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Integrating resilience and sustainable development prevention of the Cascadia aftermath in Portland

Tesi in:
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9. ENERGY SUPPLY, RENEWABLES

10. PLACARD BEFORE vs AFTER

0. PREAMBLE

The choice of integrating resilience and sustainable development is made in order to enforce the mere concept of sustainability: something that the earth needs with the aim to increase longevity and achieve results in the long run.

What makes it more important is the fact that sustainability comprises a series of strategies that are essential for reaching the resilient status.

In a technical and architectural context, a resilient building is one that can handle sudden shocks or chronic stresses caused by natural hazards, while keeping on working as it would do usually.

Many hazards could hit Oregon, the one that will cause the worst aftermath is the Cascadia shake, also known as “The Big One”.

Because of its great impact, the Cascadia earthquake is taken as the natural hazard that will size the stress test.

As said above, the geologists and scientists forecast a time span during which no service will be available.

Since the object of analysis is a building, the resilience aspects that will be assessed and improved are the ones related to the construction: water supply and energy supply.

The assessment will be made mainly through site analysis, technical data inquiry and the use of a performance-based design software named “Sefaira”.

The latter will also be one of the main tools that will lead to decisions, which combine design and energy-performance.

The general way to proceed is:

1-baseline status assessment;

2-consumption reduction;

3-storage enhancement

The target of the ‘stress test’ is to reach a time span of 7 days of “off-grid” self-sufficiency respectively about water supply and energy supply.

1. RESILIENCE

1.1 RESILIENCE - WHAT IS IT?

According to the studies of Arup International Development: resilience is "the capacity of cities to function, so that people living and working in cities – particularly the poor and vulnerable – survive and thrive no matter what shocks and stresses they encounter (Junmookda, 2015)[1]".

In order to describe how much a system can maintain or regain its functionality in case of any disruption or inconvenience. When chronic stresses or supernatural events suddenly happen, there is the possibility of damaging socially and physically entire areas. Since cities are intricate systems that are constantly getting adjusted to changing conditions, then the idea of city resilience becomes conceptually relevant.

The power dynamics that influence the way cities work and successfully deal with hazards are not necessarily taken into account when it comes to resilience, which represents its conceptual limits.

The traditional disaster risk managements is different from resilience, the first is based on estimations of the amount of risk that specific supernatural events can cause, the second is aware from the fact that a various series of disaster[1]s, either chronic or sudden, can hit the city and are not undoubtedly expected. Hence, it is evident that rather than preventing or mitigating the disadvantages attributable to specific events, resilience focuses on improving the potential of a system to cope in case of various shocks and stresses.

RESILIENCE - WHY CITY RESILIENCE?

During the 21st century it people will move more and more to cities, where their health and prosperity will depend upon a knotty interconnection among information, infrastructure and institutions. There is the need of cities that comprise communities able to face

[1] (Junmookda, City Resilience and the urban nexus, 2015, New York City, ARUP)

all that obstacles a wealthy and secure urban living. Which can be: disease, global warming; terrorism; political controversies; economic aberration; fast urbanization; water, food, energy and housing security, along with other elements.

The system will be composed by an estimation of the risks that can likely happen, combined with the decrease of predictable perils. This then gets along with the consciousness that unforeseeable threats can unleash too.

In order to avoid all the disadvantages that aftershocks carry with them, our cities have to be resilient. In particular, the speedily growing ones in developing countries, should determine which is the development path that improves their safety the most, in the mindset of a future planning.

In case the private or the public sector (like the government, stakeholders, investors, donors or politicians) want to advance more resilient cities, they must gain knowledge about which are the most profitable projects and investments. Consequently they need to comprehend how is a city's administrative web organized, in order to know how their ability to take appropriate action is influenced. Which are the elements that would contribute in a positive way or negative one. Actually it still doesn't exist any common definition of city resilience, or a net that leads the decision making process.

RESILIENCE- THE RESEARCH

The work is based on literature, case studies and cities. This project's goal is to research and create a series of metrics that lead the evaluation of resilience at the area and city scale. Once the level of resilience will be measured, such a research aspires to give urban planners, investors, goverments and so forth, a track to follow in order to provide a higher level of safety in communities, especially in the ones that struggle the most against stresses on all point of view.

SOURCE: LITERATURE

Approachesl Resilience is such a broad concept that there have been many different approaches in order to evaluate it. Two of them

can be the assed-based one and the system-based one. The first is mainly focused on physical evaluations, the second tends to be similar to the concept of resilience, as well as the view of ‘systems of a systems’.

Urban planning can influence social systems that can determine human behavior, which (as a domino effect) can be determined by other kinds of systems like the physical one. There are plenty of approaches that could be applied to assess resilience.

From the literature source is deductible that said approaches consider through different points of view the continuity of essential services, the requirement of critical facilities, the natural environment, the manner used for communities’ management and the human knowledge and behavior.

On account of the fact that empirical evidence suggests that urban systems that exhibit particular qualities or characteristics are more likely to be resilient, the “City Resilience Framework” summarizes the seven qualities of a resilient community. They can be applied at different scales, from the city to the individual one.

At this point there is the necessity of a scheme that interrelates and combines all the characteristics of a city. It should look at the city/community on different perspective, like the human, the economic, the administrating and the environmental one. It should also assess the city/community about physical aspects, like infrastructures, and less concrete aspects, like the citizens education. Eventually it has to take into account all the peculiarities that describe a resilient city or system.

SOURCE: CASE STUDIES

Functions and failure lA more inclusive approach would be a performance-based one, which defines resilience in terms of a city’s ability to fulfill and preserve its core functions. As case studies demonstrate, a city’s functions rely on a combination of assets, systems, practices and actions undertake by multiple actors, a performance-based approach has a greater potential to address questions of scale, power dynamics and interdependency.

Then the Arup International Development's study proposed that urban resilience could be described in relation to seven essential functions of a city.

They collected information from a study of over 100 case studies about cities that experienced natural disasters along with together with recent guidance or urban resilience. According to the research, the result of this analysis produced a refined list of 8 city functions that are critical to resilience. "The functions proposed that a resilient city: safeguards human life; protects; delivers basic needs; maintains and enhances assets; facilitates human relationships and identity; promotes knowledge; defends the rule of law, justice and equity; stimulates economic prosperity and supports livelihoods. The city's ability to perform these functions determines whether the city is resilient or not. This quality can be perceived as good health, a safety, social harmony and prosperity. Conversely, a city that is not resilient would be identified by ill-health or insecurity, conflict, and an unsafe environment. (ARUP, 2015)[2]"

SOURCE: CITIES

Fieldwork I For my study I looked more closely to the cities that experience natural hazards which are similar to the ones which could most likely happen in Portland (object of analysis) which are: earthquake, drought, hurricane and flood. Such cities were: Surat, India; Conception, Chile, New[2] Orleans, USA , it was useful in order to familiarize how is the aftershock of such disasters and how the cities did react. Moreover the fact that such cities are located in different areas enhance the possibility to better understand all the possible Portland's aftershock scenarios, hence which would be the factors that would contribute to face such events, granting resilience.

[2] (ARUP, City Resilience Index, 2015, New York City, The Rockefeller Foundation)

1.2 CITY RESILIENCE FRAMEWORK – QUALITIES OF THE SYSTEM OF EVALUATION

According to the studies made through the sources listed above and thanks to the fieldwork of Mercy Corps; GIP Pacifico and Findeter; TARU Leading Edge; Fundaciòn Alto Rìo; City of New Orleans and the American Red Cross Southeast Louisiana Chapter; and Arup Cape Town the City Resilient Framework document highlights seven qualities of a resilient system.

Reflective

Reflective systems are the ones that use studies and investigations of what happened in the past, as tools that shape planning guidelines and laws, instead of trying to find a everlasting solution based on the existing state of affairs.

Such systems recognize that the world changes continuously and certain events are not specifically predictable.

Robust

When systems are robust, they don't just rely on a valuable thing or a planning norm in order to inform future decision-making. Robust systems make sure that they are able to cope disasters without collapsing and/or a huge depletion of function.

Redundant

Redundant systems are the ones that acknowledge that a natural hazard may hit the city/community at any moment, hence, they are designed in order to face emergencies and sudden needs of various kinds. They should present a network of infrastructures like water pipes and electricity cable as well as infrastructure reserves that help in case of a temporary absence. Such infrastructures need to be planned in advance, energy and cost efficient,

Flexible

As circumstances can steadily change, flexible systems will develop along so that they can respond to the new scenario. Integrating traditional knowledge with new technologies could help

to achieve flexible systems. Moreover the urban planning should prefer polycentric approaches rather than one-centered ones.

Resourceful

Resourceful systems plan in advance all the elements needed to help communities to satisfy their essential needs in case of chronic stresses or during an aftershock. They include the capacity to anticipate future conditions and the creation of a network of sources and services that are available when needed and that can grant that life in the community still goes on in a decent way even after natural disasters.

Inclusive

As the adjective indicates, inclusive systems are the ones that include. More specifically they include an active engagement with the community without anyone left out, otherwise the systems wouldn't be inclusive and even less resilient. It commits to a joint vision of building city resilience or to a sense of shared property.

Integrated

Systems have to be integrated on various points of view. The integration of information help the system to work efficiently at a community scale and to respond rapidly through smaller feedback loops throughout the city. The integration of investments, of policy and decision making, increase the possibilities to get a better community result.

At this point, the aim is to use certain sources that would lead me to a series of indicators that concern Portland as well as Cities in general, taking one of them and evaluate it. Through this it will then be created an evaluating process that could be applied to all the indicators that matter.

Basing on the study of the CITY RESILIENCE FRAMEWORK:

The Arup association with support from the Rockefeller Foundation, realized a research project entitled: The City Resilience Index (CRI), it represents the first sketch from where to beginning the development of a city resilience framework and consequently the beginning of the selection of the aspects that need to be treated.

Every city is unique. The way resilience manifests itself plays out differently in different places. The City Resilience Framework provides a sort of metric system through which the aspects and level of cities' resilience can be estimated. It consists in 12 key indicators that describe the fundamental attributes of a resilient city.

"A resilient city is a city where there is or are the following twelve aspects:

1 Minimal human vulnerability

Indicated by the extent to which everyone's basic needs are met.

2 Diverse livelihoods and employment

Facilitated by access to finance, ability to accrue savings, skills training, business support and social welfare.

3 Adequate safeguards to human life and

health. Relying on integrated health facilities and services, and responsive emergency services.

4 Collective identity and mutual support

Observed as active community engagement, strong social networks and social integration.

5 Social stability and security

Including law enforcement, crime prevention, justice, and emergency management.

6 Availability of financial resources and contingency funds

Observed as sound financial management, diverse revenue streams, the ability to attract business investment, adequate investment, and emergency funds.

7 Reduced physical exposure and vulnerability

Indicated by environmental stewardship; appropriate infrastructure; effective land use planning; and enforcement of planning regulations.

8 Continuity of critical services

Indicated by diverse provision and active management; maintenance of ecosystems and infrastructure; and contingency planning

9 Reliable communications and mobility

Represented by various and affordable possibilities of communication, transportation and information networks, and emergency planning.

10 Effective leadership and management

Involving government, business and civil society, and indicated by trusted individuals; multi-stakeholder consultation; and evidence-based decision-making.

11 Empowered stakeholders

Indicated by education for all, and access to up-to-date information and knowledge enable people and organizations to take appropriate action.

12 Integrated development planning

Indicated by the presence of a city vision; an integrated develop[3]ment strategy; and plans that are regularly reviewed and updated by cross departmental working groups (ARUP, 2015) [3]"

[3] (ARUP, City Resilience Index, 2015, New York City, The Rockefeller Foundation)

CITY RESILIENCE FRAMEWORK – LAYERS OF EVALUATION

Yet, accordingly to the City Resilience Framework research, the Framework has a hierarchy: it is composed from categories, that fall into twelve indicators which are specified into qualities, all of these layers aim to grant a greater articulation of resilience.

Categories

Are the four perspectives of a city: the health and wellbeing of individuals; infrastructure & environment; economy and society; and, finally, leadership and strategy.

Indicators

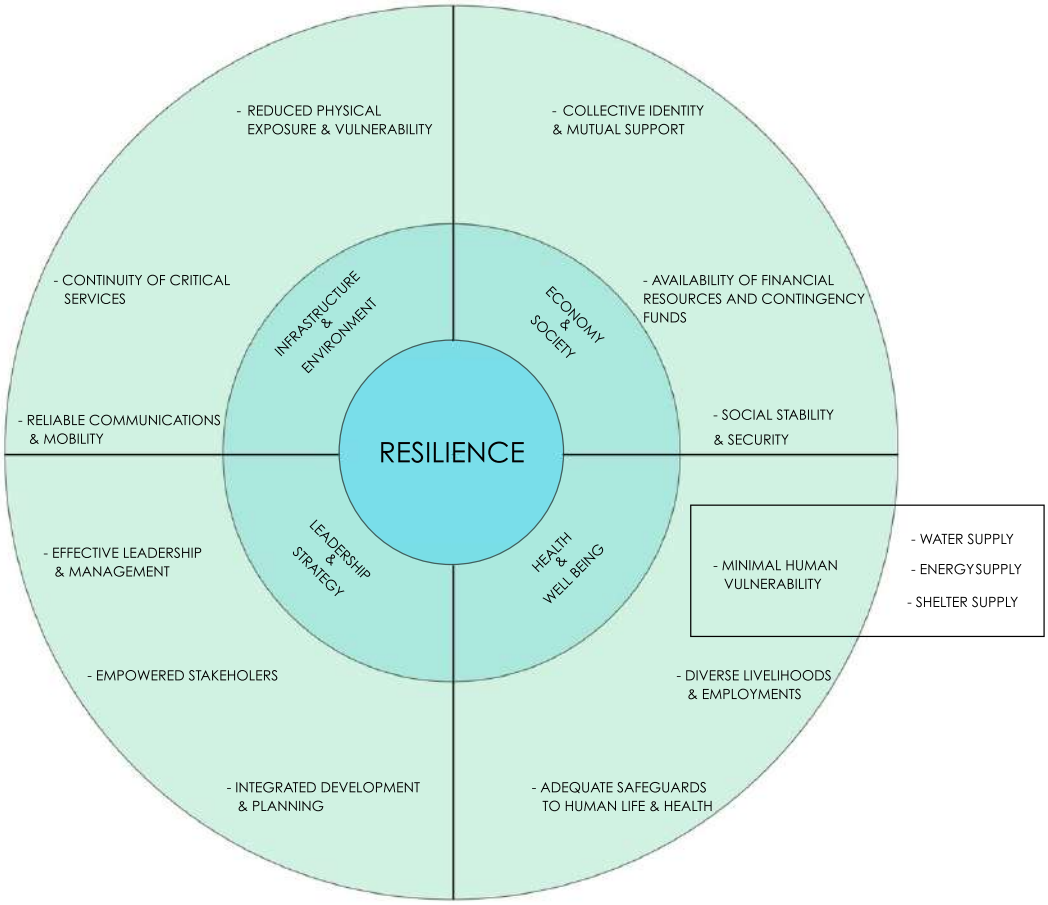
They are 12 indicators which illustrate the result of operations needed to create a resilient community, rather than the operation themselves. This highlights that resilience is not achieved with isolated interventions and in isolated contexts, but is the outcome of various actions, taken by different subjects in different areas.

Qualities

Qualities represent a more specific layer of communities' resilience assessment. It is the most precise because it actually distinguishes the difference from a community which is just livable, sustainable or prosperous, from one which is specifically resilient.

The framework shows the aspect of a city/community that have to be analyzed and observed in order to make it Resilient. At this point what is missing from the City Resilience Framework study, is a process of evaluating the qualities in order to carry out an accurate assessment that will be used as a guideline during the planning for improving the city's/community's safety.

In order to know how to grade all the metrics, it could be useful gaining knowledge from past experiences.


- REDUCED PHYSICAL EXPOSURE & VULNERABILITY
- COLLECTIVE IDENTITY & MUTUAL SUPPORT
- CONTINUITY OF CRITICAL SERVICES
- AVAILABILITY OF FINANCIAL RESOURCES AND CONTINGENCY FUNDS
INFRASTRUCTURE & ENVIRONMENT
ECONOMY & SOCIETY
- RELIABLE COMMUNICATIONS & MOBILITY
RESILIENCE
- SOCIAL STABILITY & SECURITY
- EFFECTIVE LEADERSHIP & MANAGEMENT
LEADERSHIP & STRATEGY
HEALTH & WELL BEING
- MINIMAL HUMAN VULNERABILITY
- WATER SUPPLY
- ENERGY SUPPLY
- SHELTER SUPPLY
- EMPOWERED STAKEHOLERS
- DIVERSE LIVELIHOODS & EMPLOYMENTS
- INTEGRATED DEVELOPMENT & PLANNING
- ADEQUATE SAFEGUARDS TO HUMAN LIFE & HEALTH

CITY RESILIENCE FRAMEWORK – RECOGNIZING THE TARGET

After identifying the natural hazards that will most likely happen in Portland, the case studies of cities with a similar exposure to natural disaster have been selected. The source of the studies comes from *City Resilience Index, Research Report Volume 1, Desk Study* made on April 2014.

SURAT, INDIA

BUILDING CROSS-SECTORIAL LEADERSHIP FOR DISASTERS

Hazard: flood

Even thought Surat is a prosperous city in India, as it is also the fastest growing one, it needs many efforts to satisfy the increasing demand of infrastructures and services.

Lately it has experienced various hazards like social unrest, outbreak, pneumonic plague and flood. This has greatly influenced the city's successful efforts to enhance resilience.

