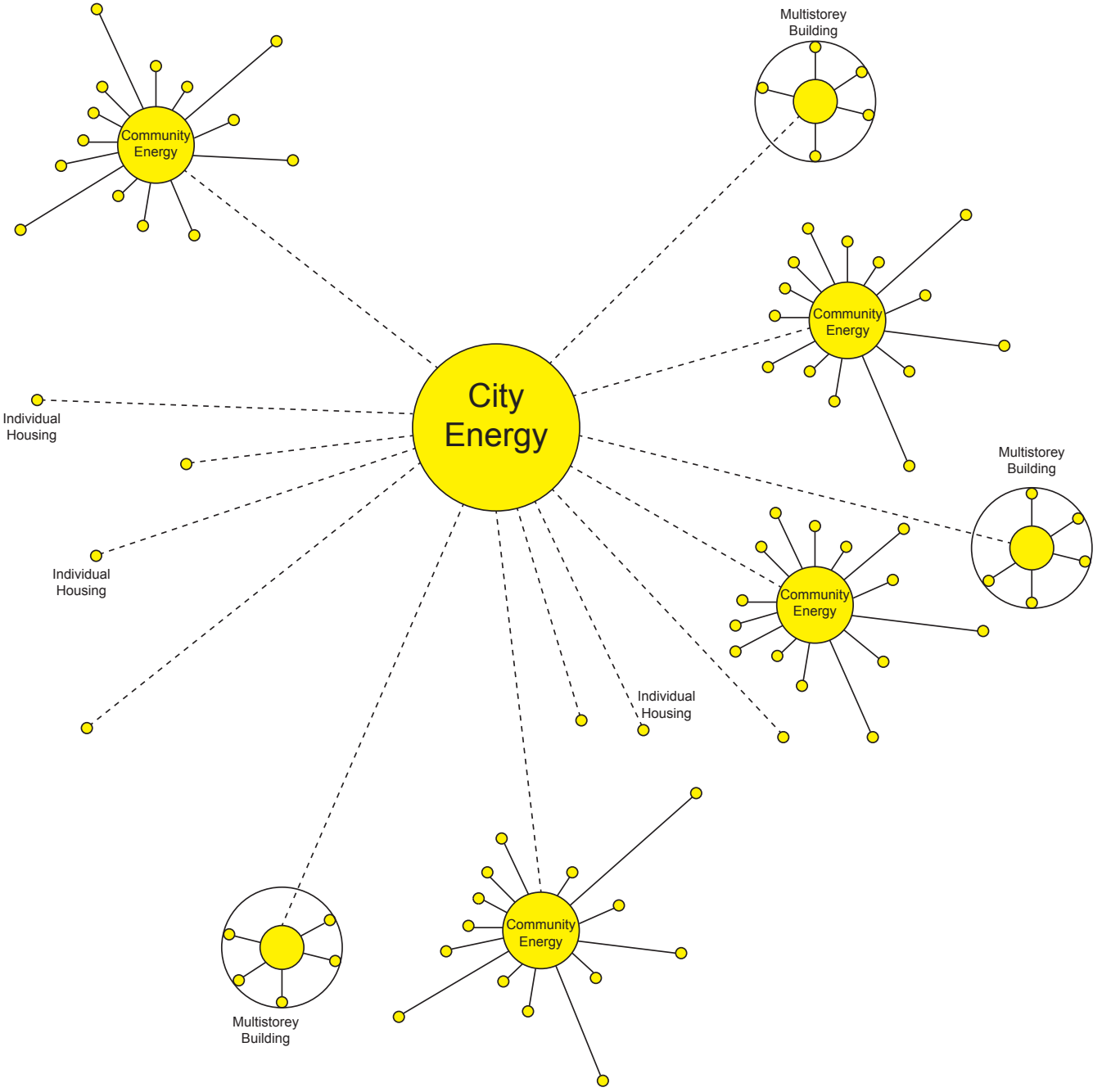
Individual Housing Tank

Connection

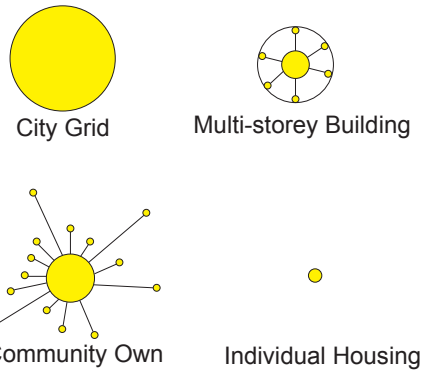
Energy Network

Where individual houses, communities, multi-storey buildings with solar panel, wind mills can collect from s**un and wind energy, (among other systems)** store it, consumed it and provide to the city grid their surplus.

The residents could choose if they want to own the energy, how they should manage and maintain it. Then use the city grid energy if it is needed.



Symbology

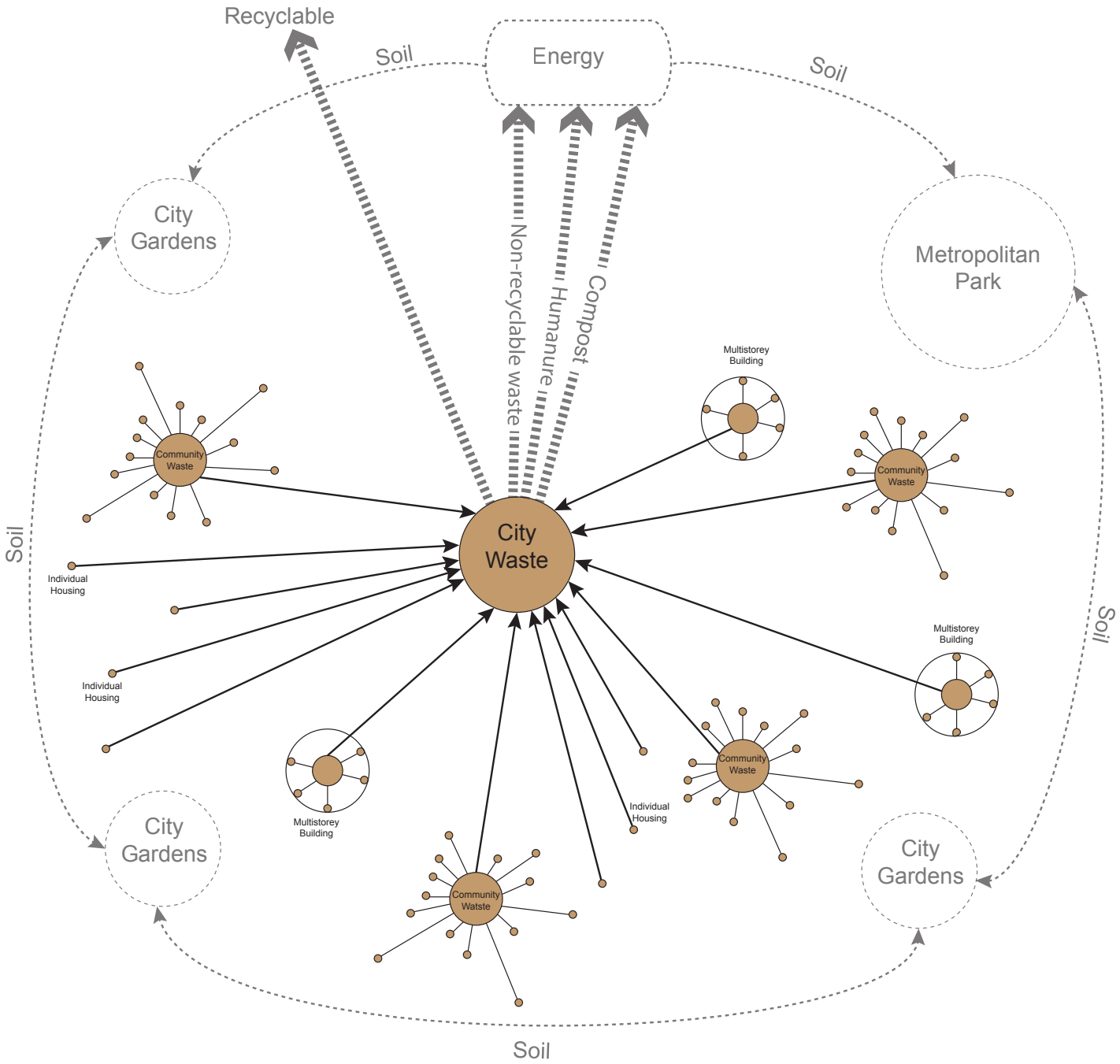


Waste Network

Where individual houses, communities, multi-storey buildings have their **own composting systems and recycle stations** which are connected with the central city waste network.

Recyclable waste can be picked up weekly with a track to be sorted in the city station.

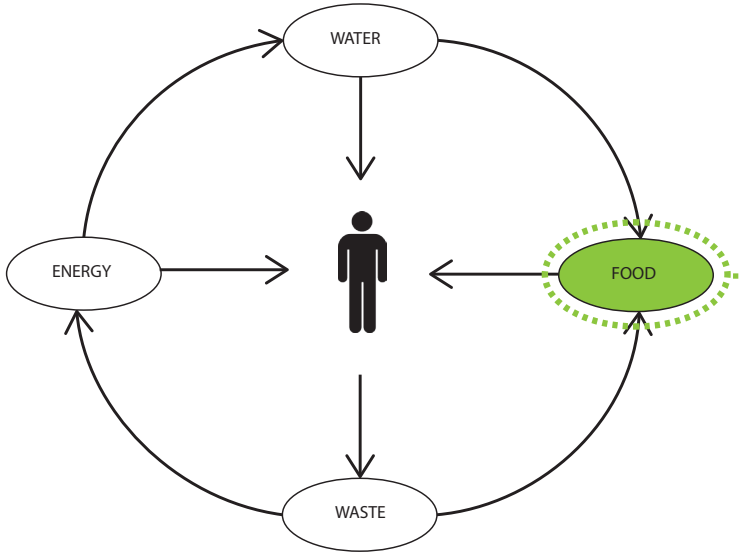
Compost and humanure can be stored in their own gardens or can be picked up fortnightly ("Dry Waste Network") with a truck to later produce biogas for public transportation or city district heating. The left material (soil) can go to land remediation after.



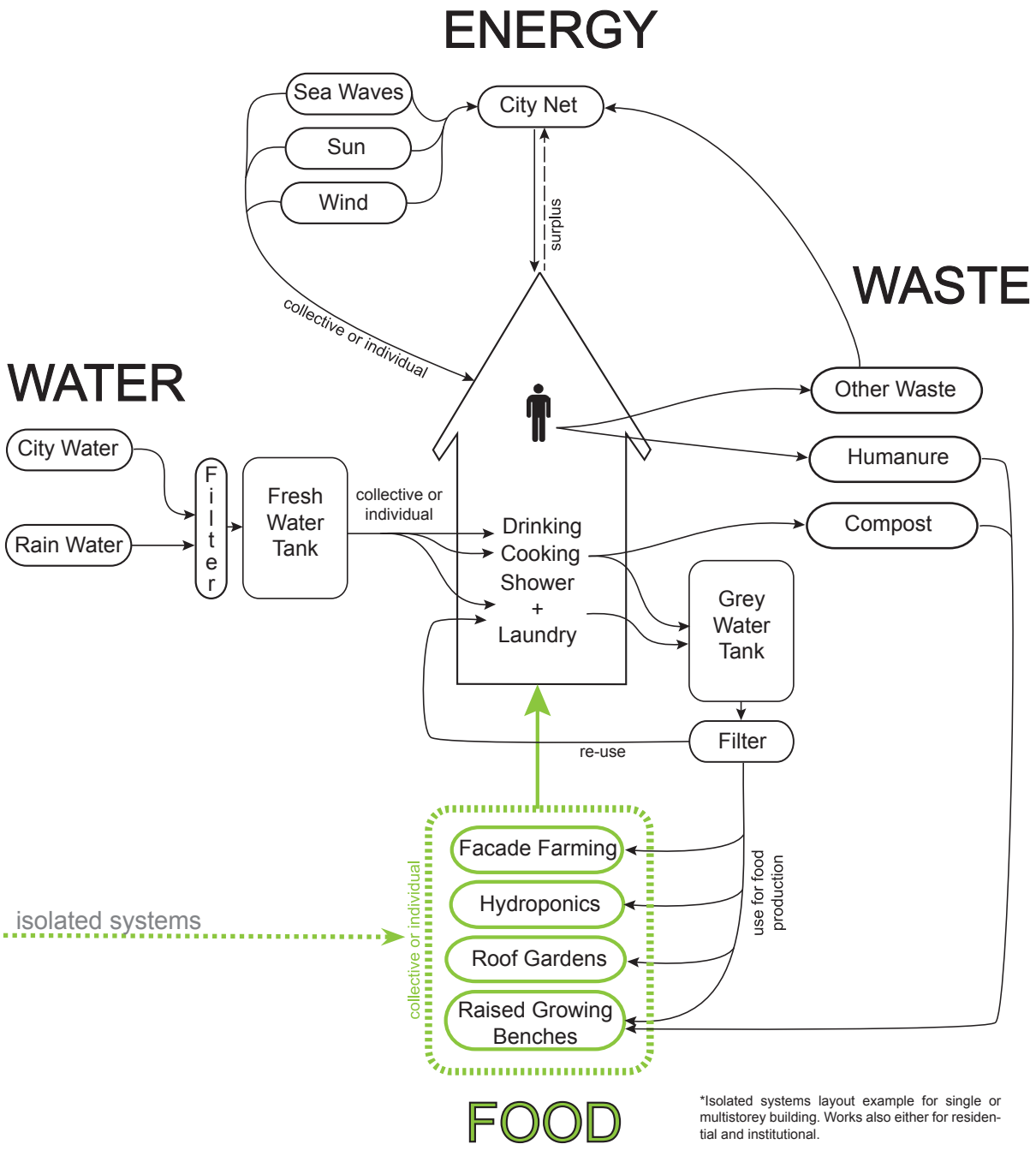
5.2 Sub-strategy: Food isolated systems

While the strategy *Food Decentralization shows* a macro or general view of the proposal, now the S*ub-strategy called Food Isolated Systems* is showing how it can look in a close or micro view. From individual housing to business, community or multi-storey building.

The systems proposed are isolated from the ground, can stand alone or be attached to the building structures to perform and adapt better ensuring continuous supply in the case of earthquakes.



isolated systems



*Isolated systems layout example for single or multistorey building. Works also either for residential and institutional.

5.2.1 Isolated systems_examples

I have found some examples worldwide that I call *isolated systems* because they are isolated from the ground and they can perform quite well in the case of earthquake events. This inventory examples are currently being applied to real contexts around the world.