The city is well-known for its flooding challenges. Anyway, twenty years ago, a chain reaction following a flood permanently changed Surat's approach to flood management. It is reasoned that after the flood in 1994, poor sanitation in vulnerable communities have caused an outbreak of pneumonic plague.

While the number of suspected cases was limited, the unexpected nature and fear of a relatively unknown disease caused panic, which started locally but quickly spread nationally and internationally.

After this natural disaster, a municipal commissioner was put in place to lead the city back to normality and rebuild trust internally and externally. Improved infrastructure, such as sewerage, stormwater drainage and flood management to reduce the chances of a recurrence were strongly needed. Moreover the flood increased awareness of public health generally and the wellbeing of the workforce to contribute to economic prosperity.

With the aim of anticipate and respond to a disaster, various measures of prevention were put in places from the local government. For instance there have been made controls at the household level and there were built health clinics that provide help, in areas that are more likely to be hit from such disease.

Restoring trust in the security of Surat after the disaster, was a process which took more time than the one to rebuilt the city and to cope the pneumonic plague.

This absence of trust delayed residents from going back to the city and impacted heavily on business community.

Since the flood happened the local government, led by the Chamber of Commerce, encourages a planning for disasters ahead, which is made from a skilled group, as well as being prepared in case interventions on site are needed during and after the shock/stress. Also the business community takes care about its population education and knowledge about this topic.

CONCEPCION, CHILE

ADDRESSING SEISMIC RISK BEYOND BUILDING CODES

Hazard: Earthquake

Due to the presence and enforcement of building codes in Chile, after the strong 8.8 earthquake hit Conception's metropolitan area on February 27th 2010, luckily the number of dead people wasn't big as it usually is during earthquakes of such magnitude. Also homes and buildings did not experienced collapse, but reasonable levels of damage.

Instead, essential services such as electricity, water and sewerage networks, were destroyed and the transport faced a dead end.

What was unexpected was the almost total breakdown of communication networks: internet, telephone and radio.

(Emergency drill at Conceptiòn Municipality)

There was an absolute sense of unsafety which lead to panic, snatches and apprehension. Radio Bio Bio, thanks to its continuous maintenance, planning and back up system, was the only communication network which worked at that time. People were provided with updates about what was happening, the evolution of the situation and also they were able to communicate among each other. Thanks to this Concepciòn's citizens gained some consolation and social stability.

After the arrival of the military and the imposition of a curfew that was welcomed by the population, finally the order was gradually restored.

Concepciòn learned from what causes struggle the most: the absence of reliable communication infrastructure and the levels of social instability during the aftershock.

Similarly to the experience in Surat (India) the situation in Concepción after the earthquake demonstrates that it recovering the human and social impacts can take way longer than restoring buildings, streets and all that is material.

NEW ORLEANS, USA

Hazard: hurricane

In 2005 and in 2010 New Orleans experienced two disasters which happened near by the Gulf of Mexico and Lake Pontchartrain. The first is Hurricane Katrina and the second is the BP oil spill. Both damaged water resources people rely on for their jobs in the fishing and food processing industries.

The Vietnamese community in the neighborhood of Versailles is close to open water, therefore the hurricane and the oil spill did really damage the community. What is relevant in the study is the importance of community engagement.

The hurricane Katrina affected enormously and negatively the community: it either wrecked and damaged business buildings and residencies, including any structure in the open water, near hospitals and schools which had to close for good and it even destroyed water and electricity infrastructure.

The Catholic priest of the local church Mary Queen of Vietnam, along with numerous community leaders stimulated evacuated residents to come back to the community a few weeks after Katrina, noticing that the Government wasn't able to provide all the resources for the recovery as soon as they were needed. Consequently, it was the community that rebuilt on its own social and physical structures. Thanks to the community's strength of beginning again and to an efficient leader (the priest) it was promoted the importance of community engagement, also this episode reminded residents of their language (Vietnamese), their cultural legacy, their collective identity and of their common religion. As several elements were missing, community residents were encouraged to build and restore their homes bartering their skills among each other. For example the plumber will help rebuild water pipes and connections to the water basin and infrastructure of the bricklayer who will build or reinforce the plumber's home.

Following this wave, the MQVN CDC (Mary Queen of Vietnam Community Development Corporation) was founded in 2006 aiming to help the community residents to restore their homes, businesses and over the top lives after the Hurricane. This corporation still exists, giving the community the capacity to accommodate disruptions, extreme pressures or surges in demand. It also

provides local residents with multiple ways to achieve a particular necessity or fulfill a certain function, teaching alternative jobs.

When in 2010 the BP oil spill happened, it damaged the water local fisherman did rely on for their livelihoods. The MQVN CDC provided them different ways to get income, like teaching gardening or aquaculture.

From this case is evident how much community engagement and cooperation represents a resilient factor.

2. THE THREAT AND ITS AFTERMATH

2.1 THE STATE OF OREGON - EXPOSURE

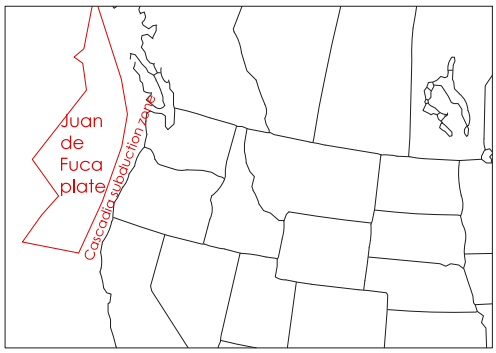
The state of Oregon could be harmed by various threats. The ones that more likely are going to hit it are: tornadoes, draught, flood and earthquake.

The latter is taken as the natural hazard that the building object of analysis will have to face.

This choice is dictated by Oregon's geology history.

Most people in the United States know just one fault line by its name: the San Andreas fault, which runs nearly the length of California and is perpetually rumored to unleash "The Big One". Such information is inaccurate, no matter what the San Andreas ever does. Every fault line has an upper limit to its potency, determined by its size (length and width) and by how far it can slip.

One of the most extensively and deeply studied fault in the word is the San Andreas one, that has upper limit of about an 8.2 – this means that it could unleash a powerful earthquake, but since the Richter scale is logarithmic, an 8.2 value is just 6% as strong as it was the 9 magnitude scale quake which happened in Japan in 2011.



Just north of the San Andreas, however, lies another fault line. Known as the Cascadia subduction zone, it runs for seven hundred miles off the coast of the Pacific Northwest, beginning near Cape Mendocino, California, continuing following up the coast to Oregon and Washington, and terminating around Vancouver Island, Canada. The "Cascadia" part of its name comes from the Cascade Range, a chain of volcanic mountains that follow the same course a

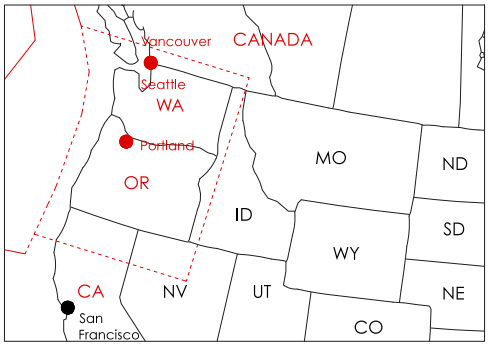
hundred or so miles inland. The “subduction zone” part refers to a region of the planet where one tectonic plate is sliding underneath another, translated is the phenomenon of subduction. Tectonic plates are those slabs of mantle and crust that, throughout the past ages did rearrange the earth’s continents’ and oceans’ shapes. Most of the time, their movement is slow, harmless, and all but undetectable. Occasionally, at the borders where they meet, it is not, that’s when earthquakes happen.

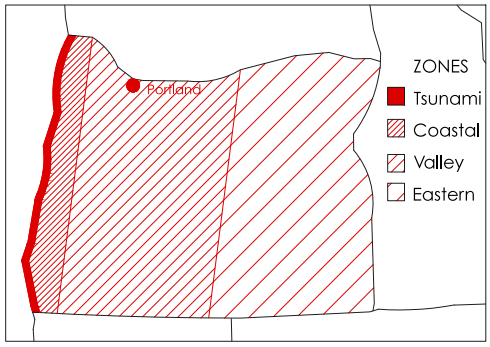
“A good attempt in order to understand the dynamics of Cascadia, is to reproduce it with hands. Take yours and hold them palms down, middle fingertips touching. Imagine that the right hand is the North American tectonic plat, which holds the entire Continent load, from the East to the West coast. The left hand represents an oceanic plate, named Juan de Fuca, that is more than 233 square kilometers wide. These meet at the Cascadia subduction zone. Now slide your left hand under your right one. This is the same way the Juan de Fuca plate moves: falling firmly beneath North America’s one. When you try it, your right hand will slide up your left arm, as if you were pushing up your sleeve. That is what North America is not doing. It is tightly wedged un stuck against the surface of the other plate.(Schulz, 2015)[4]”

It could keep going like this for a while, since, as continent stuff goes, it is young, made of rock that is still relatively elastic. (Like human beings, rocks get stiffer as they age). Nonetheless it cannot keep on going like this forever. Indeed there is a limit: the craton, also known as the nucleus of the earth. The magnitude of the predicted earthquake depends upon how much surface of the Cascadia subduction zone collapses. In case it breaks only its southern part the resulting magnitude value span will be between 8.0 and 8.6. In case instead the entire subduction zone collapses, the resulting magnitude’s value span will be among 8.7 and 9.2. The first is “The Big One”, the second is the very “Big One”.

Flick your right fingers outward, forcefully, so that your hand flattens back down again. When the very “Big One” quake will unleash, the northwest edge of the continent, from British Columbia (in Canada) to California State (in the United States), will sink down as much as two meters and bounce ten to thirty-three meters to the west, losing, within minutes, all the elevation and compression it has gained over centuries. A portion of such movement will happen beneath the Pacific ocean, causing the displacement of colossal quantity of seawater. (Watch what your fingertips do when you flatten your hand.)

Water will outpour upward into a huge hill, then promptly collapse. One side will rush west, toward Japan. The other instead will slide eastbound, in a twelve-hundred-kilometer liquid wall that will reach the Northwest coast, on average, fifteen minutes after the earthquake begins. When the tsunami will recede and the shake





will stop, the West Coast will have a totally different aspect.

“In the Pacific Northwest, the area of impact will cover some hundred and forty thousand square miles, including Seattle, Tacoma, Portland, Eugene, Salem (the capital city of Oregon), Olympia (the capital of Washington), and some seven million people. When the next full-margin rupture happens, that region will suffer the worst natural disaster in the history of North America. Roughly three thousand people died in San Francisco’s 1906 earthquake. Almost two thousand died in Hurricane Katrina. Almost three hundred died in Hurricane Sandy. FEMA projects that nearly thirteen thousand people will die in the Cascadia earthquake and tsunami. Another twenty-seven thousand will be injured, and the agency expects that it will need to provide shelter for a million displaced people, and food and water for another two and a half million. (Schulz, 2015)[5]” “ This is one time that I’m hoping all the science is wrong, and it won’t happen for another thousand years (Murphy, 2015)”

Think of Oregon geology as a clock, measuring time in earthquakes. During the last 10 000 years, forty considerable earthquakes unleashed on the coast.

Doing some simple math, on average a dominant shake happens every 243 years in this area. The last one was on January 26th, 1700, that is 314 years ago.

Right. We’re overdue.

THE STATE OF OREGON - RECCOMENDATIONS

If Cascadia shake uncorks to its highest magnitude, it will cause the worst natural disaster in the United States' history. As a consequence people could take action, either as individuals, families and communities.

Being prepared for the threat would determine whether we will be able to find our loved ones or not; whether sleeping inside a little damaged home or on a bunk in a refugee center; whether going hungry and thirsty for days or managing until supplies arrive. And, eventually: whether living or dying. In the Pacific Northwest, being prepared for the threat and its aftermath would signify the difference among bouncing back in years or not bouncing back for decades.

THE STATE OF OREGON – AFTERMATH

The devastation provoked by the quake in Japan during 2011 was the result of the size of the gap between what the best scientific analysis and research predicted and the country's preparation level against the risk was. It is possible that the same situation will happen when Cascadia will unleash, with the difference that the gap between science and preparedness is way bigger.

Chris Goldfinger, a professor at Oregon State University0s College of Earth, Ocean and Atmospheric Sciences, says that the scientific part of this event is funny, and that he loves studying it. Anyways the discrepancy among what we know and what we should do is increasing. There is an urgent need to take action, otherwise the threat will destroy the Pacific North West. Mentioning the professor:

"I've been through one of these massive earthquakes in the most seismically prepared nation on earth. If that was Portland, let's just say I would rather not be here. (Schulz, 2015)[6]"

OSSPAC (Oregon seismic safety policy advisor commission) also known as the earthquale commission, started developing a plan about the Cascadia's scenario, searching for Oregon's infrastructure and risks and estimating the impacts.

"[B]usiness as usual " said plan shows that the aftermath is a future that could consist of decades of economic and population decline, actually turning into a "lost generation" that will hammer the State of Oregon's regional and national economy.

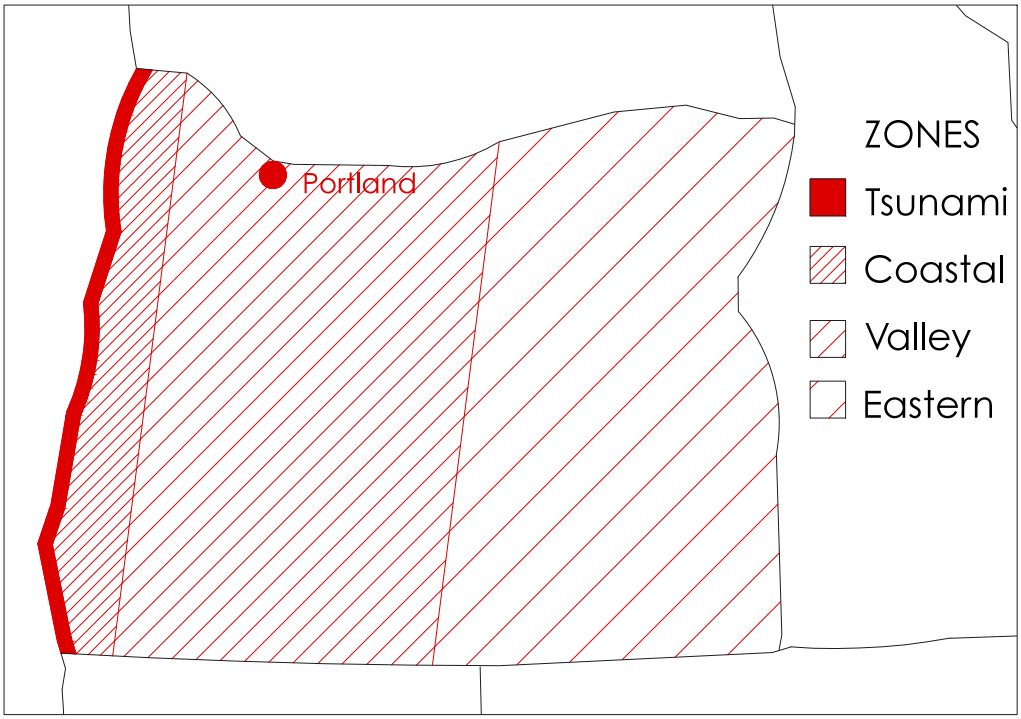
According to OSSPAC, the State of Oregon is divided into four impact zones for the Magnitude nine quake:

-Tsunami;

-Coastal;

-Valley;

-Eastern



Damage will be extreme in the Tsunami zone, heavy in the coastal one, moderate in the Valley and light in the Eastern zone.

THE STATE OF OREGON - PORTLAND

The largest city of the State of Oregon is Portland. It is as well a seaport and the seat of Multinomah County. The city covers 380 square kilometers and has an estimated population of 632,309 (assessment made in 2015), making it the 26th most populated city in the United States of America.

When The Big One will hit the city, Hillsides will slide. Buildings will collapse. Roads will buckle. High-rises will sway. Bridges will crack. Some will fall. Pipes will snap.

More specifically:

-I-5 bridges, highways, and railroad lines may not be passable.

-Only one Port of Portland Terminal (6) has been seismically retrofitted.

- Portland International Airport is located on a ground that could easily melt provoking liquefaction during an earthquake.

- FEMA's primary emergency response airport is in Redmond, 242 kilometers away.

"we're on the cutting edge" says Alice Busch of the Multinomah county's human services department. "We're encouraging people to be self-reliant."

Because of the entity of the disaster, the usually recommended 72 hours of self –sufficiency are not enough anymore. OSSPAC suggests an autonomy of 1 week.

After that time receiving help will be easier.

The thesis work aims to connect resilience with sustainability. Making my self contribute to the resilience of the community. As written above, resilience could be possible through the interventions of various members: stakeholders, politicians, educators, engineers and so forth.

As an architecture student, I believe that my role is to take care of the Human vulnerability indicator, more specifically about the sub-indicators that are related to:

- Shelter supply
- Water supply
- Energy supply

One building is taken as object of analysis and design in order to create a general system that could work for all the buildings of the various communities.

2.2 THE BUILDING - SELECTION

The building is taken as object of analysis and retrofit because of its location, function and structural characteristics.

In case Cascadia happens, the closest working cities from Portland will be: Spokane, Washington, 588 Kilometers north; Boise, Idaho, 718 Kilometers east; and Redding, California, 706 Kilometers south.

The City of Portland commission did divide the Portland metro area into five evacuation zones. Such division is mostly dictated basing on the geographical configuration of the city. Successively, the transportation analysis assessed these zones to determine if they were appropriate or needed additional refinement to be effective in an evacuation scenario.

“Zone 1 includes northwest Portland: north of Burnside Road, and west of the Willamette River. Zone 1 comprehends the following zip codes: 97209, 97210, 97229, and 97231.