Facade Farming

Space saving when growing food in facades of any type of buildings; from houses to multi-storey buildings, from residential to commercial or institutional buildings.

The crops isolated from the ground become more resistant to seismic activities moving together with the building structure.

Rain and re-use of the buildings grey water from storage tanks can keep the food fresh even if the city piping network is broken.

Pasona HQ, a business building located in Tokio, Japan
Image source: Inhabitat.com

Residential facade farming
Image source: apartmenttherapy.com

Balcony farming
Image source: ecofriend.com

Pasona HQ
Image source: Inhabitat.com

Balcony farming
Image source: spottedbylocals.com

Hydroponics

A good option to grow food vertically and horizontally outdoor, in green houses and indoor. The hydroponic systems reduce time maintenance consuming and are also space efficient.

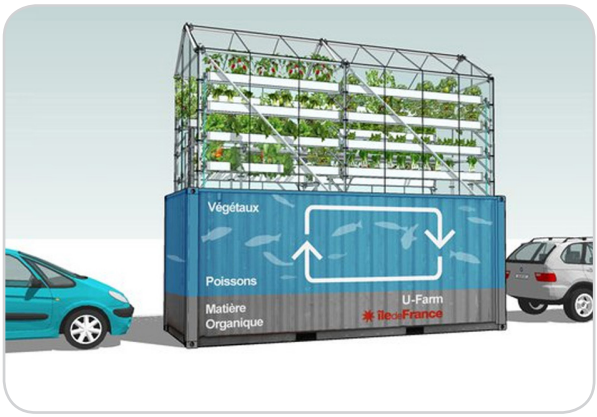
As an isolated system from the ground it can move with the building structure and in case of energy cut off the hydroponic systems can be irrigated manually.

Aquaponics

Another system that can be added to hydroponics is called “Aquaponics”. It allows to grow fish in a closed loop system where the fish waste contains many nutrients and they can feed vegetables and the water is returned back clean to the fish by using filters.

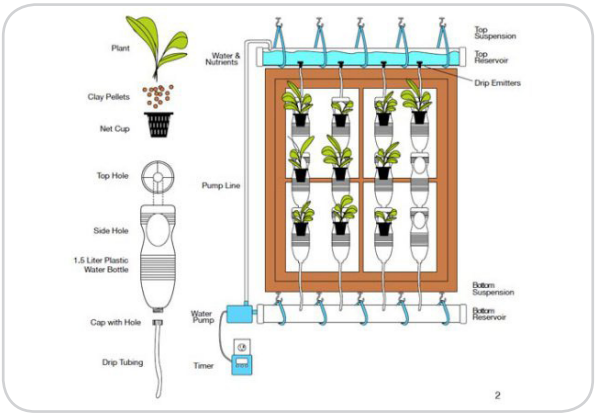
Hydroponics system
Image source: trainonline.com

Window farming- hydroponics system with reclaimed PET bottles
Image source: veoverde.com

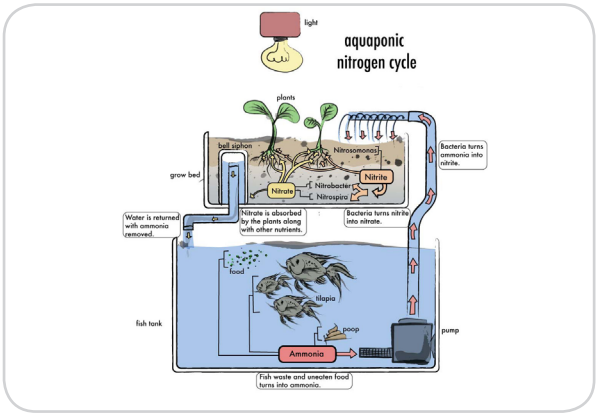


Aquaponics system UFU (Urban Farming Unit)
Image source: sustainablediary.blogspot.com

Hydroponics system
Image source: arch5541.wordpress.com



Window farming-hydroponics system with reclaimed PET bottles
Image source: survivingthemiddleclasscrash.wordpress.com



Aquaponics system
Image source: diyaquaponicsguide.com

Roof Gardens

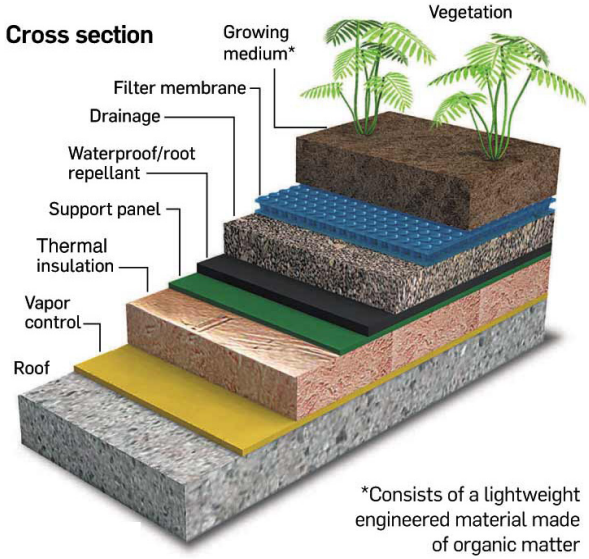
Roof gardens are very useful when the space is limited.

The system allows growing food on roofs of multi-storey buildings in urbanized areas, but also in a individual housing.

In addition the roof gardens have thermal properties, they can retain heat, prevents large temperature fluctuations, collect and filter rain water and improve air quality.

Envisioning of a green Beirut
Image source: wanderlustandwords.blogspot.com

Roof gardens
Image source: ekoidejos.lt



Roof garden section detail
Image source: blogs.trb.com

Garden Village Apartments
Image source: ebsconsultants.com

Raised growing benches

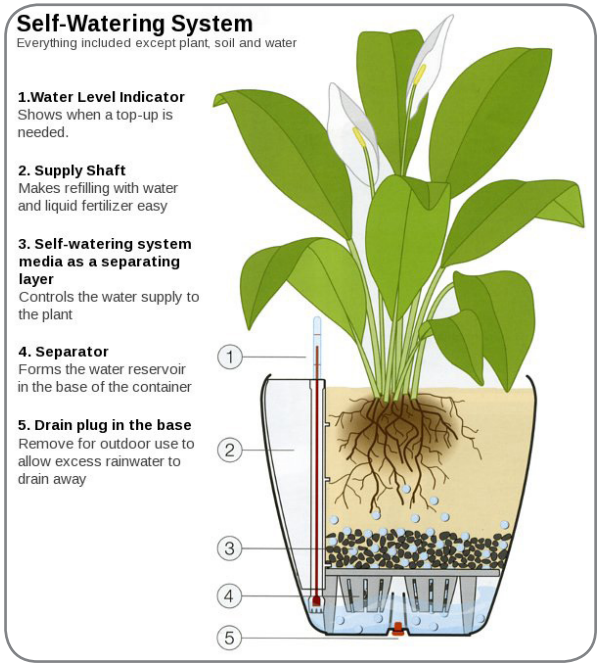
Isolated systems for earthquake resistance can move as independent bodies. Isolated from the ground allowing long life to crops and protecting them from liquefaction and ground disruption in the case of earthquakes.

Outdoor growing bench
Image source: point2.com

Pasona HQ, Indoor growing bench
Image source: Dezeen Magazine

Self-watering containers

Self-water containers have a combination of an absorbing system and evaporation ensuring the soil medium remains with moisture therefore the plants can take water when it is need it.