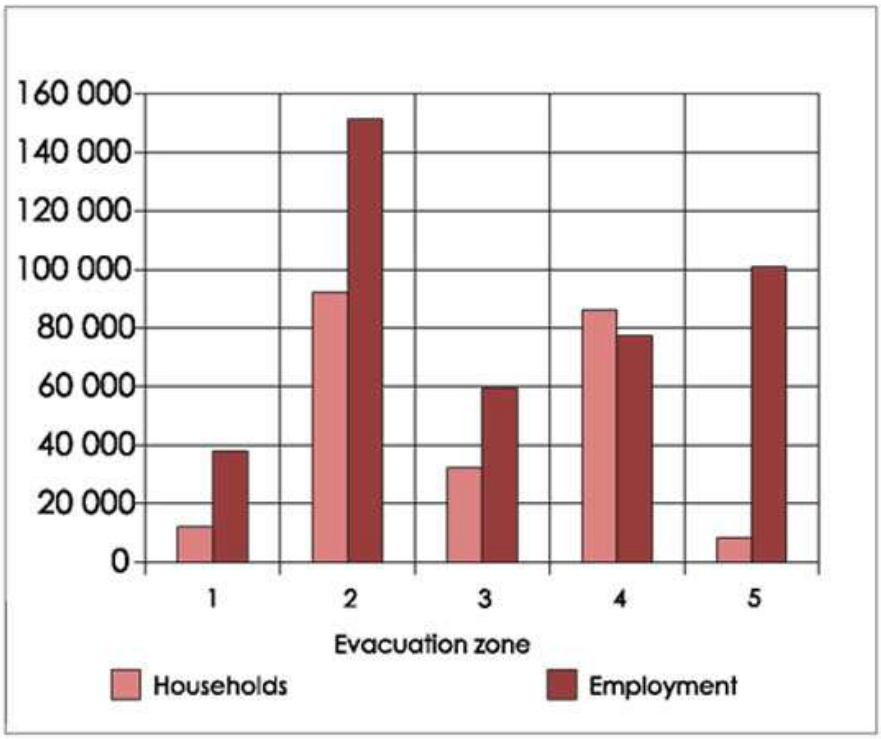
Zone 2 includes northeast Portland, north of Burnside Road, and east of the Willamette River. Zone 2 comprehends the following zip codes: 97203, 97211, 97212, 97213, 97217, 97218, 97220, 97227, 97230, and 97232.

Zone 3 includes southwest Portland, south of Burnside Road/Highway 26 and west of the Willamette River. Zone 3 comprehends the following zip codes: 97201, 97204, 97205, 97219, and 97221.

Zone 4 includes southeast Portland, south of Burnside Road and east of the Willamette River. Zone 4 comprehends the following zip codes: 97202, 97206, 97214, 97215, 97216, 97233, 97236, and 97266.

Zone 5 includes the City center between I-405 and I-5 and contains zip codes 97204, 97205, 97209, and 97210. (Novick, 2014)”

From the collection of data related to evacuation zone’s residential and household population, it is clear that zone 2 is one of the most critical in evacuation planning because of its high employment ad residential population.



The City has also identified evacuation routes that traverse through the evacuation zones, generally following the principal roadways. Said evacuation routes have been categorized as primary or secondary. It is implied that primary routes would customarily be evacuated before secondary routes. It is assumed that the latter are designated as alternate or back-up routes and feed into the primary ones. The primary and secondary routes, per zone, are described in the following bullet list.

- Zone 1: I-405, Naito Pkwy, Highway 30, Burnside Rd.

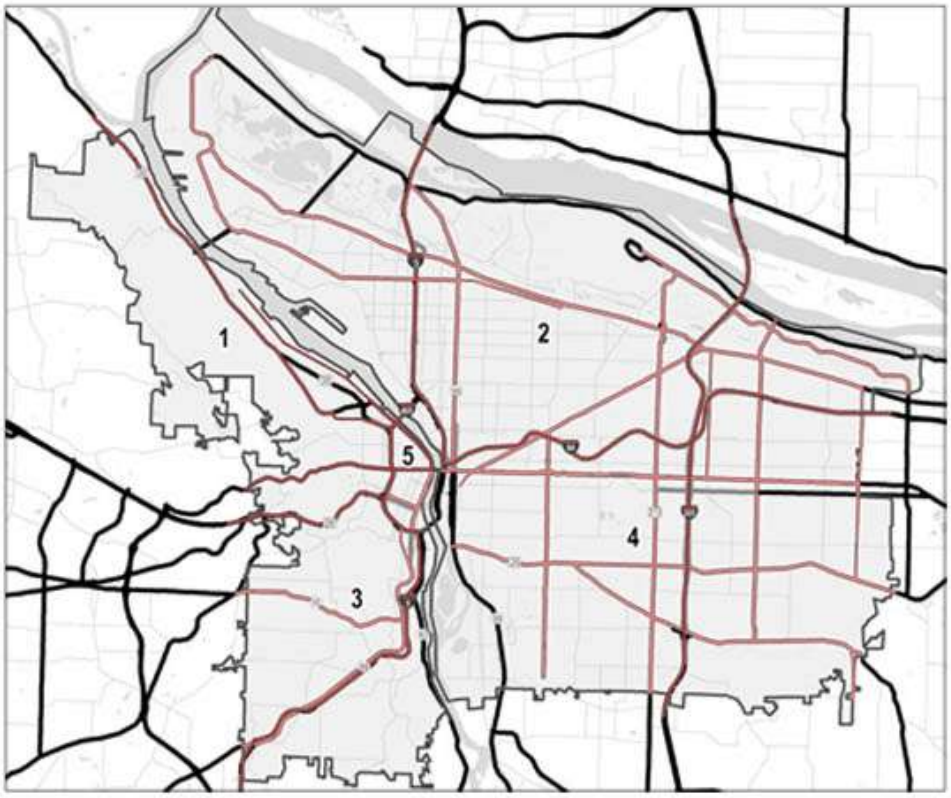
- Zone 2: I-5, I-84, I-205, Columbia Blvd., Lombard, Airport Way, Sandy Blvd., Highway 99 (Martin Luther King Blvd.), 82nd Ave., 102nd Ave., 122nd Ave., 162nd Ave.

- Zone 3: Highway 26, I-5, I-405, Burnside Rd., Highway 10, Highway 99W (Barbur Blvd.)

- Zone 4: I-84, I-205, Highway 26/Powell Blvd., Foster Rd., Burnside Rd., 39th Ave., 82nd Ave., 122nd Ave., 162nd Ave.

- Zone 5: I-405, Burnside Rd., Naito Pkwy., SW Clay

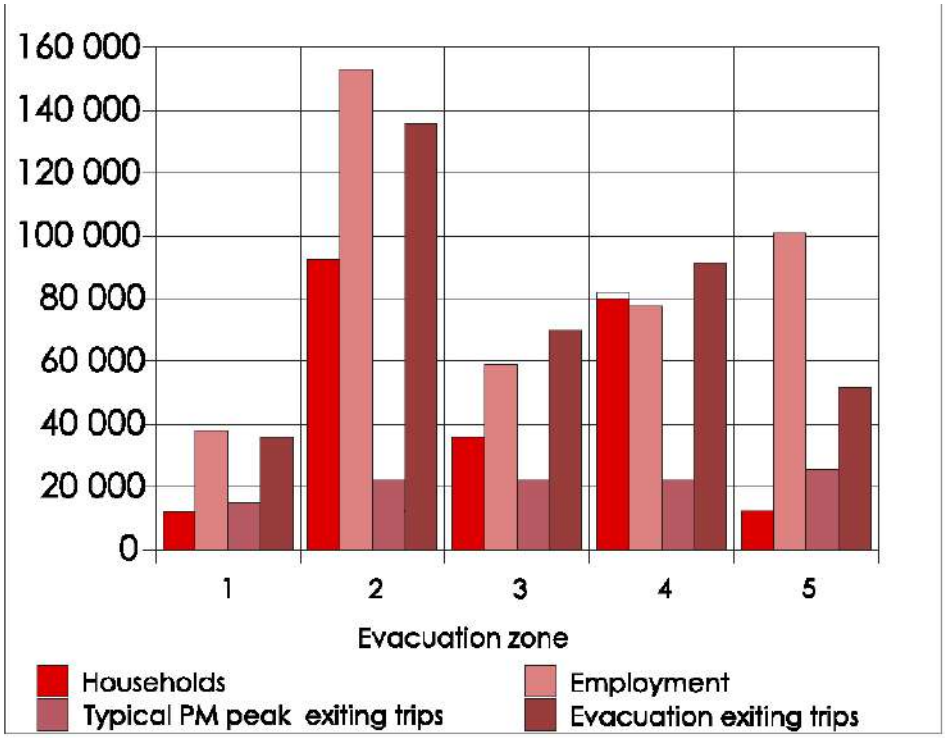
It is taken into account that in the future these itineraries could be re-discussed, due to gentrification and other processes that will transform the city.



Each one of the itineraries may also be assigned to a specific evacuation task. For instance there could be one for the application of selected closures, one for the placement of signage, one that will perform better with the inversion of its traffic flow, one that is designated for clearing debris and all of the other functions that, if well planned, can be used to increase the efficiency of an emergency evacuation.

Through the travel demand model, it was possible to assess evacuation travel times and roadway capacity.

Travel time represents the time that takes to travel home in addition of the time that it takes to travel to the boundary of the zone the evacuee vehicle is exiting.



From the results its clear that in the event of an evacuation, Zone 2 (north and northeast Portland) and Zone 4 (southeast Portland) would generate the highest evacuation trips and experience the highest travel time increase. Because the high employment and residential population rate of Zone 2 would make it complex and long (time-wise) in case of evacuation, such zone was identified as the highest priority zone to evacuate.

From all the data collected so far, it is clear that neighbors in Zone 2 may face unique challenges. Going more in depth it is possible to find out the different levels of vulnerability among all the Portland's neighborhoods.

The bureau of planning and sustainability of the City of Portland, produced the Vulnerability risk analysis. It is a tool that helps to identify census tracts within the City of Portland that have higher-than-citywide average populations with characteristics that make evacuation and displacement harder than it would be in a regular scheario: they are renters rather than homeowners, lack college degrees, have lower incomes and are over 65 years old.

The vulnerability analysis consisted into assigning a "vulnerability score" to each neighborhood. There are a total of four vulnerability factors. Every time a neighborhood shows that it has such kind of vulnerability, it gets a point assigned. A neighboorhoof could reach

a score that can range between 0 and 4 for each of the census tracts based on four risk factors.

The following table details the risk factors, the evaluation criteria and the scoring method:

RISK FACTOR	EVALUATION CRITERIA	VULNERABILITY SCORE: YES (1)	VULNERABILITY SCORE: NO (0)
% renters	Is proportion of renters in the census tract greater than 45.6%?	1	0
% Population age 25+ without bachelor's degree	Is proportion of population 25+ without bachelor's degree in the census tract greater than 56.3%?	1	0
% Households with income at or below 80% MFI	Is proportion of households with income at or below 80% MFI in the census tract greater than 43.7%?	1	0
% Population 65+	Is proportion of household with age at or over 65 years in the census tract greater than 10%?	1	0
VULNERABILITY SCORE		Max: 4	Min: 0

Every census tract gets evaluated basing on the above listed criteria and the total scores on the four risk factors are added to reach the overall "vulnerability scores". Census tracts that score at least 3 out of maximum 4 are defined as "vulnerable census tracts".

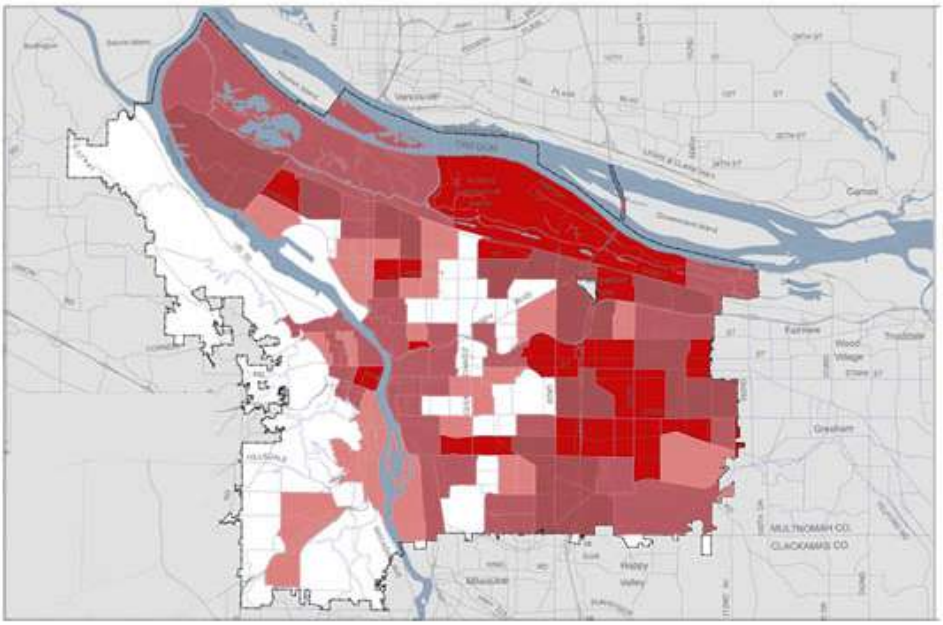
Data sources for the creation of the vulnerability assessment:

Data for the first three risk factors was drawn from tract-level 2008-2012 American Community Survey

(ACS) estimates.

The percentage of households with incomes at or below 80% of the HUD-adjusted MFI was calculated

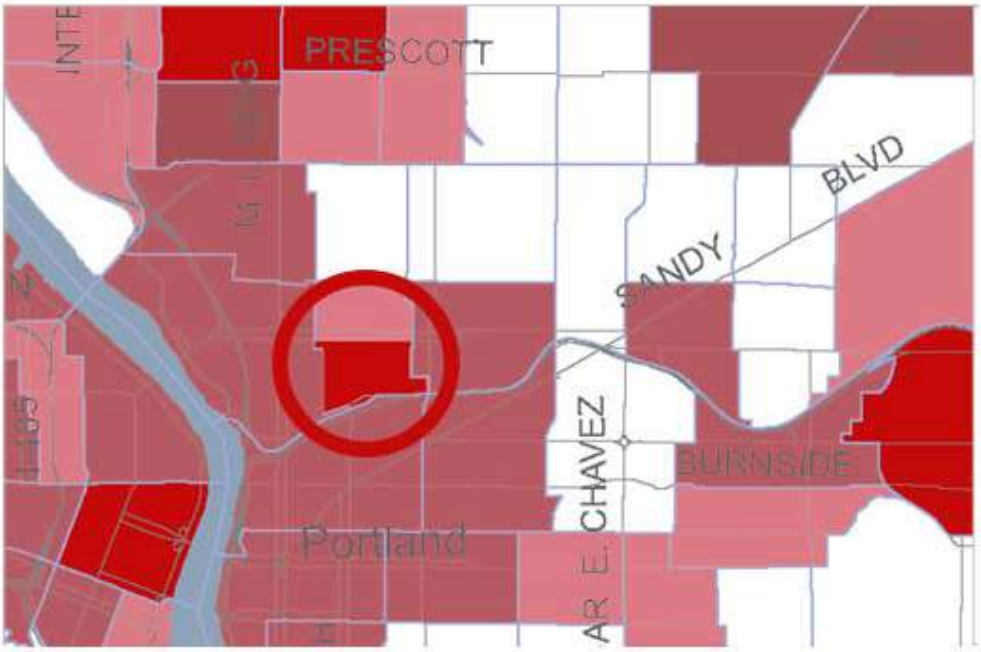
from 2007-2011 HUD Comprehensive Housing Affordability Strategy (CHAS) data. The values relevant to this calculation come from Table 8 of the census tracts dataset. “Tracts with boundaries in more than one local jurisdiction are split into multiple rows; values for each portion were summed before calculating percentages for the overall tract. For FY 2011 HUD-adjusted MFI for the Portland-Vancouver-Hillsboro, OR-WA area was $72,900. (Development, 2007-2011)” .



The assessment of Portland’s neighborhood’s risk factor shows that 7 neighbors in Zone 2 ranked a vulnerability risk factor of 4.

Among them there is the Sullivan’s Gulch neighbor. Portland has about 1800 unreinforced masonry buildings[4], some of them area located in this area. Such structures are likely to collapse. Sullivan’s Gulch presents also some critical services, among which: schools, medical care facilities and emergency coordination centers.

[4] U.S. Dept. of Housing & Urban Development (HUD), 2007-2011, Comprehensive Housing Affordability Strategy data released


PRESCOTT
BLVD
SANDY
CHAVEZ
BUNNSIDE
Portland

THE BUILDING – BRIEF

The Cascadia earthquake is taken as the natural hazard that will size the stress test.

As said above, the geologists and scientists forecast a time span during which no service will be available.

Since the object of analysis is a building, the resilience aspects that will be assessed and improved are the ones related to the construction: water supply and energy supply.

The assessment will be made mainly through site analysis, technical data inquiry and the use of a performance-based design software named “Sefaira”.

The latter will also be one of the main tools that will lead to decisions, which combine design and energy-performance.

The general way to proceed is:

1-baseline status assessment;

2-consumption reduction;

3-storage enhancement

The target of the ‘stress test’ is to reach a time span of 7 days of “off-grid” self-sufficiency respectively about water supply and energy supply.

A mixed use building which hosts a medical care facility is taken as object of analysis because of its location and function. Its address is: 1600 NE Broadway street, Portland, OR 97232, US.

The structure is a steel frame and is supposed to resist to a Magnitude 9 earthquake. This doesn’t mean that it will be reliant to a post-quake use.

For such reason in this project the indicators treated will be the water supply and energy supply ones, introducing first passive and then active strategies to reach the one-week self-reliance target suggested by OSSPAC.

Besides hosting a medical care facility, the building includes also offices, three underground parking lots and five floors of residencies.

The construction's dimensions are North-South lenght: 56,26 m; West-East lenght: 57,75m; Height value above ground : 19,55m. The total number of floors is 9, 3 of it are below ground and 6 of it are above.

Because of the negligible consumption of Water and Energy of the parking floors, in this project it is assumed that those are not supposed to be occupied during the natural hazard's aftermath. Consequently while running water and energy consumption assessments, the underground floors are not taken into account.

The overall tenant area of the above ground floors is of 14 773 square meters.

It has been designed following the ASHRAE 90.1, 2010 version. Which provided minimum requirements for energy-efficient design and construction of buildings and their systems.

The path followed for integrating sustainability with resilience goes from analysis to retrofit, more in depth the indicators were addressed in the following way:

1 - Research of the threats that can likely hit the area;

2- Selection of the one threat which has the biggest impact;

3- Estimation of the worst-case scenario and its aftermath;

4- Deduction of the Target self-sufficient time;

5- Improvement of the indicators that can be enhanced, with the aim to reach the targeted time.

The indicators enhancement is done following the below described general process:

1- Assessment of what is the baseline condition. Is the target met? Is it not?

2- In case the target isn't met, employment of the assessments' data to deduce all of the possible interventions that can better the situation;

3- estimation of how much the intervention or bundle of interventions can increase the autonomy-time value, in order to cut off useless expenses that produce a negligible advantage;

4- Keep on going with the introduction of strategies in order to meet the target or to get as close as possible to it.

3. INTEGRATING RESILIENCE WITH SUSTAINBILITY

3.1 WATER SUPPLY – AFTERMATH SCENARIO

Bull Run comprises the dams that satisfies Portland's primary water supply. The water travels from the eastern and goes into reservoirs. Those are open air ones, this means that when "The Big One" uncorks, they will crack. Pump stations and treatment facilities will fail, also 65% of the city mains are brittle cast iron, consequently they would crackle under a quake. The result is a total loss in water pressure either for drinking or not potable uses.

Portlander's faucets and toilets will be dry for weeks.

For the first week, water will have to be pumped, purified and trucked. During the aftermath firefighters will pump the Williamette river water (the river that crosses Portland dividing it into West and East side) into gallon tank trucks, or directly to fires with Portland's three fireboats. Sewers will break down. Bucket-flushing toilets in the houses will only cause the system to clog. Going "au naturel", over time, will pollute the ground supply and rive. Imagine on a month to flush.

Some actions have been taken: the Portland Water Bureau has strengthened one conduit from Bull Run, with plans to update the other two in the five-year budget. New tanks completed at Powell Butte and Kelly Butte (City Reservoirs) by next year and at Washington Park by 2020 (replacing the beloved open-air reservoirs) will be quake-proof, and the new Tilikum Crossing and Sellwood Bridge (quake proof bridges) both carry water lines.

Upgrading the entire system would be like rebuilding the city. Planners recommend a "backbone" of new pipes to critical care facilities, firefighting nodes, and distribution points, in case of such critical facilities OSSPAC suggests to have a system that allows to reach the 7 days of self-sufficiency Target. Following move: within five years, the Water Bureau will begin a $56.6 million seismically "strenghtened" water line across the Willamette. At home, invest in a storage tank or water purifier (see sidebar, left). The Portland group 'Public Hygine Lets Us Stay Human' outlines an emergency "two bucket" toilet system to maintain hygiene.

WATER SUPPLY – BASELINE ANALYSIS

The "Water data trend" document reported in 2012 by the Environmental Protection Agency, has statistics about the Water Use per square foot basing on the destination of the built surface.

Putting together such information and the knowledge about the building destinations and area, it is possible to know how much water is consumed yearly.

After that, the kind of water and amount of each category will be assessed for each use. While for the offices and apartments, the computation is pretty straight-forward, the clinic's estimation of percentages of water usages is a little bit harder because of the delicacy and variety of functions exercised in it.

For such reason, the clinic's floor plan is analyzed more in depth in order to determine which functions are exercised or not in it. Once

the Usage breakdown is determined, it comes to assess the percentage and type of water used for each detailed function. The calculation is made with the aid of the data collected in the document “Emergency water supply planning guide for hospitals and health care facilities” American water works association, 2012.

WATER SUPPLY – STORAGE AMOUNT

Now that the building water consumption is known, it is easy to determine how much it is the amount of water that the building will need to reach the 7 days target.

It is sure that it will need a minimum of water storage is fundamental. Water tanks will have to be suited to store: sterile, potable and not potable type of water, with the required treating systems, like filtration, sanitation, inverse osmosis and UV lower bacteria.

The tank installed for sterile water storage has a 6 500 L maximum capacity that is far above the requirement of sterile water for one week (4 583 Liters).

Tanks installed for potable and not potable water storage have a maximum capacity of 10 000 L. Their size is determined by live load that they will provoke on the slab. Because of static reasons, the tanks are installed on F-2 and F-3, the two floors underground, which are designed to withstand high weights like the ones of articulated trucks. Their slabs are supposed to hold a load of 250 pound per square feet that means 1221 Kilograms per square meter.

The fully loaded tanks wouldn't weight more than 1161 kilograms per square meter. That means that the geometry and capacity of the tanks designed can be withstood.

Some parking stalls are sacrificed with the purpose of making room for the tanks.

In order not to take too much parking stalls off and not to load the slabs excessively, the overall account of storage ranks the following values: 1 tank of sterile water, 3 tanks of potable and 4 tanks of not potable water are installed.

Those tanks need a specific maintenance and inspection for granting the quality of the substance they contain and that all the devices they are connected to, work.

AMOUNT OF WATER STORAGE THAT IS POSSIBLE TO BE INSTALLED

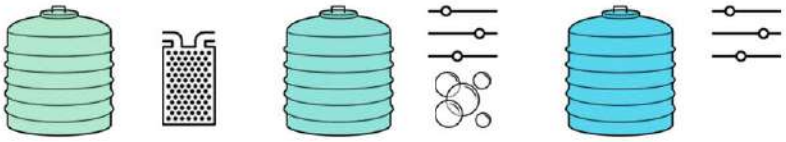
CLINIC SUPPLY NECESSITIES		OFFICE SUPPLY NECESSITIES		RESIDENTIAL SUPPLY NECESSARY	
-STERILE	6441 L	-STERILE	0 L	-STERILE	0 L
-POTABLE	2083 L	-POTABLE	1700 L	-POTABLE	123903 L
-NOT POTABLE	10230 L	-NOT POTABLE	10319 L	-NOT POTABLE	299078 L
-DRINKING ONLY	190 L	-DRINKING ONLY	121 L	-DRINKING ONLY	4273 L

OVERALL WATER NEEDS PER DESTINATION

STERILE:	POTABLE:	NOT POTABLE
7 days= 6441 L	7 days= 129 769 L	7 days= 299078 L
hourly= 38,34 L	hourly= 772,43 L	hourly= 1780,22 L
DRINKING ONLY:	It is assumed that DRINKING WATER is currently stored in jugs or bottles inside home units and activities storage rooms.	
7 days= 4583 L		

STORAGE SYSTEMS:

STERILE:	POTABLE:	NOT POTABLE:
1x6 500 L sterile tank	3x10 000 L water tank	4x10 000 L water tank
D= 2,67 m; A= 5,60 mq	D= 3,34 m; A= 8,76 mq	D= 3,34 m; A= 8,76 mq
with final treatment: - inverse osmosis - UV lower bacterias	with: - filtration - sanitation	with: - filtration
Live load on slab = 1161 KgF/mq	Live load on slab = 1142 KgF/mq	Live load on slab = 1142 KgF/mq



WATER SUPPLY – AUTONOMY TIME

-BUSINESS AS USUAL

The amount of potable water stored is 30 000 L and the not potable one reaches 40 000 L of storage.

While the sterile tank satisfies the entire amount needed, potable and not potable ones don't.

The off-grid autonomy time for water supply of the building is calculated after satisfying all the needs of the clinic for the seven days required.

Potable water available after that is 27 917 L and not potable water availability is of about 29 770 L. Such quantities respectively ensure an autonomy of 38 hours and 16 hours Business as usual.

Therefore there is the need of introducing certain strategies that reduce the amount of consumption and/or increase the quantity stored.

-STRATEGY 1: Eliminating leaks

According to the Environmental Protection Agency, the average household's leaks can account for more than 10 000 gallons of water wasted every year or the amount of water needed to wash 270 loads of laundry.

Fixing these leaks would save 11% of water consumption.

A cutback like this will increase the self-sufficient time for potable water up to 42 hours and 30 minutes and for not potable water up to 18 hours.

-STRATEGY 2: Replace water fixtures

Most of us know we can save water when turning off the tap while soaping ourselves. More than that, there are products that will help save water when we turn on the tap as well.

Watersense labeled faucets and faucet accessories, for instance aerators, are high-performing, water-efficient fixtures that will help you reduce water use in you home and save money on water bills.

Such kind of fixtures allow to save around 35% of water use: this includes 1,5% savings of the quantity of water coming from taps, 3% savings of the quantity used by washing machines, 11% savings of the quantity used by showers and 16% savings on the quantity of water used by bathrooms.

Said replacement will bring to a reduction of consumption of 12,5% and 19% respectively of potable and not potable water, and to an increase of potable water supply autonomy of 5:30 hours and not potable of 4 hours.

-STRATEGY 3: Office shut down and avoiding the usage of clothes washer during and after the hazard

In case there is still need of supply after two days, the office will shut down since there are no beds and people wouldn't stay there anyway. Furthermore, the clothes washing does not represent essentialness for the surviving purpose.

The shut down will cause few savings for the potable water but a 44,8% reduction of not potable use, which is cut down by almost a half. Therefore the not potable water autonomy time will increase of 7 hours, overcoming the first day milestone.

-STRATEGY 4: Rainwater harvesting

Differently from the interventions done so far, this doesn't contribute to reduce the water consumption, but helps to increase the quantity of supply stored.

The rainwater harvesting surface is located on the roof of the first floor and on the one of the fifth floor. The top roof's area is not used because it is planned to host a photovoltaic system.

The roofs suit their function of catchment because of: material, slope and size.

The material that covers their top is an adhesive PVC membrane. This means that will not obstruct the water flow, and not either contaminate it.

In order to dodge contamination, it is important to avoid wood shingles or metal flashings that contains lead.

The roofs are all flat, with a slope among 1 and 2% that allows the water to flow to the gutters gently during rain events.

The size of the roof's catchment area grants a certain quantity of water harvesting depending on the weather conditions of the city.

The overall catchment area is 958 square meters, it would harvest a quantity of 2430 Liters a day based on an average rainfall depth.

The formula used for said assessment is the following:

Harvested water (G/day) =

= catchment area (sf) * rainfall depth (in)* conversion factor (0.623)

The quantity calculated in imperials is then converted into the units of the international system.

On a minimum rainfall depth day the system will harvest 488 Liters, while on a heavy rainfall day it would catch 4385 Liters.

-STRATEGY 5: GREY WATER SYSTEM

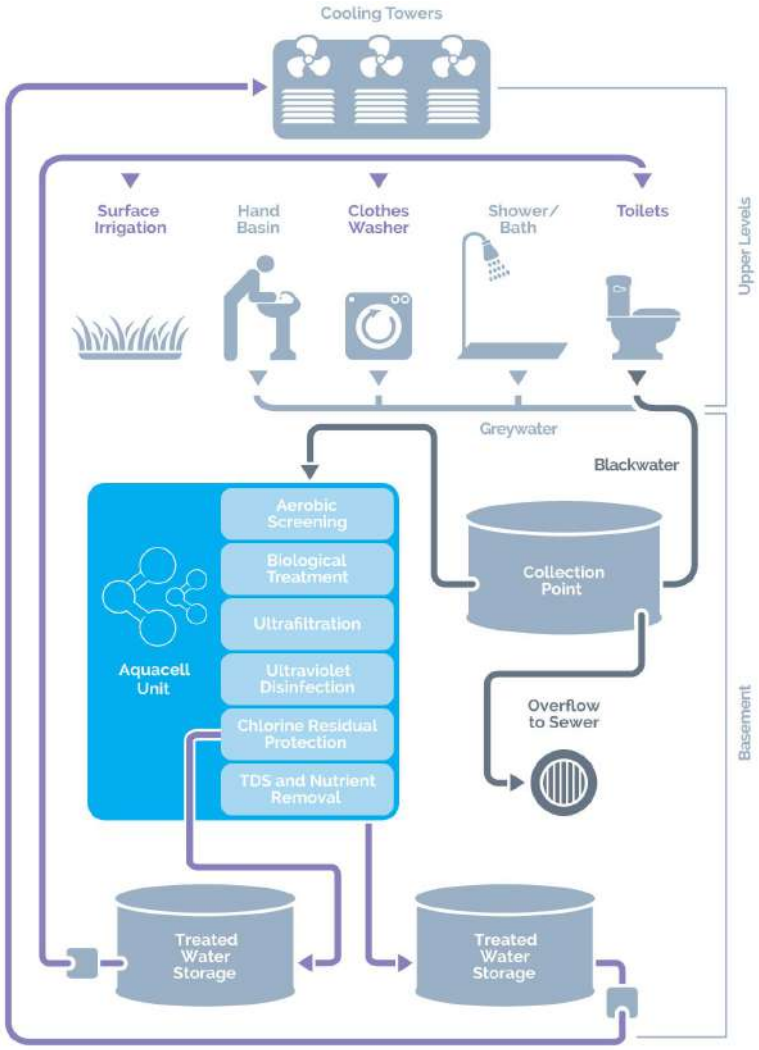
This strategy as the rainfall one, aims to increase the tanks replenishment too.

The grey water system will be connected to the rain catchment one.

This means that the water will be caught by the rain system, once filtrated and treated it will be either potable or not potable and then used for basins, showering and (when put into operation) clothes washing. After such usages, the water turns into grey water and is pumped into a surge tank.

The latter is constituted by any type of container that is suitable for holding, while not storing, the initial flow of water. The surge tank must be emptied completely each time grey water is dispersed to the treatment system. Moreover grey water must not sit for extended periods of time in the tank.

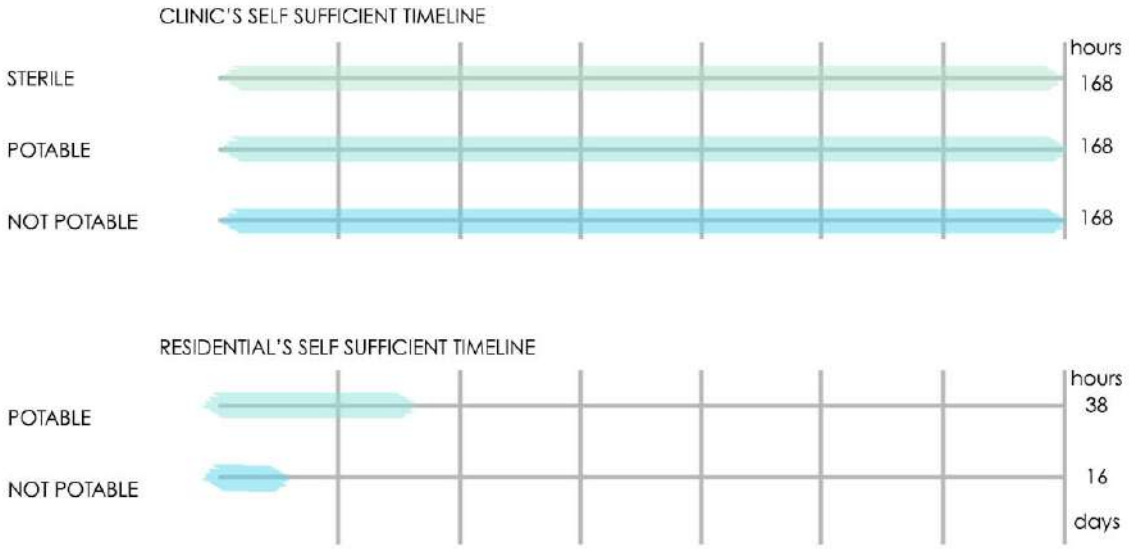
After that the water will be used for flushing toilets, consequently it will turn into black water and let flow into the sewage mains.



The system will grant an increase of supply autonomy of 2 hours per day and of 3:30 hours per day respectively for potable and not potable water.

The target of seven days water supply is fully reached for the clinic only. The apartments will have a total autonomy for two days for the potable water usages and of one day and a half for the not potable water usages.

After that, daily necessities will be satisfied for a restricted time of the day as explained above, until reinforcements will arrive to the shelter.



3.2 ENERGY SUPPLY

The resource of energy is intended to be enough to satisfy four main functions: heating, cooling, lighting and equipment.

The amount that provides lighting is treated a more in depth, than the others, for two main reasons: its necessity depends upon various factors and it represents the most considerable cause of energy consumption.

ENERGY SUPPLY – AFTERMATH SCENARIO

Differently from the water supply, the energy's starting point is different. The water supply's assessment needed a preliminary storage system, meanwhile the energy supply assessment has already a way to storage energy. Since the building is a mixed uses that comprehends a clinic in the space, the latter features an engine power generator on its pertinent surface, connected to a tank of diesel of 1 300 Liters of capacity.

This industrial power generator employs different fuel consumption rates depending on the percentage of load.