Self-watering pot system
Image source: plantcontainers.com

As a closed system the water is stored at the bottom of the container so the plants can absorb the water from their roots through capillarity and loose it from their leaves by evaporation. Self-watering containers are very efficient because there is no water loose when it is irrigated and all the nutrients from the soil remain inside the container. They also consume less time greatly reducing the time that the plant needs to be watered compared to the traditional potting system.

Self-watering PET bottle system
Image source: Daniela Gonzalez

Other stand-alone systems

There are no limits at creating solutions. Systems can vary according to the places qualities, climate conditions, peoples needs and budget.

Bed with growing and lighting systems incorporated
Image source: homedit.com

Hanging shoes containers for vertical farming
Image source: seedsandfruit.com

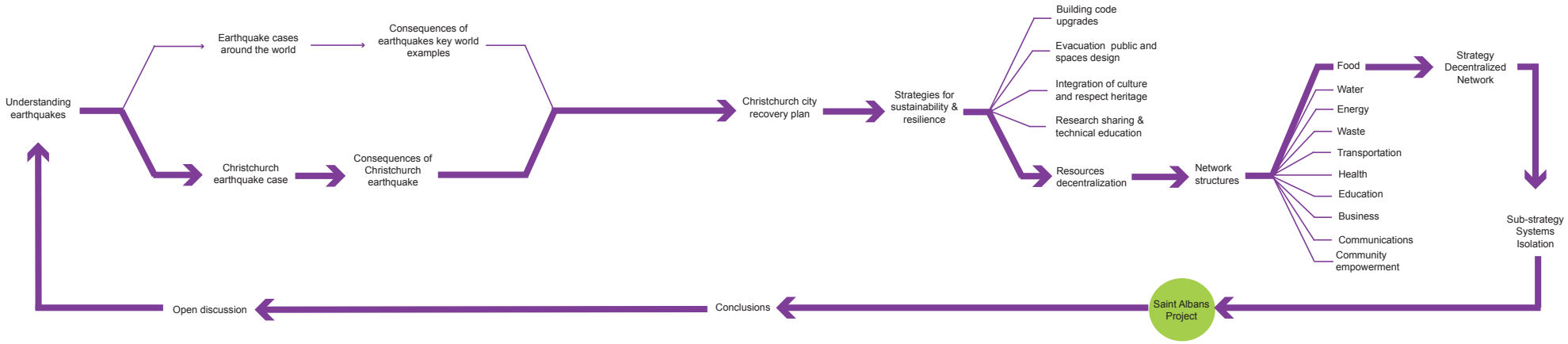
Stand-alone system for sun light efficiency and space saving
Image source: bostongreenfest.org

Furniture design with indoor farming
Image source: washingtonpost.com

Hanging growers with light incorporated
Image source: www.lushome.com

Vertical garden using only PET bottles and soil. Irrigation is manually
Image source: Daniela Gonzalez

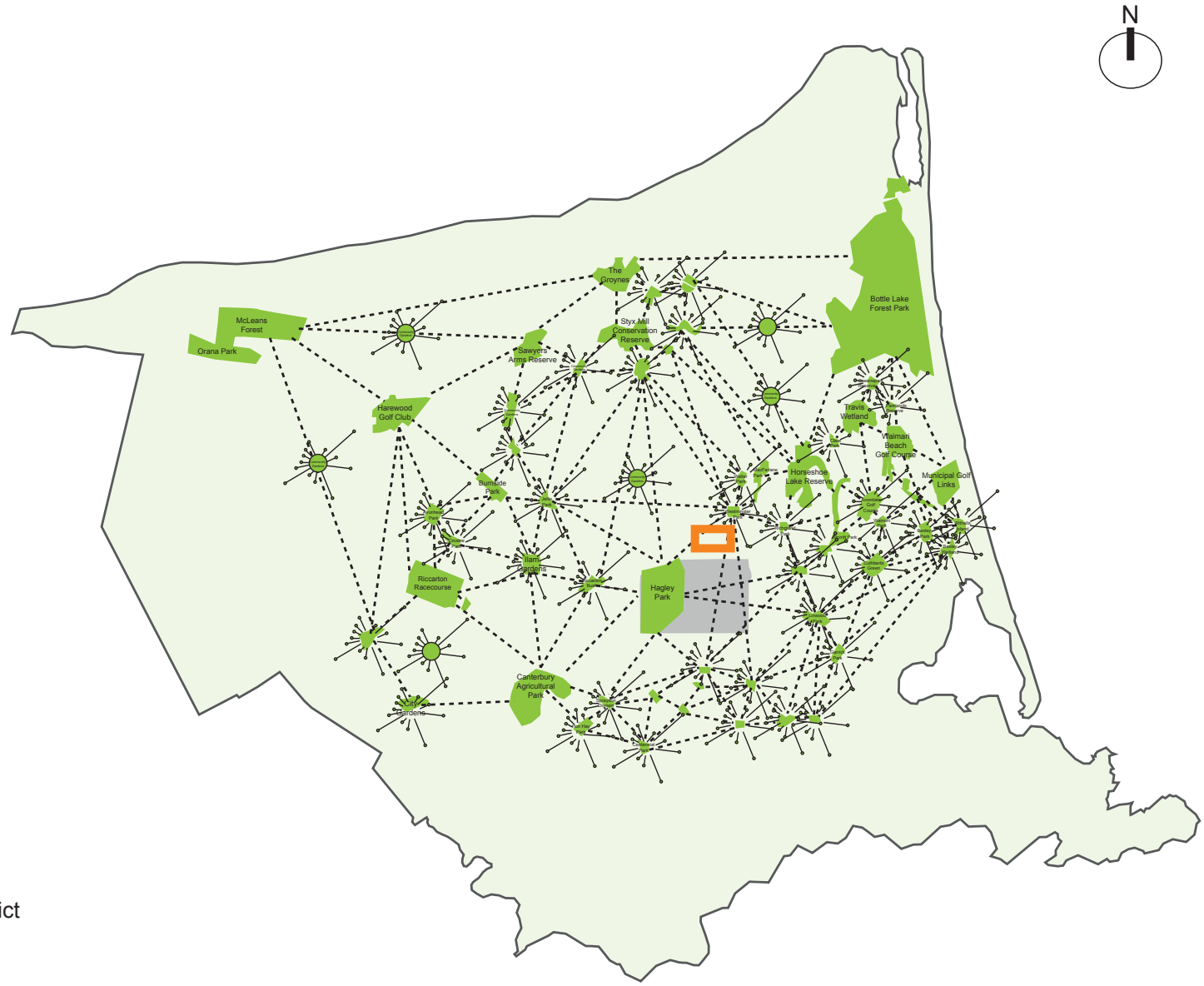
5.3 Saint Albans Project



Food Combined Decentralization System_applied to Christchurch city

The following image shows the map of Christchurch and how it can look with the food combined decentralization network using existing public parks and gardens, community gardens and private residential gardens.

To be consistent with the idea of decentralization I have chosen a working area out of the City center or CBD (Central Business District); a residential block in the neighborhood of Saint Albans.