Business at usual the engine power generator needs to satisfy huge energy demands (above 80 kWh/m2/year) thereupon it works at 100%. This implies that the system will consume 56 liters per hour, calculated on such rate, the hours satisfied by the diesel tank are 23.21, the outcome of the total energy produced ranks 5803 kWh.

ENERGY SUPPLY –AUTONOMY TIME

-BUSINESS AS USUAL

Indeed the lighting power density installed is influenced by daylight that is calculated on the local weather conditions and the building's sun exposure. Lighting also depends upon the position of the building's windows and the properties of glazing installed on them, the quality, quantity and installation of lighting fixtures installed and the presence or not of thoughtfully placed redirecting devices.

From the energy performance analysis it emerges that lighting is the main source of energy expense, indeed it represents 44% of the power expenditure, whereas heating represents 20%, cooling is 17% and equipment is 19%. Withal the software daylight dial, showing the percentage of floor area that is under lit, over lit or well lit in line with the LEEDv4 metrics, highlights that there is a high percentage of area that is under lit. At the baseline status under lit area is 92%, Well lit area is 3% and over lit area is 5%.

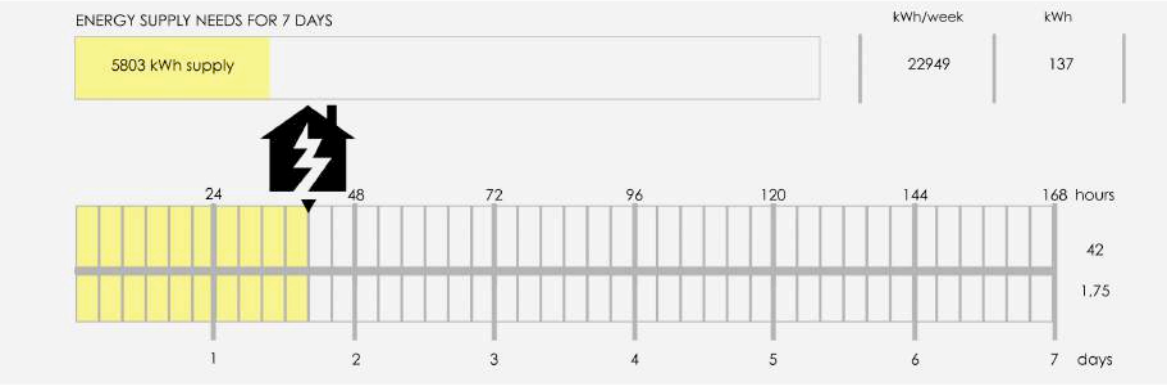
The daylight dial also shows spatial Daylight Autonomy levels (sDA) and Annual Sun Exposure (ASE). The first is used to evaluate whether a space receives enough usable daylight throughout the year. Specifically, it describes the percentage of floor area that obtains a minimum of three hundred lux for at least half of the annual occupied hours. A good value is included between 55 and 100% of Daylight Autonomy. Business as usual the building ranks a spatial Daylight Autonomy level of only 8%.

To address it, there is the necessity to reduce the amount of surface that receives poor quantities of daylight.

Annual Sun Exposure helps to see whether a space is subject to over lighting. It describes how much of space receives excessive sunlight, which can cause visual discomfort, also known as glare, or increase heating loads. Annual Sun Exposure measures the percentage of floor area that receives at least 1000 lux for a minimum of 250 hours of occupation per year. Business as usual the building ranks 5%, this represents a good value since it is in between the optimal span, that goes from 0 to 10.

To address the Annual Sun Exposure it would be necessary to reduce the over lit area of the building.

The latter does not represent any big deal, because it is evident that the main intervention to do is to enhance the daylight levels decreasing the area that is under lit.

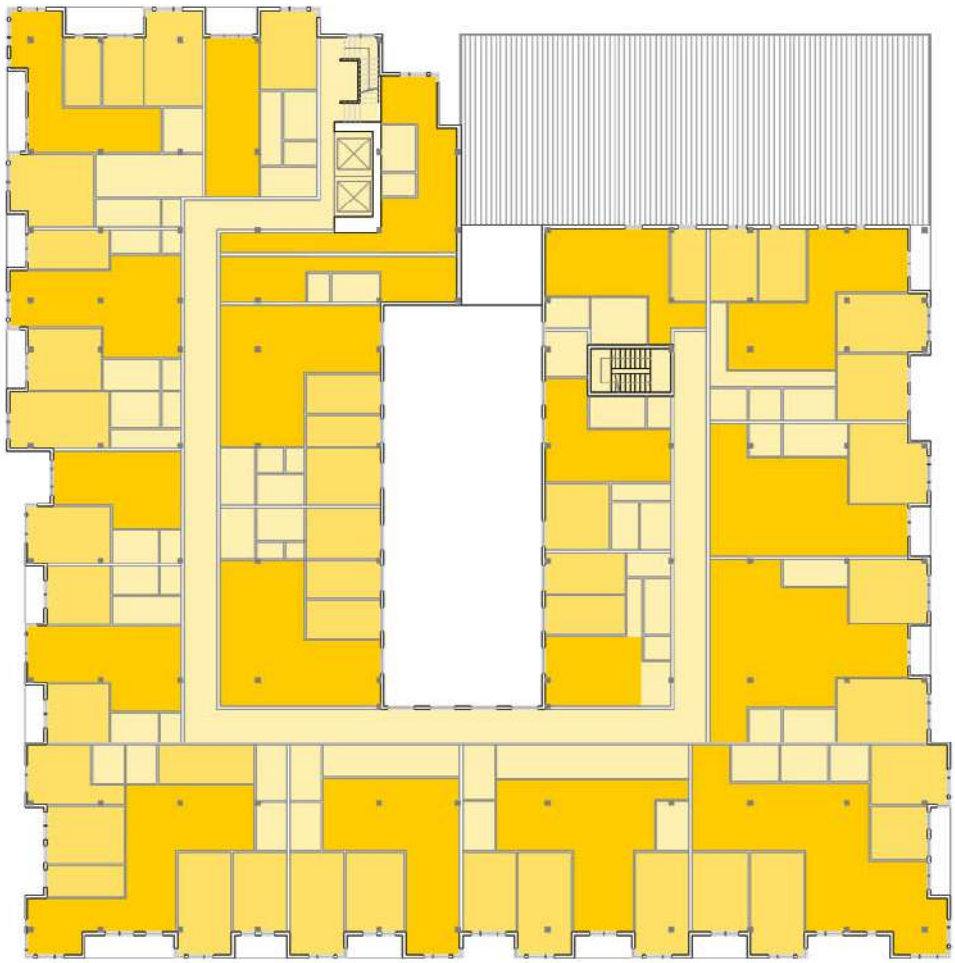


-STRATEGY 1: DAYLIGHT RETROFIT

Then it comes to boost the under lit area. This one will be addressed more in depth and thoughtfully.

With the aim to decide where to intervene, a preliminary analysis is made.

In first place the floor plans' surfaces have been divided into three categories: servant, served low and served high. Servant spaces are, as per usual, the secondary spaces like kitchens, bathrooms, corridors, stairs and closets. Served spaces are divided into two sub-categories for a daylight reason. The low ones are the ones that are mainly used during night times, such as bedrooms, whereas the high ones are the ones that are used mostly during day times, such as living rooms or studios.



The servant spaces are for definition auxiliary, it is not supposed that the occupants would use them for extended time spans, thereupon the interventions on them is negligible.

Served Low spaces need few daylight-related retrofits because the changes would not affect those spaces as much since they are used mostly during sun absence.

Served High spaces comprehend all the rooms where daylight enrichment would represent a real change.

Concerning the surfaces where we find glare, they will be addressed placing horizontal shadings on the south façade apertures and vertical louvers on the west and east ones.

The geometry of said elements is dictated from the sun elevation in Portland.

Under lit areas represent the main challenge. The interventions aim to increase first served high space well lit area, after maybe the served low space one, if possible.

Following the analysis described, windows and skylights have been placed on walls and roofs.

In order to check out how the retrofit would influence the building's energy performance, the windows and skylights were drawn on the three dimensions model employed to run analysis. Various solutions have been analyzed in order to get to select the one where there is more daylight indoor without creating unwanted cooling or heating loads, nor glare surfaces.

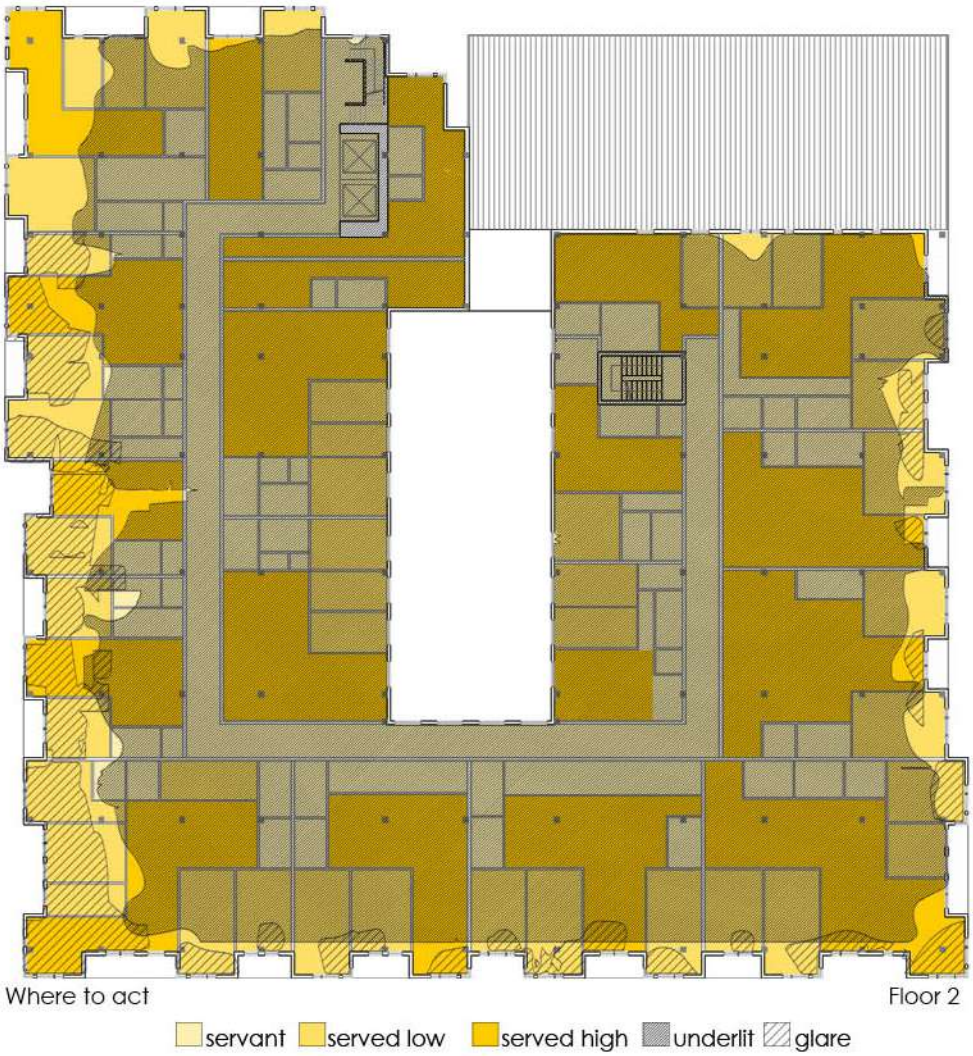
SKYLIGHTS

It is assumed that all the skylights that will be introduced, are provided with baffles which role is to shade, redirect light and prevent undesired heat gains.

ENERGY STAR has established a minimum energy performance rating criteria by climate conditions for skylights it's required that the U-value is minor or equal to 0.27 Btu/h*ft2*F which means 2.83 W/m2*k.

The dimensions of the skylight mightily affect the illumination level and temperature of the space below. As a rule of thumb, the size of the skylight should never be more than 5% of the floor area in rooms with many windows. In this case skylights are mainly placed in rooms with no windows, and they respect the suggestion of not

having an area of more than 15% of the room's total floor areas for such spaces.



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The choice of material for the glazing was among plastic and glass. While plastic is hard to break and represents a low cost solution, it has a downsize. Plastic surfaces scratch easily, and they may become brittle and discolored over time. Also, unless the glazing is

coated with a special film, many plastics also allow most of the ultraviolet rays in, which increases fading damages to furnishings.

The choice of glass as the glazing material represents a more expensive one. This adoption is supported by the material's properties. It is more durable and does not discolor.

The kind of glass used for skylights must be "safety glazing", a generic term for both tempered and laminated glass.

The glazing used is composed by a tempered glass on the exterior and by a laminated pane on the interior side. The tempered layer is the one that withstands the impact the most, and the laminated one is fabricated with a thin sheet of plastic embedded near the center of the glass. One along with the other keep the glass from breaking into large, sharp pieces. Said combination gives maximum impact resistance while protecting occupants from falling shards of glass.

The glazing is supposed to have a good insulation ratio and to be treated with low-e (low emissivity) coatings to further reduce heat gain or loss impacts.

The Solarban R-100 STARPHIRE glass is chosen as the installed glazing on skylights. This is dictated by its low Solar Heat Gain Coefficient of only 0.23 and by its U-value of 1.6 W/m2*k for each thickness of 25 mm of pane installed. Two panes of 30 mm each will be put on each skylights and the space in between will be filled with argon gas. Therefore there will be an overall 0.35 W/m2*k U-value.

WINDOWS

The action for this case started by the improvement of the efficiency of existing windows. The baseline glazing has a U-value of 0.52 W/m2*k.

Replacing that material with a SOLARBAN 70XL double paned window, filled with some argon in between will enhance the U-value up to 0.27 W/m2*k. Moreover caulking gaps, joints less than 0,5 centimeters wide and stationary cracks, and weather stripping doors and windows that move, will reduce air leakage while improving comfort.

The new windows' apertures will adopt the described glazing. Analyzing its behavior with the software, it is clear that the designed

glazing helped for enhancing the well-lit area, but there is more that can be done.

BALCONIES

During the daylight retrofit, balconies have been introduced in order to allow more sunlight to get in while providing a nice view to the outside.

They have been realized cutting off the south-facing wall in some of the façade areas.

Different scenarios have been elaborated. Each showing a distinct area cut off combination.

In order to repute what areas could have been pulled out, the building's structure and dimensions have been identified.

Three main scenario have been designed and then analyzed.

The best one leaves the building with still a big portion of under lit area, but delivers an enormous daylight performance enhancement.

In such balconies curved windows that run from the slab to the ceiling are installed. The choice of the curved window is dictated by the fact that the intervention wants to leave a trace, therefore it has a geometry quite recognizable in the front elevation.

Said curved windows, are composed by three modules, two of them have a fixed frame and one is movable, and slides in front of one of the fixed frames.

The glazing selected for the new windows placed in the balconies is solarban 70XL made.

The creation of balconies with such placement produces the following advantages: under lit area decreases from 92% to 63%, the well lit one raises from 3% to 21%, such improvement can justify the augmentation of the over lit area from a 5% to a 12% and the Annual Sun Exposure from the 5% to the 15%.

Treating surfaces that receive glazing is not as critical as poorly enlightened ones, sometimes adding curtains and easy interior shading devices could greatly help.

Moreover spatial Daylight Autonomy is brought up from 8% to a 36%. Such improvement turns into a greatly advantage when a natural hazard hits.

Indeed, in case of Cascadia (or some other natural threats) electricity would be shut off for a while. Having a decent value of spatial daylight autonomy is handy for occupying spaces and being oriented while not consuming any source of energy.

The overall spatial daylight autonomy doesn't meet the target for every each, but upper ones highly reach it.

The daylight factor meets the target of being equal or major than 2% for half of the floors, thanks to the interventions it has been more than doubled.

LIGHTSHELVES

In order to enhance such autonomy, light shelves have been added on the south façade, combining such devices with the shading that were supposed to be installed.

Light shelves bounce visible light up towards the ceiling, which reflect it down deeper into the interior of the rooms.

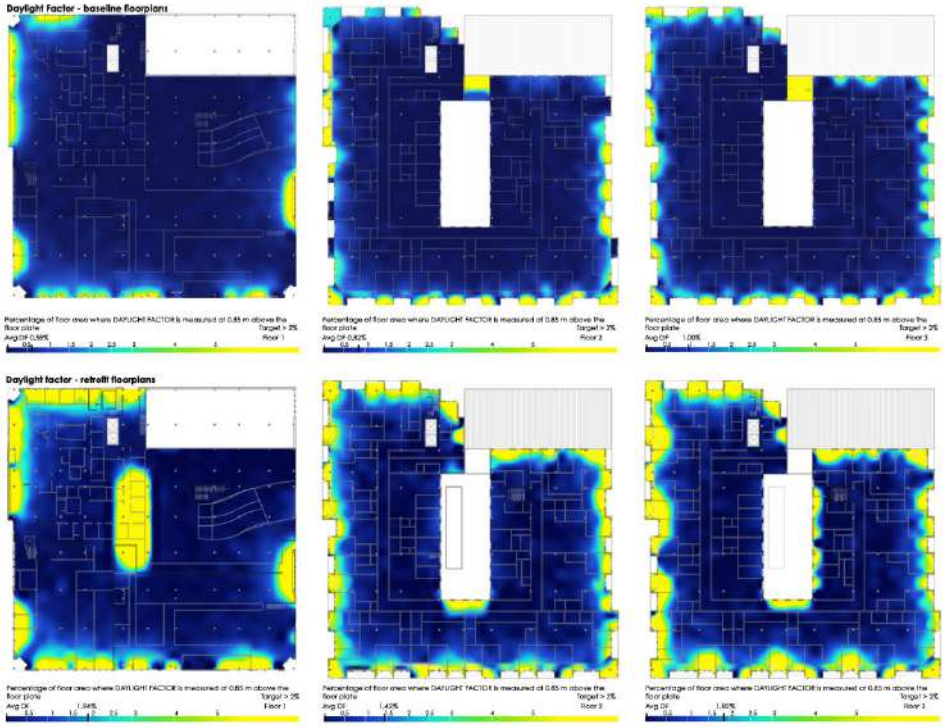
Their sizes and height is related to Portland's sun elevation and the exposition of the building floors to sunrays.