Symbology

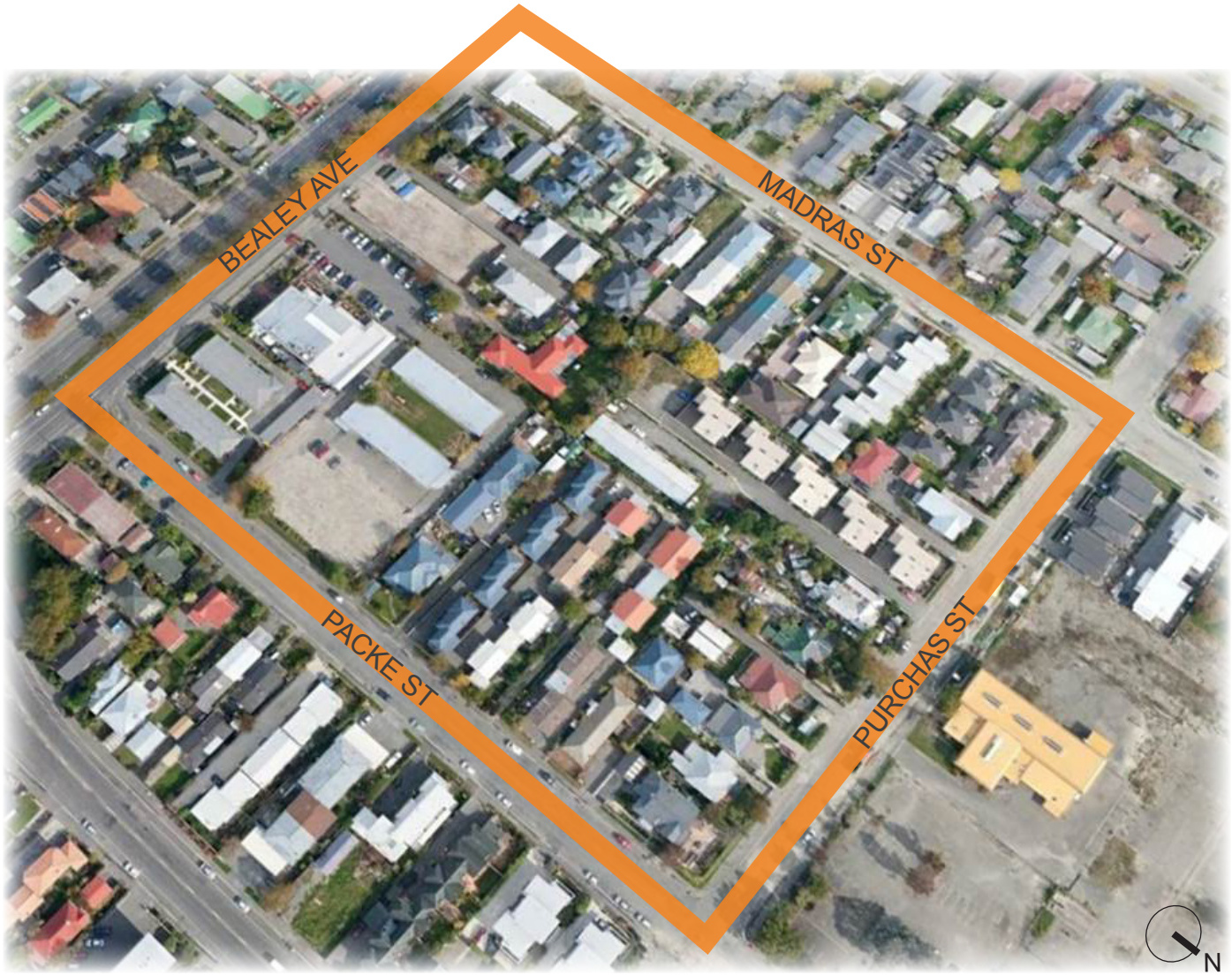
- Public Gardens
- Community Gardens or multi-storey building
- Individual Housing
- Connection
- Christchurch city boundaries
- CBD Christchurch central business district
- Work chosed area in St Albans

Christchurch-Saint Albans Area

Saint Albans is one of the several zones in Christchurch which was badly affected by liquefaction.

Saint Albans block

A common block in the residential neighborhood of Saint Albans, to the north of the city center, was elected to apply the Resources Decentralization in a closer view.

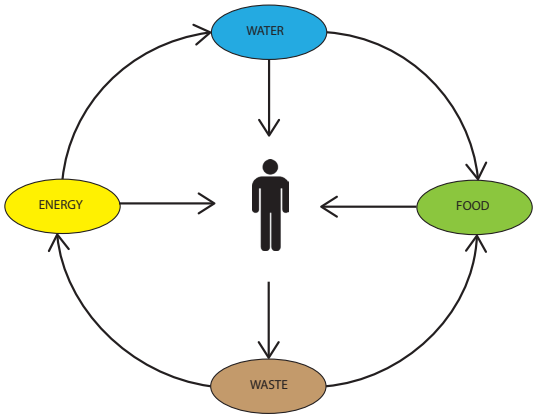


View of a Saint Albans block, the empty sites show demolished properties.
Image source: Google maps

Strategies applied to Saint Albans block

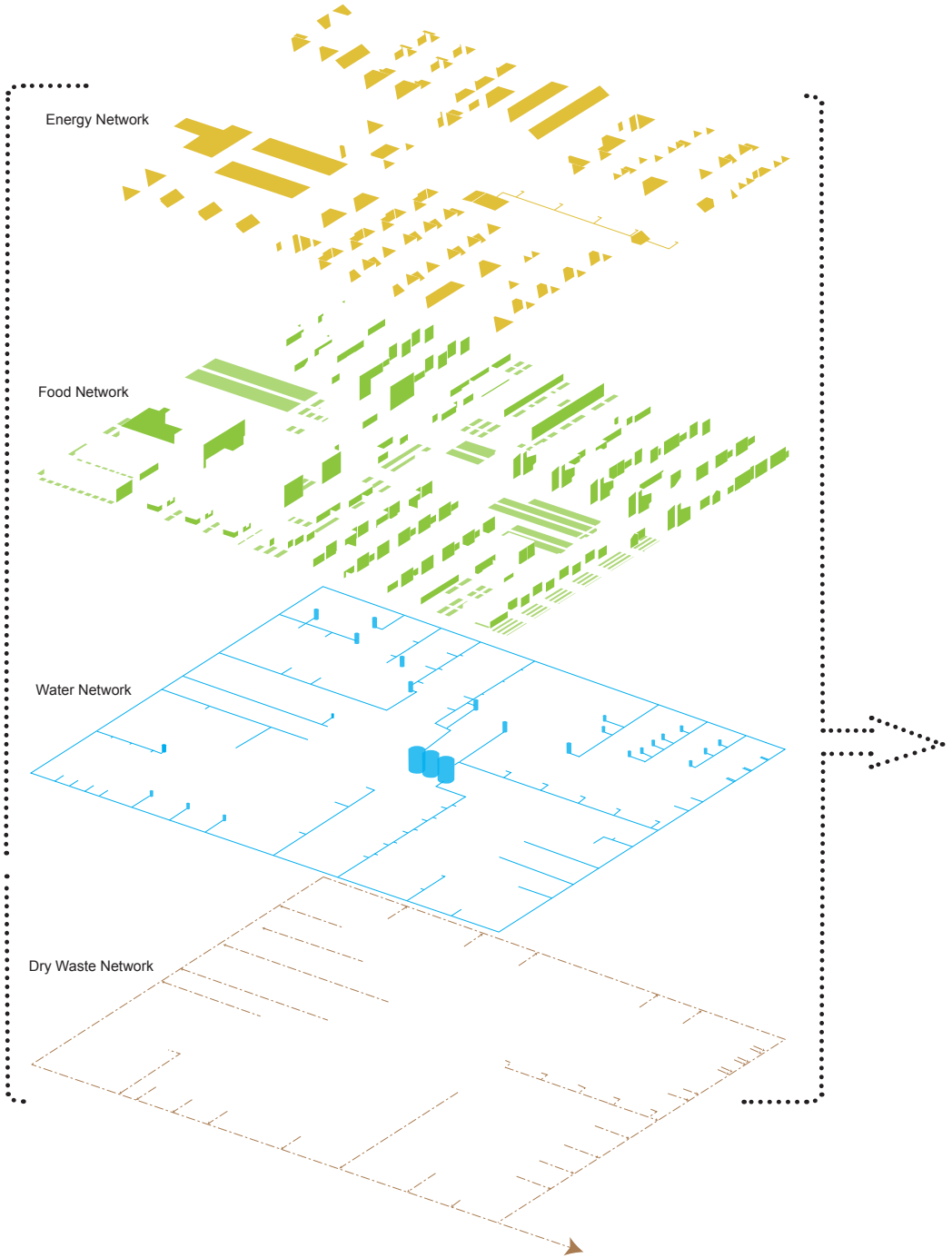
The Resources Decentralization Strategy is applied to the residential block in Saint Albans.

The four most vital resources that were selected previously in this report now are shown in layers. The idea is to understand how they can look in the physical space.

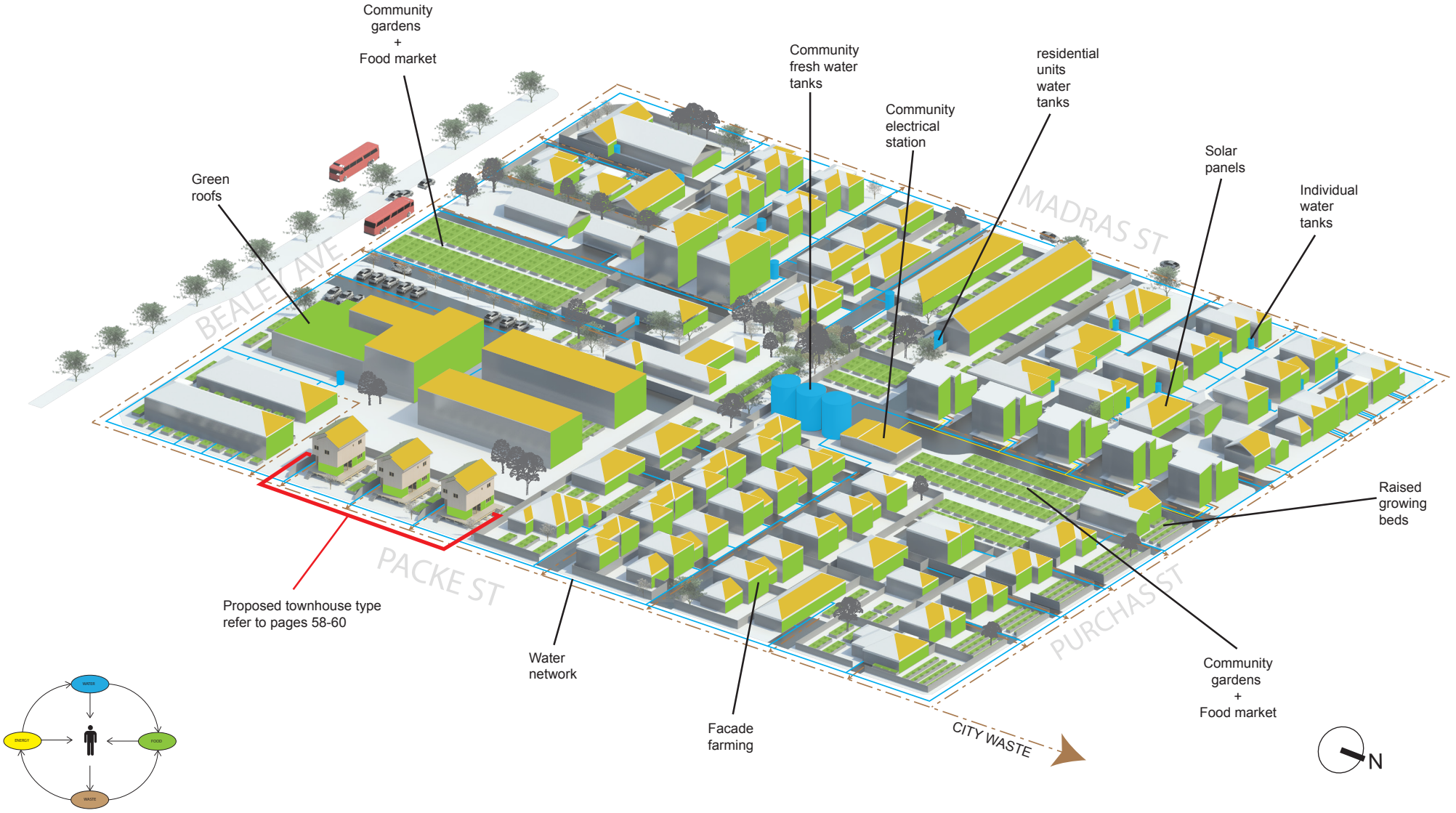


Four resources for human survival