The ideal height from slab is 1,98 meters, such height allows sunrays to be reflected inside while avoiding the possibility of glare into the eyes of the occupants. The length follows the one of the window where the shelf is installed, the exterior depth is 95 centimeters while the interior one measures 40 centimeters.

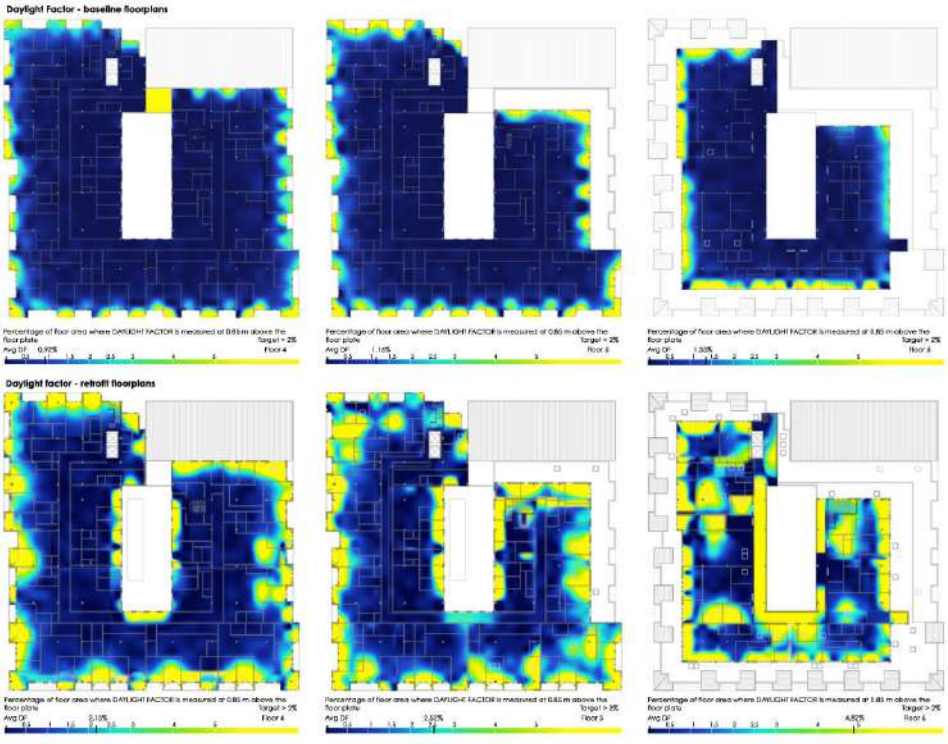
Aiming to maximize sun entrance, and accordingly to the building orientation and the weather data, from the second to the fourth floor, the light shelves installed are of exterior type, on the fifth and sixth, they are interior ones.

Their sizes also have a safety reason. On the floors fifth and sixth, where interior light shelves are designed, they eliminate the possibility that occupants involuntarily bang their heads against such device. External shelves are best paired with internal shelves and mounted at the same height.

Daylight Factor Analysis: baseline floorplans



Daylight Factor Analysis: retrofit floorplans



It is planned the installation of blinds either above, either below the light shelves, so that people can adjust them in relation with the sun elevation's variation throughout the day.

In order to get best results, light shelves should be mounted horizontally. In case the surface of the shelf is highly reflective, then the angle that the sunlight is reflected onto the ceiling, will be equal to the angle of incidence of the incoming sunlight.

The material that best suits for this destination is an opaque aluminum composite.

Keeping a clean, reflective top surface is a paramount to the performance of the architectural light shelves.

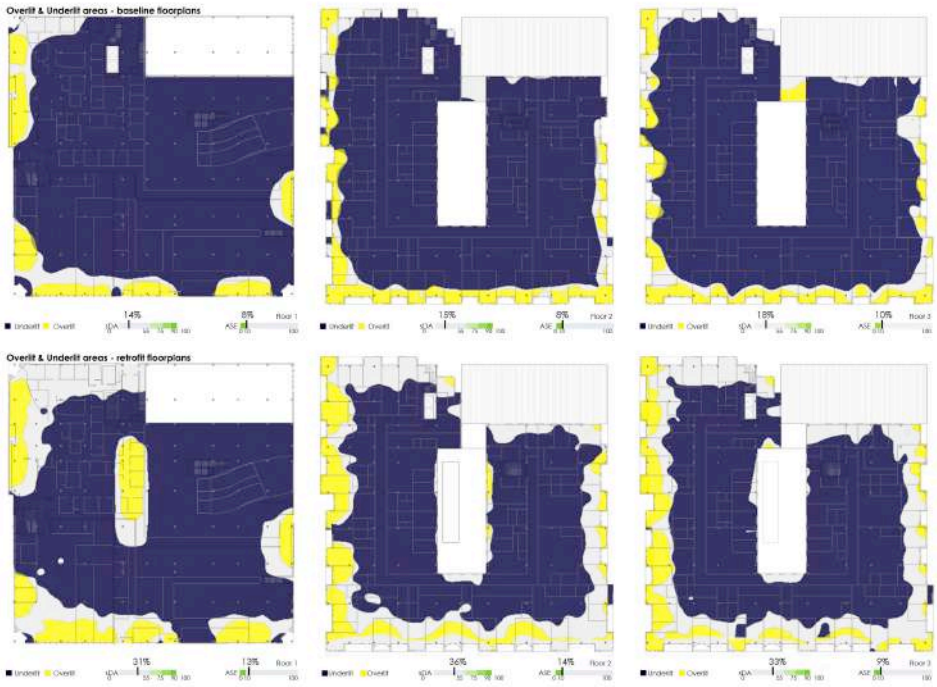
For such reason, the shelves are provided of a bracket each for their installation on the window frame. This allows the panels to be assembled separately from the window's frame installation. Furthermore it permits to the shelf to be effortlessly tilted for cleaning and water draining.

What the light shelves provide, is an augmentation of the lightness of the indoor spaces. Such a one will likely contribute to increase the well lit area percentage. It is not going to be any source of glare because the light that penetrates the window is redirected.

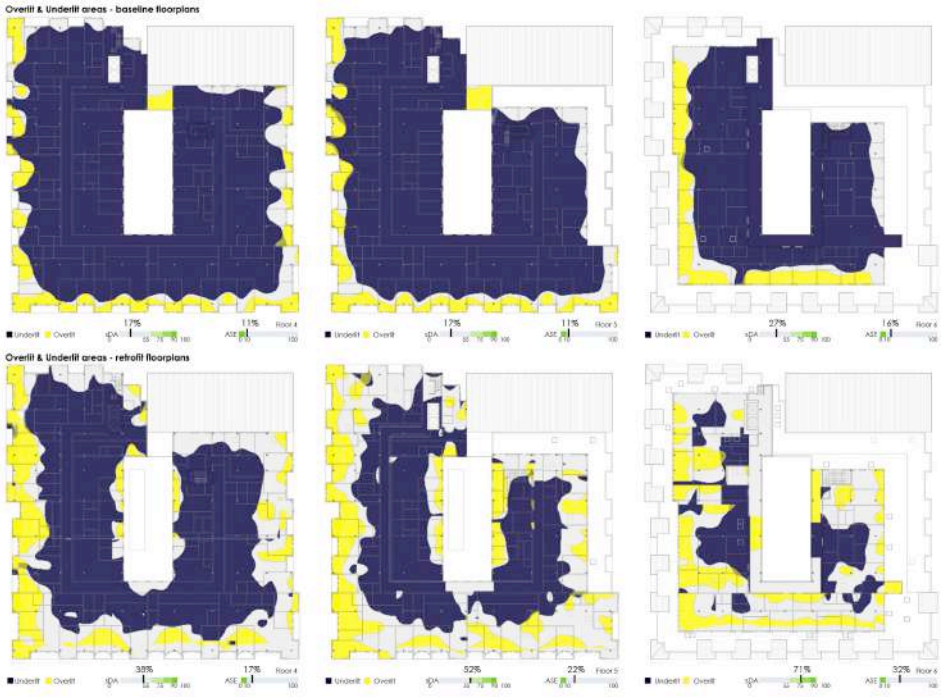
Light shelves' provision cannot be assessed through the software that has been used for making all the calculations done so far. The estimation of their provision will be done through geometric calculus, taking into account the sun elevation during three scenarios: winter solstice, summer solstice and mid season.

Daylight Factor Analysis: baseline floorplans

Overlit & Underlit areas analysis: baseline floorplans



Overlit & underlit areas analysis: retrofit floorplans



- STRATEGY 1: DAYLIGHT RETROFIT-OUTCOME

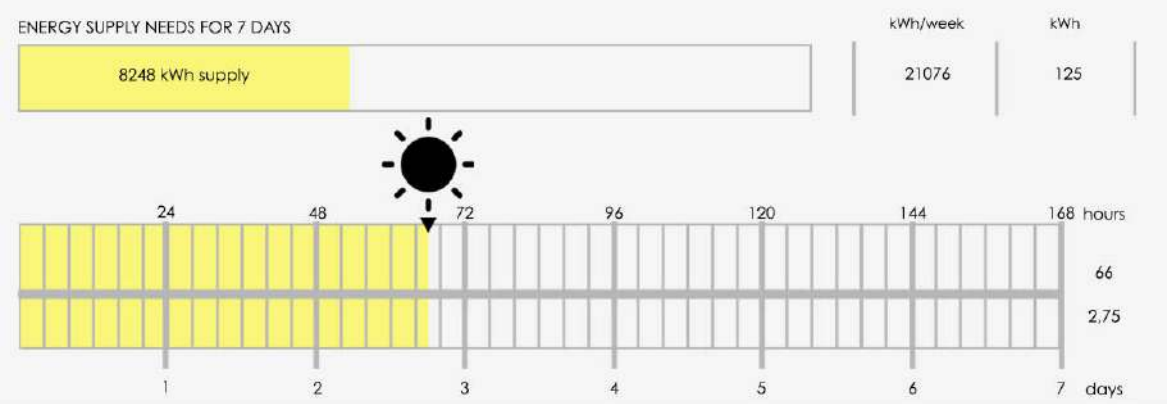
This first retrofit will drop down the energy use intensity from 81 kWh/m2/year to 75 kWh/m2/year mostly from reducing impacts on heating and implementing the daylight autonomy of the building.

Impacts on heating dropped significantly because of the new quality of the glazing that reduces them.

The energy needed to satisfy the 7 days target drops from 22 949 kWh/week to 21076 kWh/week (meaning a reduction of 1873 kWh/week).

Said energy reduction will reduce the percent load at which the engine power generator works from 100% to 75%, implying a fuel consumption rate of 39.4 liters per hour. In this scenario the hours satisfied by the tank are 33, so that the total amount of energy produced is 8248 kWh.

Consequently the autonomy time increases from 42 hours to 66.



-STRATEGY 2: LIGHTING

Even thought the daylight has been addressed and the daylight quality of the building has been largely increased, the energy segments dial on the analysis run after the retrofit, show that the power expenses for lighting purposes are still predominant compared to the overall balance.

The lighting power density (LPD) installed at the moment is of 6 W/m2. The types of bulbs installed are: halogen incandescent and compact fluorescent bulbs (CFL). For the first ones electricity passes through a metal filament unit heat makes it glow, and a gas filled, coated capsule surrounds the filament to keep it hot with less energy.

For the second ones Electricity passes through a gas filled tube to produce ultraviolet light. A fluorescent coating inside the tube, phosphor,makes the light visible.

While the CFL bulbs provide higher savings than the incandescent ones, the CFLs are not dimmable.

-STRATEGY 2: LIGHTING RETROFIT

A good solution would be to replace said bulb types with LED ones.

Light Emitting Diodes are small light sources illuminated by the passage of electrons through semiconductor material

The United States department of energy's data collection shows significant savings on the installation of LED.

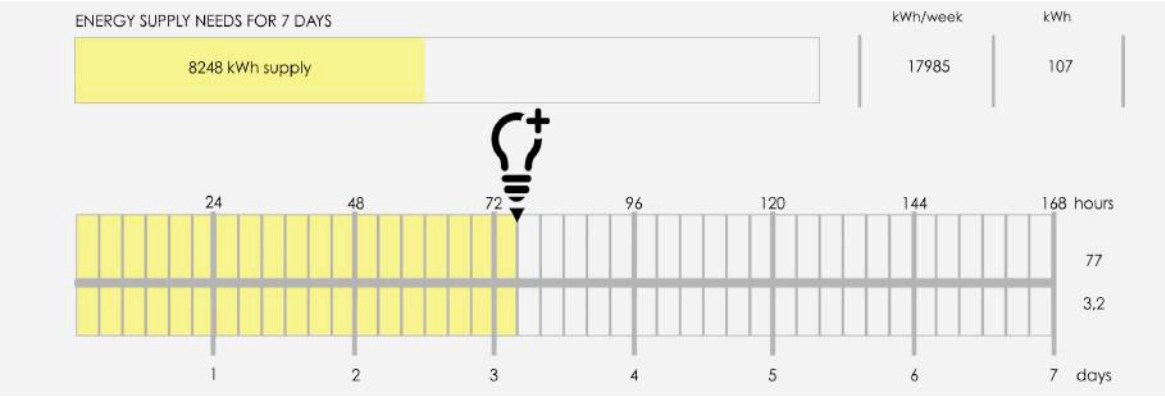
The latter indeed provides 80% saving on regular incandescent bulbs, lower annual cost, optimal watts equivalence among the lumens required in the area and the bulb power that has to be installed. By the same token LED a life span far longer compared to any other kind of bulb.

The retrofit project plans that most of these devices will be connected with sensors that detect the presence or absence of people into certain rooms. Sensors will contribute to further drop down the actual Lighting Power Density installed reaching the 3 W/m2.

-STRATEGY 2: LIGHTING RETROFIT OUTCOME

Running an energy performance analysis after replacing the baseline bulbs with Lighting Emitting Diodes ones, does not only show an energy use intensity reduction of 9 kWh/m2/year (which is not negligible at all) it also highlights that the energy consumption is finally not lighting dominated.

The lighting energy hugely decreases from the baseline 519 208 kWh/year, passing through the daylight retrofit demand of 501 018 kWh/year to 249 718 kwh/year. As a consequence of this significant cutback, the active heat gain impacts provoked by the lighting are drastically reduced. As a domino effect energy for cooling functions has a lowered demand. It overall reduces the energy needs for the week even more. The first retrofit outcome weekly energy necessity was: 21076 kWh/week and its self-sufficient time amount is of 66 hours. With the bulb replacement these values get to be respectively: 17 985 kWh/week and 77 hours (respectively a reduction of 3091 kWh/week energy consumption and an increase of 11 hours of autonomy).



-STRATEGY 3: COMPONENTS INSULATION

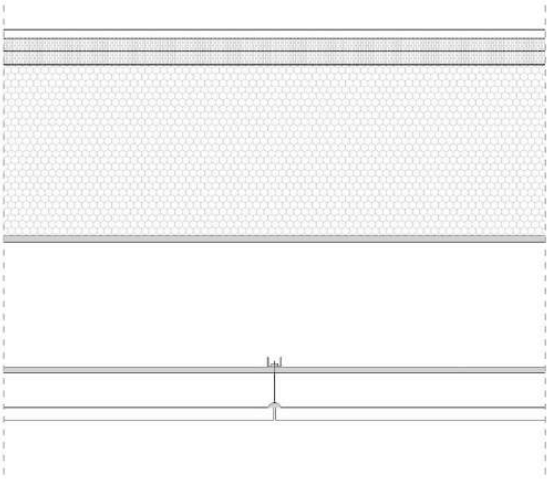
Roof and wall conduction represent now what impacts the most on heating and cooling gains and losses.

Since the replacement of the baseline glazing with a more performing one brought to a compelling reduction of Energy Use Intensity, then increasing the resistance to the heat flow of the roof and wall components might bring to another good energy cut off.

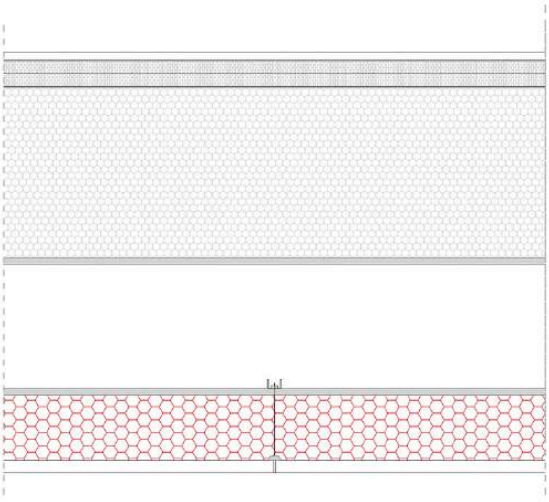
-STRATEGY 3: COMPONENTS INSULATION

RETROFIT

The roof R-value (resistance to the heat flow) will be increased from the actual 3.7 W/m2*k to a 7 W/m2*k by simply adding spray foam inside the false ceiling space.