Resources in layers

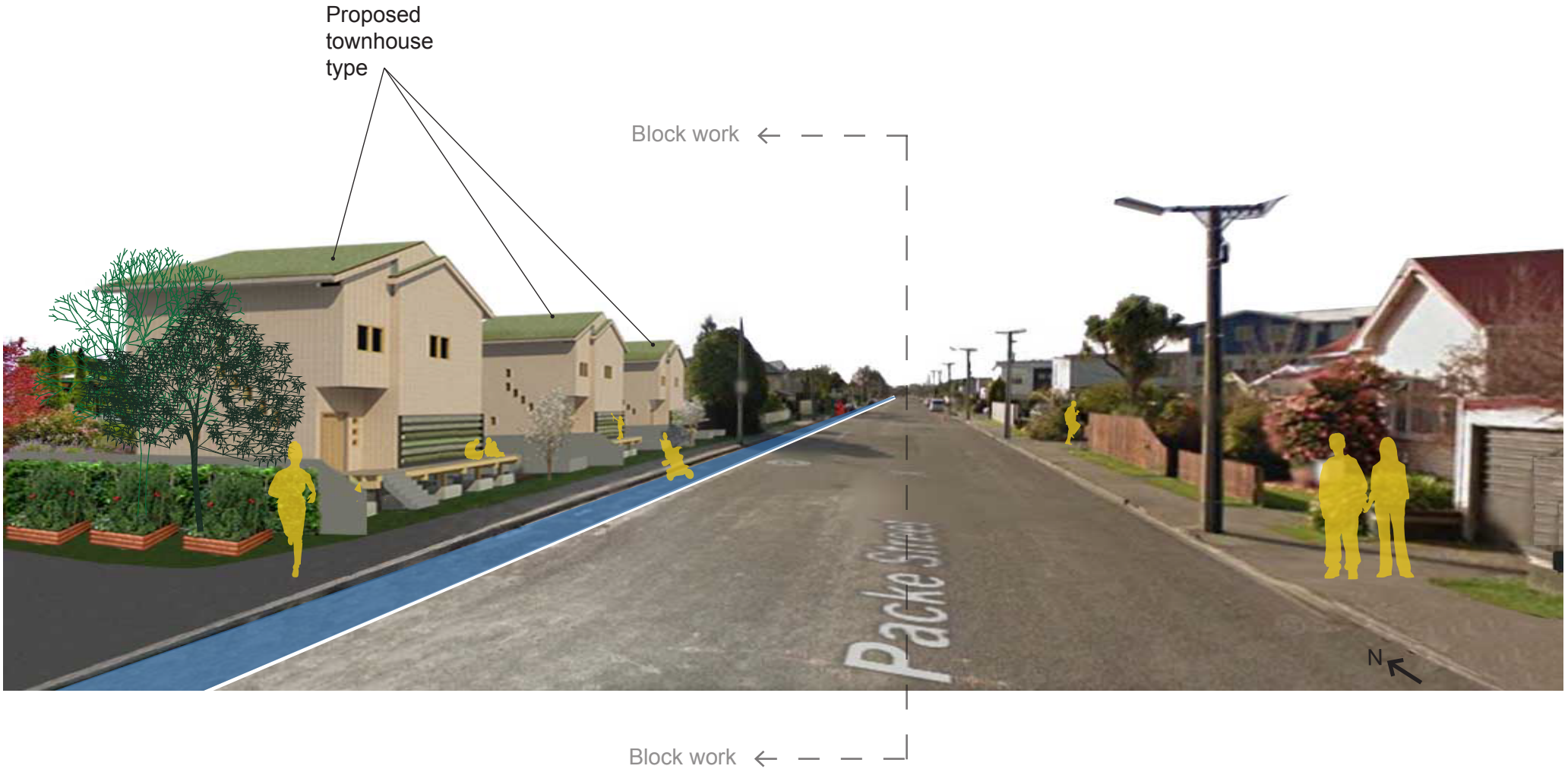


Saint Albans block



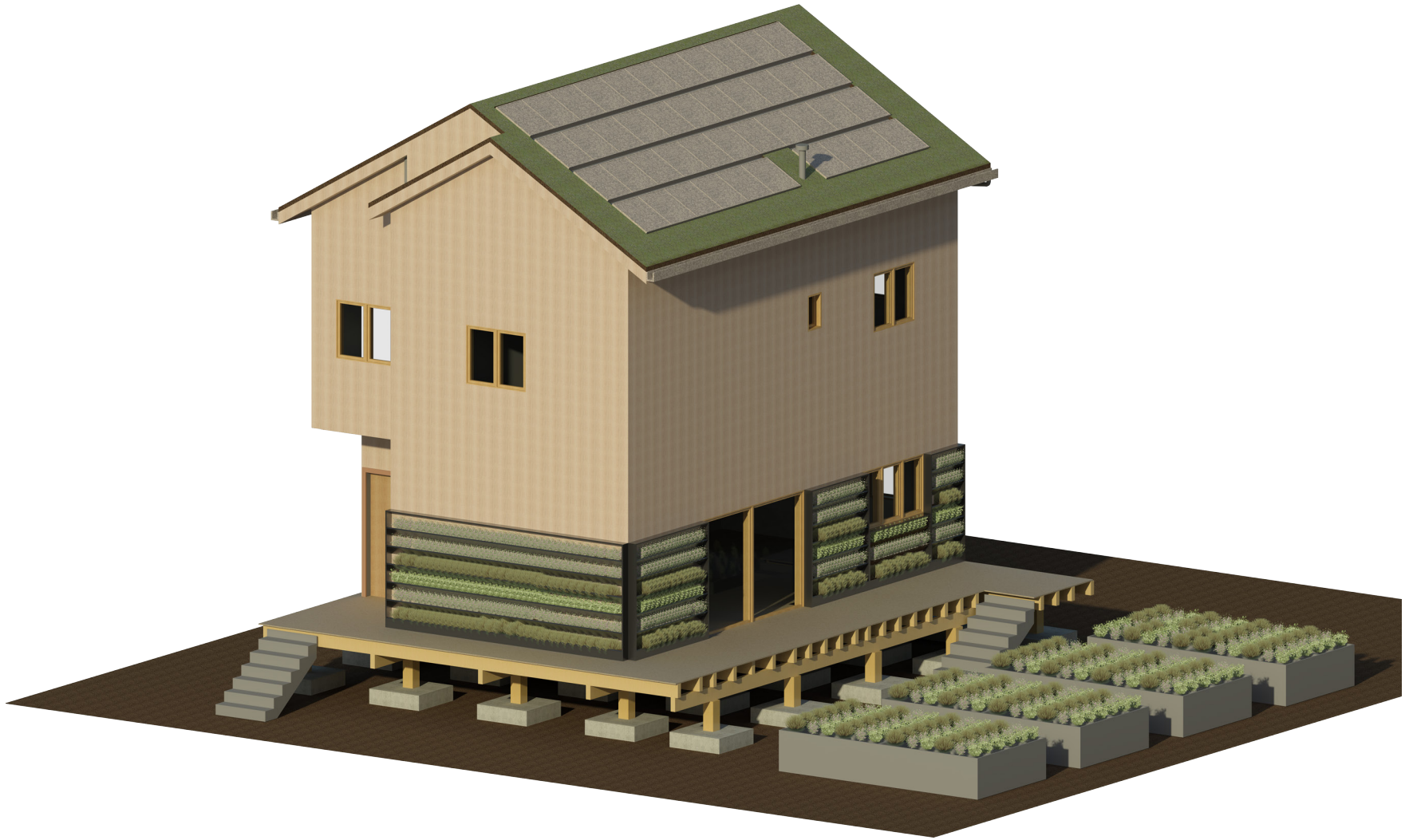
Closed view to the block

The view shows a perspective of the block from Packe Street to the north.