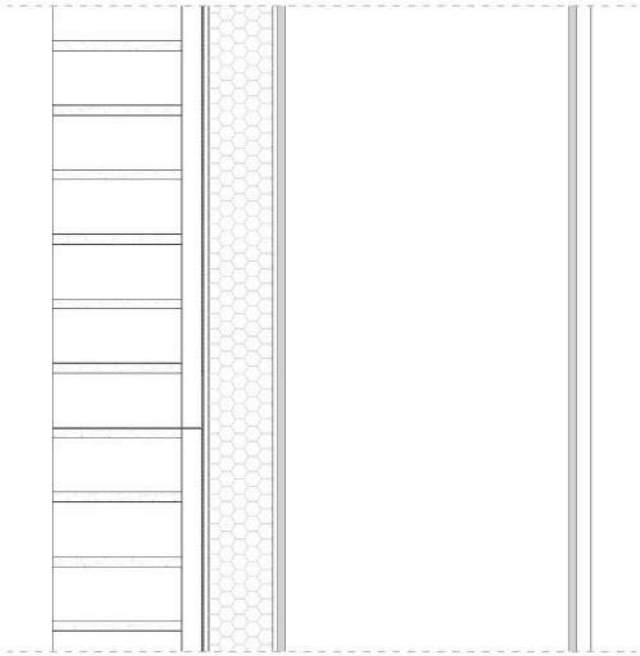
Baseline roof detail



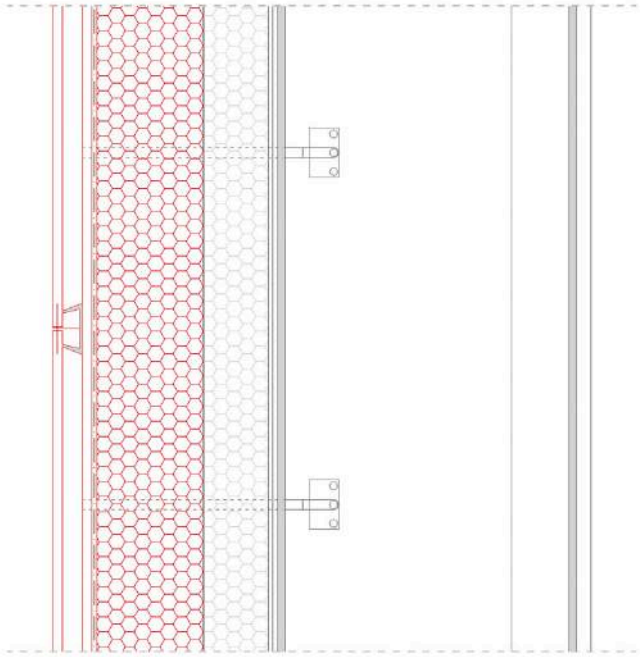
Retrofit roof detail

The wall R value will be doubled, from 3 W/m2*k to 6 W/m2*k

The intervention consists of taking off the actual cladding layer that is made of bricks, which depth is 12 centimeters. Such room will be employed for the installation of an extra layer of insulation and a new cladding. In order to install the maximum insulation possible, the cladding material should be thin.



Baseline wall detail



Retrofit wall detail

DuPont Corian solid surface will be used for the exterior cladding because of the possibility to create customized panels, with a

seamless look if desired, therefore it suits for cladding irregular geometries like the curved balconies facades' tracts.

It is chosen also because it has a small depth: 1,2 centimeters, that still allows resistance against winds. Plus it adds a unique mix of character and personality to the structure while maintaining a sleek finish, nonporous homogeneity, resistance to weathering agents and UV rays, and easy graffiti removal.

The thickness of the insulation added is of 7,5 centimeters because the room that this layer plus the cladding, will occupy, is supposed to equal the baseline wall depth, in order not to replace the actual windows flashings.

It will have a predominant dimension, the horizontal one. On the regular areas of the facades, there will be installed panels that are 0,70 meters height and 3,65 meters long. They will be mounted upon a frame of vertical and horizontal uprights that will be connected to the steel structure through brackets.

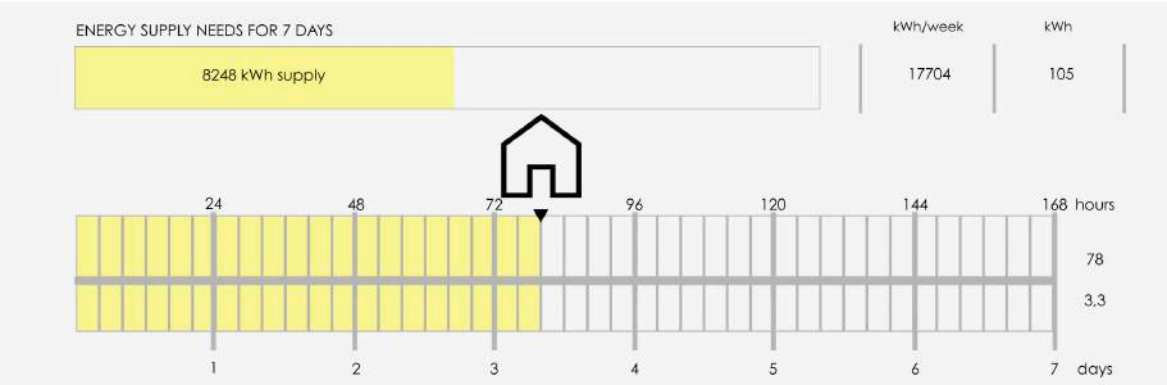
The aperture of balconies presents the challenge of connecting the existing wall to a new one where a window frame is installed. Joints will be treated carefully in order to prevent windows' overturning and/or water to enter. The first risk is eliminated through the sealing of the frame to the beam above it, the second is avoided placing flashings at the top and bottom of the frame and taking care of the way they are mounted and the place.

The slab's portion that at the baseline status is used to be an indoor floor and that in the retrofit project is the balcony's, requires a better insulation. The better design choice for addressing such demand, is to wrap the slab with insulating material on the above, exterior and below surface. The height of the balcony's floor components should not overcome the interior floor altitude in order not to let water in. The floor mounted on the balcony will be 1,5% sloping outward, aiding the rainwater drainage.

-STRATEGY 3: COMPONENTS INSULATION RETROFIT OUTCOME

The third retrofit does not turn into a huge reduction of the Energy Use Intensity, nonetheless it is helpful for reducing the heating energy demands and increasing the indoor comfort.

The autonomy time increase is of one hour only, but now that the envelope is tighter, during winter, occupants can enjoy comfort indoor temperatures without excessive energy consumption for heating purpose.



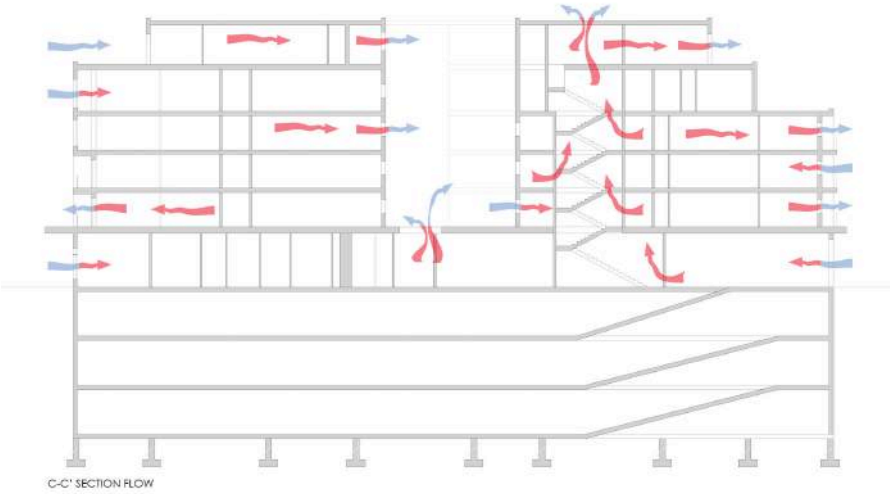
-STRATEGY 4: NATURAL VENTILATION

The insulation enhancement caused a big reduction in the amount of energy needed for heating purposed, but the amount of energy necessary for cooling did not change that much.

A passive strategy that could address the latter is to increase natural ventilation. The way to do it is through the augmentation of the percentage of windows that could be operable.

-STRATEGY 4: NATURAL VENTILATION RETROFIT

The baseline percentage is of 5%, three different scenarios have been analyzed as part of the bundle of strategies adopted so far. Each one has a different percentage of operable windows the one that better performs better has a value of 10%.



The scenario with the best performance is mainly dictated by the highest reduction in annual energy consumption and in annual energy use per gross internal area. Other parameters that are taken into account are: annual utility cost, annual space cooling, annual space heating and annual grid fuel used. Indeed increasing natural ventilation provides an overall energy consumption reduction through the decrease of cooling loads and equipment loads. The downsize is that in case the flow is augmented excessively, it would turn into way too high heating loads, grid fuel used and comprehensively of energy consumed.

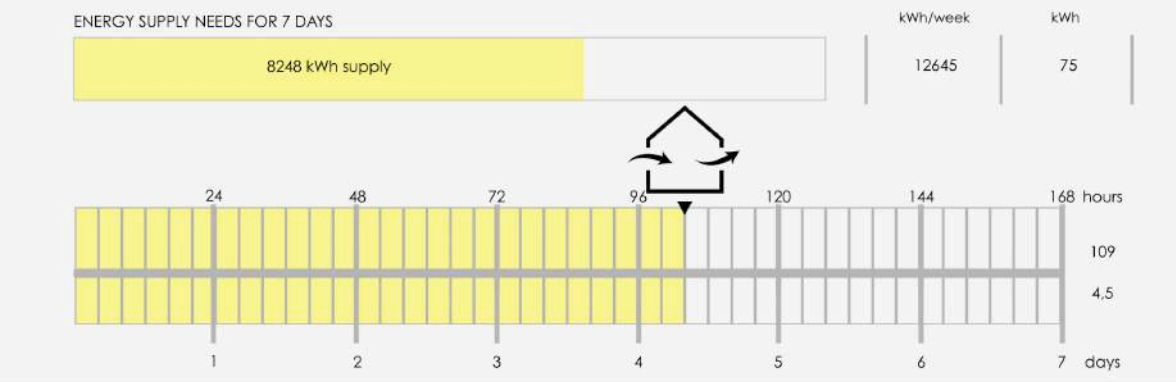
The baseline ventilation was single sided, through this intervention we can get a cross and stack ventilation flow. The latter is obtained through the presence of operable skylights in the stairwells top roofs.

-STRATEGY 4: NATURAL VENTILATION RETROFIT OUTCOME

Employing natural ventilation is for sure an advantage with the raising concerns regarding the cost and environmental impact of energy use.

It provides ventilation through outdoor air to ensure safe healthy and comfortable conditions for building occupants without the use of fans.

This means that it turns into a free cooling service without the need of the HVAC.



Indeed while the energy demand for heating is somewhat sacrificed, the cooling one is cut in half from the 238 831 kWh/year amount obtained with the third retrofit to the 122 961 kWh/year amount. The decreasing usage of mechanical systems make equipment energy demand fall from the 392 383 kWh/year value obtained with the third retrofit, to a 198 675 kWh/year value.

An additional bonus is that no longer will any noisy fan be a concern.

The Energy Use Intensity further slumps to 45 kWh/m2/year, that is a big declining compared to the 65 kWh/m2/year obtained with the three retrofits.

Weekly energy demand drops of 5059 kWh/week, getting to 12 645 kWh/week energy demand. Meanwhile 31 hours are added to the

autonomy time, reaching a total of 109 hours and overcoming the milestone of 4 days of autonomy.

-STRATEGY 5: AIR SOURCE HEAT PUMP

Increasing ventilation rised up the heating energy demand. Thought it is not a big deal, nonetheless there is something that can be done in order to reduce the amount of energy consumed for heating purposes.

The baseline building has a condensing boiler whose COP coefficient of performance is a sort of a good one (0.85), but it could never be as good as heat pumps' COPs are.

A heat pump could be an air to air, water to water, water to air or geothermal one.

For the building object of design, the choice was amongst air source and geothermal source. At the very beginning the geothermal heat pump sounded like the better choice because of its peculiarities.

For this system the ground serves as a heat source during the winter and as a heat sink during the summer. It works better during colder seasons because it is buried several meters (about 51 for this project) below ground level, where the earth is warmer than usual because of the tectonics activity happening down there. There is an empty not-built area opposite the building, which could have been used for diving the loop field.

In spite of all the advantages the geothermal brings, said solution is not flawless. Indeed the main purpose of the thesis project is to have a building that could be a shelter during and after natural hazards, especially earthquakes. The pipes of the geothermal loop field are flexible, but the joints are made of cast iron, which would snap during a quake. Thereupon the pump used for heating will be an air to air one.

An air source heat pump works by absorbing the heat from the outside air, concentrating it and using the resulting energy to heat your home. In most homes this energy heats water that is then used in under floor heating, air convectors or even radiators. In this particular case radiators are used for distributing the heat produced.

Compared to a geothermal pump, the ASPH still performs well in temperatures as low as -15 degrees Celsius. Looking at the ASHRAE Standard's weather data conditions of Portland, it is clear

that the city's temperatures range never falls below the -10 degrees Celsius, so the selection of the air to air system will work well.

They provide a low level of heat, but consistently. For this reason they are usually cheaper to run than electricity-based heating systems, but may work out more expensive than gas heating.

Air source heat pumps are also easy to install in retrofit projects, like the one treated during such thesis work.

-STRATEGY 5: AIR SOURCE HEAT PUMP RETROFIT

It is planned that the new pump will be mounted replacing the existing boiler, which was in the garage entrance's repaired from pedestrians' traffic and strong winds, so that its efficiency is not going to be affected.

Fans and compressors make noise. The location by the garage door is perhaps the one furthest away from windows, and habitable rooms.

Every residential heat pump sold in the United States of America is dotated by an EnergyGuide label, which shows the heat pump's heating and cooling efficiency performance rating, comparing it to other existing models and makes.

Air source heat pumps' heating efficiency is indicated by (HSPF) the heating season performance factor, that expresses in Btu the total space heating required during the heating season, divided by the total electrical energy consumed by the heat pump system during the same season, expressed in watt-hours.

Cooling efficiency instead, is indicated by the SEER, the seasonal efficiency ratio, that is the total heat removed from the conditioned space during the annual cooling season, expressed in Btu, divided by the total energy consumed by the heat pump during the same season, expressed in watt-hours

The HSPF indicator estimates the efficiency of either the compressor and the electric- resistance elements.

The SEER is the amount of an air source heat pump's cooling efficiency. Usually, when the SEER rises up, so does the cost. The

energy savings, can return the higher initial investment several times during the heat pump's life. A brand new heat pump replacing the baseline boiler, could largely drop down energy uses.

Since Portland is located in a colder climate, it is important to focus on getting the highest HSPF feasible. In northern regions HSPF has more relevance respect to SEER.

The building requires an MCAEY air-cooled reversible heat pumps which overall installed power density is 470 kWh. The heat pump designated for clinic, offices and bank will have a power of 60 kW. The other one will have

a power of 420 kWh and will be designated to satisfy the residential floors necessities.

The system dimensions and the height of the mounting avoids that the ASHP is an obstacle against car and pedestrian traffic.

The system's frame is a self-supporting galvanized steel one, protected with polyester powder painting. Panels are easily removable for maintenance and service activities.

GENERAL FEATURES

The air source heat pump's frame consists in a self-supporting galvanized steel one, painted with polyester powder that helps to protect it. Panels can be removed easily for maintenance and service activities.

The pump's compressors are hermetic-scroll type, equipped with overload protection by a klixpn and complete with oil sight glass.

In order to avoid excessive noise, they are installed on vibration absorbing rubber and localized within a closed compartment. The latter helps in order to reduce the noise emitted while allowing entrance in case there is the necessity of service and maintenance activities even when the unit is switched on.

The evaporator is a brazewelded plate type. Its circuit is made in a manner that allows a consistent cooling of the entire water flow as well as when it works at full or partial load. The material used for insulating the evaporator, is made of flexible closed-cells lining. Installing a differential pressure switch that will stop the unit in case

there is no water circulation on the plate-to-plate evaporator, would be prudent.

The condenser is made of copper pipes and batteries bedridden on aluminum. By data sheet there was the option of choosing between the installation or not of a protection grid, since the latter was available, consequently it got installed.

The fans are axial with aerodynamic outline blade, made of aluminum and mg. The refrigerant circuit units are supplied each with a filter dryer, sight glass, thermostatic expansion valve, service valve.

Since the temperatures in Portland can reach values below zero degrees Celsius, there are devices installed for the protection of the refrigerant circuit. Said devices are the following: manual reset high pressure switch and automatic reset low pressure switch, antifreeze thermostat. In addition to that there are mounted a safety thermostat on compressor discharge line, a 4-ways valve, a solenoid valve, a check valve and a liquid receiver.

The electric board consists in a weather proof type with protection grade IP54 installed in the compressor box in order to allow for maintenance activities and services even when the pump is switched on. The heat pump will have a demand-defrost control which will minimize defrost cycles during seasons of low temperatures. Said process would reduce supplementary and heat pump energy use.

-STRATEGY 5: AIR SOURCE HEAT PUMP RETROFIT

OUTCOME

It has a COP of 3.1 which is way higher than the boiler's 0.85. Plugging this data into the energy performance software, the new assessment shows a further reduction in the Energy Use Intensity value, that goes from the 45 kWh/m2/year achieved through the fourth retrofit to a 40 kWh/m2/year. Looking at the EUI break down, such fall is possible thanks to the decrease of cooling and equipment demand and mostly from the enormous heating demand dwindle.

The energy demand goes from the last one achieved of 12 645 kWh/week to 11 241 kWh/week, this will enhance the self-sufficient time by 14 hours, going up to 123 hours, that equals five entire days.