Townhouse type model

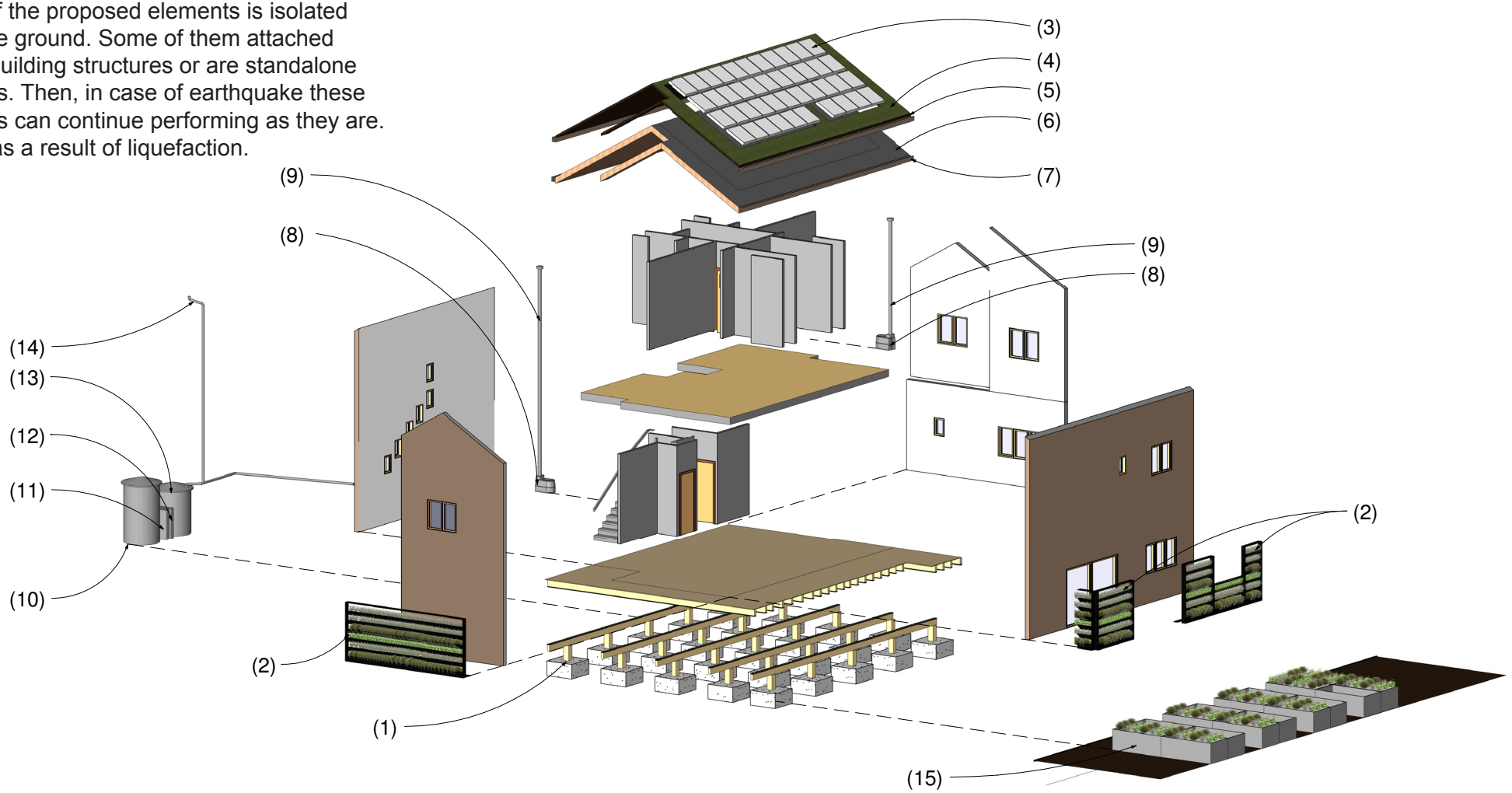
The Sub-strategy Isolated System is applied to the townhose model.



Townhouse Exploded View

Application of mentioned principles

Each of the proposed elements is isolated from the ground. Some of them attached to the building structures or are standalone systems. Then, in case of earthquake these systems can continue performing as they are. Same as a result of liquefaction.



(1) Re-levelable foundation system; if it deforms as a result of liquefaction or other ground movement it gives a good access to the supports for undo connections and pack / replace piles as required to re-level the floor. [MBIE, 2012 & NZ3604]

(2) Facade farming

(3) Solar panels

(4) Green roof

(5) Insolation

(6) Metal cladding

(7) Gutters

(8) Self-contained electric composting toilet

(9) Ventilation

(10) Fresh water tank

(11) Fresh water filter

(12) Gray water filter

(13) Gray water tank

(14) Pipes for rain water collection

(15) Raised growing benches; isolated boxes from ground, to avoid liquefaction contamination.

6. Open Discussion_conclusions

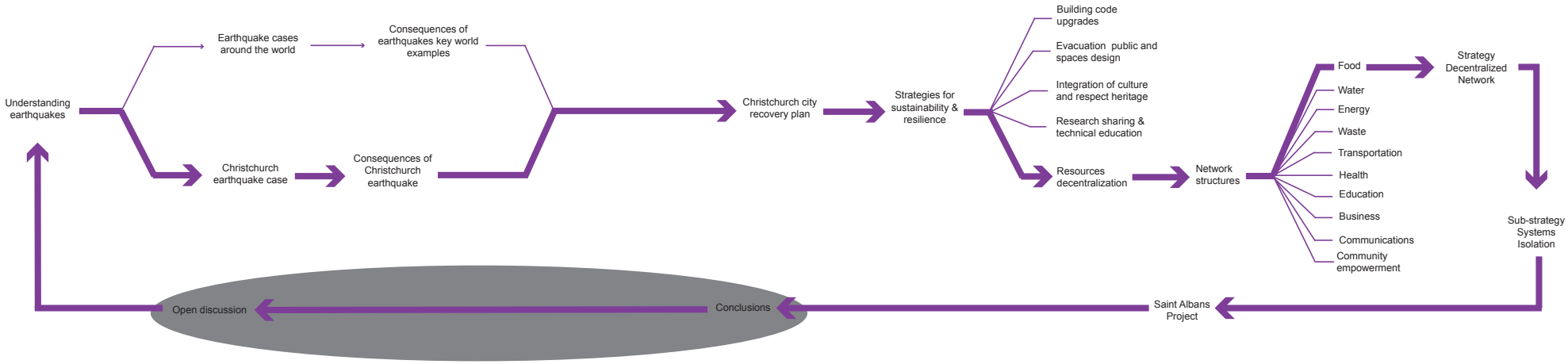


Image source: Carrot City

Research and contribution to the field

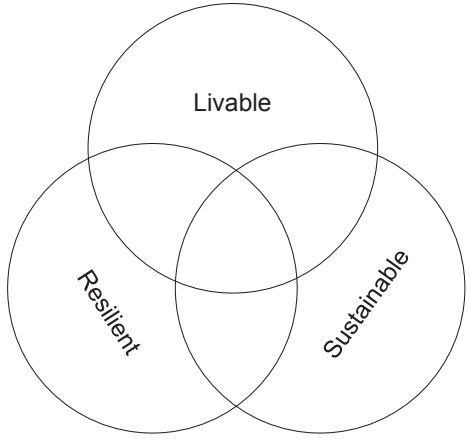
This report provides an overview on the topic of ‘earthquakes’ with their characteristics, also a research of the earthquake’s consequences for people and their settlements to understand in depth the context. As a result of this research, the contribution to the field is the application of strategies more common on urban planning for urban farming as an essential asset for improving life resilience in earthquake situations.

Sustainability meets Resilience

The Earth is composed by several complex systems and those systems are interrelated with each other. What changed in one system will eventually affect other systems. To explain it even simpler, for example, we have humanity as a system and nature as and other system; both linked to each other and a third system called economy that is also interrelated to the others.

Today we are facing several issues related to climate change, resources depletion, landscape contamination and social inequity which are leading to uncertain future situations. Then, the concept of sustainable development comes from the idea to make a balance in those three systems to ‘sustain’ our Earth and provide to the future generations a place to live.

Another concept coming up is called resilience and it can be understood as the capacity to absorb or overcome disturbances at the same time that keeps its basic functions and structure working to meet the needs of the systems. [Walker and Salt, 2006] Consequently our systems must evolve perpetually to achieve subsistence through sustainability. And resilience becomes an important tool supporting sustainable development from these uncertain disruptions.



Urban agriculture as a combined and distributed network with isolated systems

The Earth is shaking constantly and is elastic. Because of this we need system structures that can perform in the same way.

In one hand we have this distributed networks that can keep the functions in different areas no matter where is the disruption. On the other hand we have the isolated systems that are detached from the ground so they can move freely with the earthquake avoiding major damages related to the ground, especially ground ruptures and liquefaction.

Therefore combined distributed network and isolated systems are the resilient key elements to support urban agriculture in seismic areas. And urban agriculture is sustainable because it provides food security, community empowerment and footprint decrease, among other benefits.

But these ideas can go beyond earthquake events; they could be adaptable to other contexts and climate disasters, perhaps could be adaptable to other types of issues, such as social; like overpopulation, greed or resources depletion including peak oil among others.

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