-STRATEGY 6: MECHANICAL VENTILATION WITH HEAT RECOVERY

A further increase to the amount of operable windows would have dropped down the cooling energy demand even more. The reason why it was kept under a 10 % value is because increasing the quantity of natural ventilation even more would have turn into an excessive increase of energy demand for heating purposes.

Draughts create a similar problem. While they serve to ventilate a home, they are a major source of heat loss and can make rooms feel uncomfortably chilly.

Having adequate ventilation in your home is still important for good health. It removes moisture and stale air along with smells and pollutants, and replaces them with fresh air to breathe.

Modern energy efficient homes are more airtight (less draughty) than older buildings because they have to follow specifications for air-tightness in the Building Regulations. Because of this modern homes are sometimes fitted with Mechanical Ventilation with Heat Recovery (MVHR) systems also known as ‘whole house ventilation’ systems.

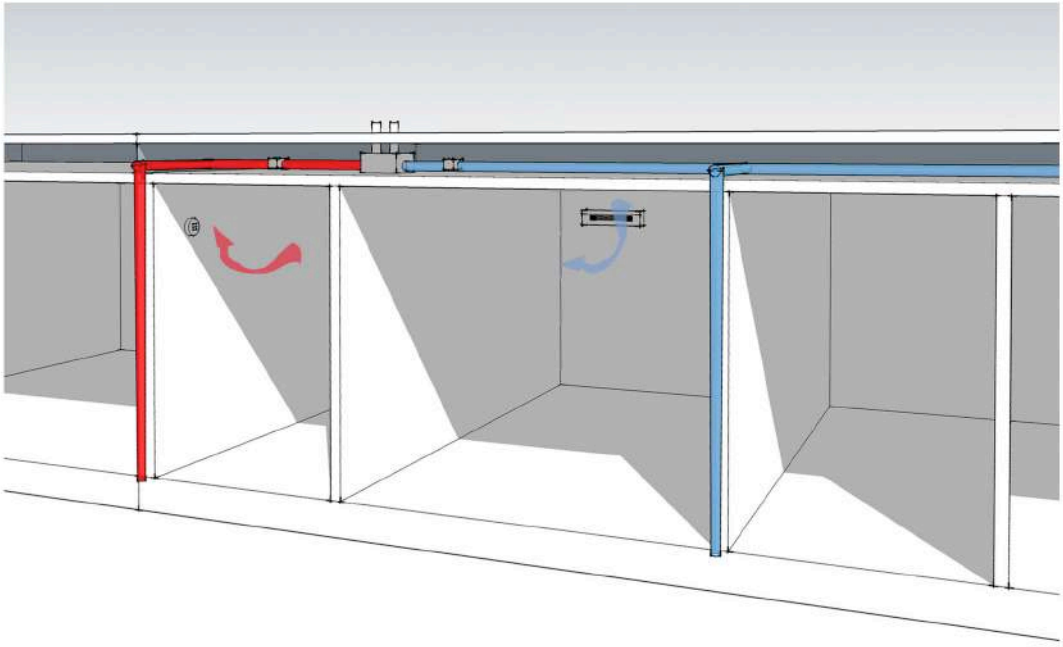
How they work: Whole-house MVHR systems extract warm, damp air from the home and draw in fresh air from the outside. The warm, extracted air is passed through a heat exchanger to recover the heat before being expelled outside. The cool, fresh outside air is also passed through the heat exchanger, without coming into direct contact with the pollutant air where it is pre-warmed before being pumped in to the property.

-STRATEGY 6: MECHANICAL VENTILATION WITH HEAT RECOVERY RETROFIT

The mechanical ventilation with heat recovery systems will get and distribute the heat with a series of concealed ducting in ceiling voids, leading to the heat exchanger unit in the loft or another void in the home. Units will comprise also an automatic boost setting that will be switched on when generating excessive moisture when cooking or using the bathroom.

Mechanical ventilation with heat recovery systems run continually at 80% efficiency and are inaudible during the normal use.

A good maintenance practice would be to keep the systems' filters and fans clean to ensure effective operation.



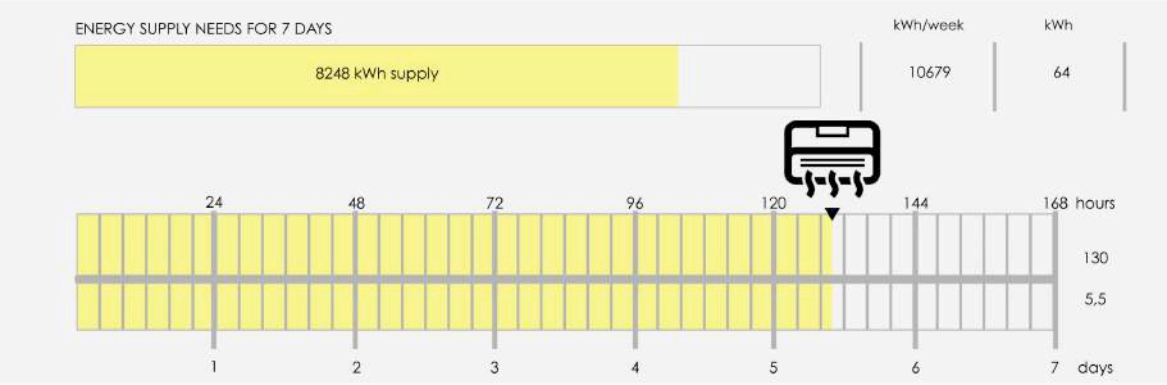
-STRATEGY 6: MECHANICAL VENTILATION WITH HEAT RECOVERY RETROFIT OUTCOME

Pre-warming the fresh air, Mechanical Ventilation with Heat Recovery heat loss is largely avoided, whilst savings and a health and well ventilated home will be ensured.

MVHR drops down the energy demand for cooling, heating, and equipment needs, so that the Energy Use Intensity falls to 38 kWh/m2/year.

This intervention represents a great goal because it allows the building to meet the 2030 challenge which is met if the Energy Use Intensity is equal or below to 39 kWh/m2/year.

Weekly energy value requirements go down by 562 kWh/week, getting to the amount of 10 679 kWh/week helping the autonomy time to increase by seven hours, satisfying 130 hours of energy autonomy.



-STRATEGY 7: RENEWABLES

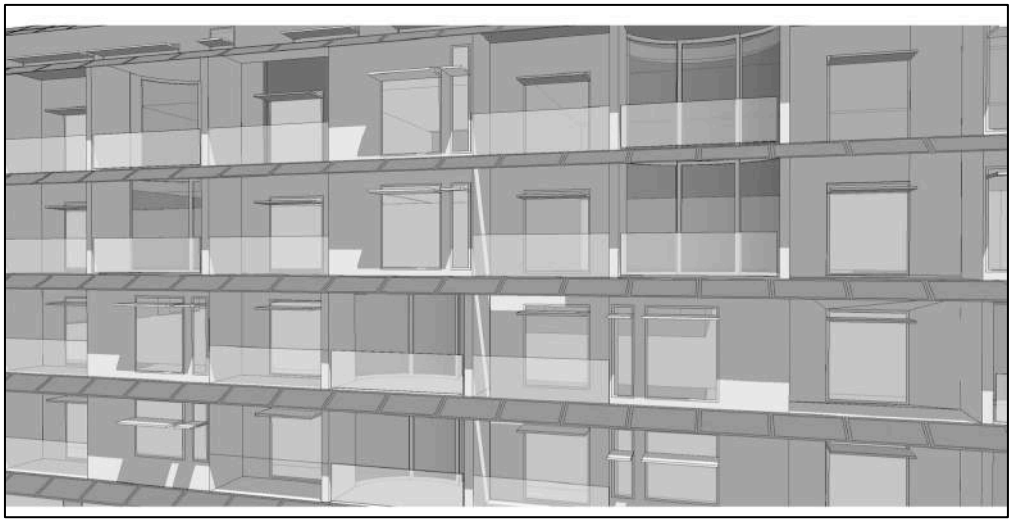
The six passive strategies employed so far helped significantly much on enhancing the autonomy time, but they didn't allow the fulfill of the seven days self-sufficiency target.

The engine power generator baseline fuel tank could be replaced with a bigger one, but a greener and longer-lasting solution is to install a renewable system.

-STRATEGY 7: RENEWABLES – PHOTOVOLTAICS

INTRODUCTION

Going solar brings along a series of advantages. It increases the building's value, boosts the United States' energy independence and protects the environment.



Photovoltaic panels are designed to be installed on the top roof through a simple roof mount system. They will also be integrated into the south, west and east facades, using a mounting that allows their static performances without being too heavily visible.

Each installation is part of the whole system and has its own characteristics:

Module installed: value of the power of the module installed

Quantity of panels: amount of modules mounted

Array type: The array type describes whether the PV modules in the array are fixed, or whether they move to track the movement of the sun across the sky with one or two axes of rotation.

System losses: The system losses account for performance losses you would expect in a real system that are not explicitly calculated by the PVWatts® model equations.

Category	Default Value (%)
Soiling	2
Shading	3
Snow	0
Mismatch	2
Wiring	2
Connections	0.5
Light-Induced Degradation	1.5
Nameplate Rating	1
Age	0
Availability	3

Tilt: The tilt angle is the angle from horizontal of the photovoltaic modules in the array. For a fixed array, the tilt angle is the angle from horizontal of the array where 0° = horizontal, and 90° = vertical. For arrays with one-axis tracking, the tilt angle is the angle from horizontal of the tracking axis. The tilt angle does not apply to arrays with two-axis tracking.

Azimut: the azimuth angle is the angle clockwise from true north describing the direction that the array faces. An azimuth angle of 180° is for a south-facing array, and an azimuth angle of zero degrees is for a north-facing array. The default value is an azimuth angle of 180° (south-facing) for locations in the northern hemisphere and 0° (north-facing) for locations in the southern hemisphere. These values typically maximize electricity production over the year, although local weather patterns may cause the optimal azimuth angle to be slightly more or less than the default values. For the northern hemisphere, increasing the azimuth angle favors afternoon energy production, and decreasing the azimuth angle favors morning energy production. The opposite is true for the southern hemisphere.

The azimut angle for different orientation of the panels are described as following:

Heading	Azimuth Angle
N	0°
NE	45°
E	90°
SE	135°
S	180°
SW	225°
W	270°
NW	315°

-STRATEGY 7: RENEWABLES – PHOTOVOLTAICS

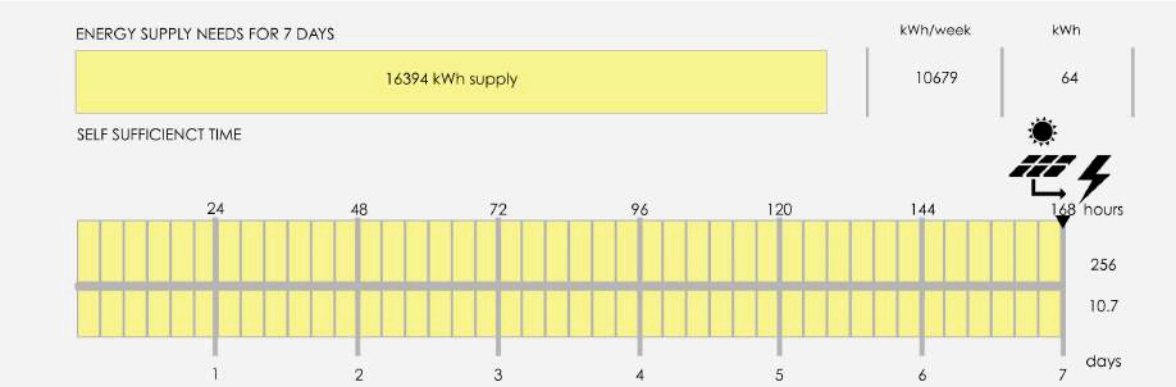
INTRODUCTION OUTCOME

The system productivity is calculated through PVWATTs Calculator. It consists of a software where there need to be plugged in all the data of the system mounted on each side like for instance: array type, tilt and orientation (azimuth).

ROOF MOUNTED						
Pvs arrangement	n° panels	n° rows		kW		
A	12	10	115			
B	11	8	80			
C	10	13	124			
D	26	8	204			
E	9	21	182			
		TOT n	705			
		standard panels		300		
		size	211500	211,5	**rendim**	**262077** kwh/year
SOUTH SIDE						
A	5	37	185			
B	1	26	26			
C	1	18	18			
		TOT n	229			
		standard panels		155		
		size	35495	35,495	**rendim**	**41677** kwh/year
WEST SIDE						
A	18	5	90			
B	18	5	90			
C	1	30	30			
		TOT n	210			
		standard panels		300		
		size	63000	63	**rendim**	**54428** kwh/year
EAST SIDE						
A	8	5	40			
B	20	5	100			
		TOT n	140			
		standard panels		300		
		size	42000	42	**rendim**	**34805** kwh/year
		standard panels total OUTPUT				392987 kwh/year

Each side of the building has a different solar incidence that leads to a different productivity. All of the outcomes have been summed up on an excel file. The productivity per year results to be 392 987 kWh/year.

This means that in case of a black-out the building's power supply is not only given by the energy supply generator, but also by the Photovoltaic system. Translated into numbers, in seven days the energy supply generator brings 8248 kWh/week; the photovoltaic system, on average weather conditions, produces 8146 kWh, summed up the building has 16394 kWh available per week in case it needs to work off-grid.



4. CONCLUSION

In the past years, a growing number of cities have been making plans and enunciating targets to achieve urban resilience.

Even thought there have been various conferences that highlighted the importance of resilience, they apparently didn't clarify the meaning of this term, which instead has been ribbing around as sustainability has been for over ten years, which basically is with no substance and as a label to fit conveniently on previous programs.

First of all there is the need to clarify what is resilience and what is sustainability instead. Indeed some people say that resilience is replacing sustainability in the guidelines of urban planning and building design.

But what is city resilience? How does it relate to sustainability?

This study aims to clarify such questions. According to Timon McPearson in "The Rise of Resilience" the latter needs to be integrated with sustainability because " the resilience we are trying to plan and design for, actually helps us move towards desired future sustainable system states, and not undesirable ones. Current resilience planning and management efforts may just as likely be locking our urban systems into undesirable trajectories, away from sustainability (McPhearson, 2014)[5]"

Sustainability shares some goals with resilience, but it is not the same. If not analyzed carefully, they can almost be opposed to each other.

As a consequence, resilience carefully integrated with sustainability should be a primary objective in the planning of future cities and in the interventions of retrofitting. In the light of the aftershocks scenarios analyzed, the concepts of disaster resilience and sustainability became extremely relevant.

All the work described so far, was made as a way to show how much sustainability is important, not only for the global warming, but also as a tool to withstand life-threatening situations, like the ones caused by natural hazards. Thereupon such project displays a way to integrate sustainability and resilience.

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[5] Timon McPhearson, The Rise of Resilience: Linking Resilience and Sustainability in City Planning, 2014, New York, The Nature of Cities

Starting from what the latter is and how it can be estimated, the process applied during the two indicators' assessment and enhancement, is supposed to serve as a guideline that can be generally applied for the treatment of other buildings' resilience as well.

WATER SUPPLY

Because of the criticalness of the clinic's services, the water storage amount available is first addressed to satisfy its functions. The remaining water supply is employed for the office and residential area supply.

The baseline self-sufficient time for these areas reaches 42:30 hours for potable water uses and 18:00 hours for not potable water uses.

The water storage can't be increased too much for two reasons: a structural one and a hygienic one.

The structural one consists in the fact that too many storage tanks in the building may cause an excessive live load that could put at risk the static properties.

The hygienic one consists in the fact that water needs to flow continuously in the water pipes, otherwise if it stays static for too long it would lead to watertight and development of bacteria.

The strategy of fixing leaks and replacing the water fixtures in order to reduce water consumption, brings to a good advance in terms of autonomy time enhancement, but still, they don't allow the target to be met. The autonomy time after the application of said strategies gets to 49 hours for potable water uses and 29 hours for not potable uses.

Rainwater harvesting and grey-water reuse bring along the possibility to have water supply available respectively for potable water uses and not potable water uses for 2:00 hours a day and 3:30 hours a day.

This means that the target can't be entirely met, but everyday there will be a time-span during which the fruition of certain services is possible.

ENERGY SUPPLY

The energy supply indicator happened to be treated and enhanced with a little less limits than the ones encountered during the project of improving water supply self-sufficiency.

This consideration comes from a series of traits of such indicator that have been faced.

Based on how much the technology developed so far, it seems that the solutions for the reduction of energy consumption could be obtained through different paths.

One way is to develop a design retrofit through the creation of a shape and the windows' position and shading arrangement/re-arrangement.

A path that brings into a more detailed scale, is to enhance the building's components (walls, roof, windows, floors) performances.

Yet another route that could be taken consists into the replacement of the existing systems (for instance HVAC & lighting) with newer and more energy-efficient ones.

Once all of the passive strategies that could be employed are over, the selection of the active strategies that could be introduced begins.

Because of Portland's weather data about wind speed, installing a wind energy conversion system would be useful only if the building reaches more than 10 floors.

Such situation leads to the decision to create a Photovoltaic system integrated in façade.

When it comes to storage, energy is easier to handle than water. Comparing water tanks and batteries: energy may need space but doesn't weight as much as water. The first doesn't have issues in case it stays stored for too long, and does not provoke any excessive live load that brings to a hypostatic scenario of the building.

The strategies applied can be recognized of two types: the ones that reduce the energy consumption and the ones that increase the energy storage.

In the first type there are the following strategies:

1- Daylight design retrofit
2- LED fixtures replacement
3- Insulation enhancement
4- Natural ventilation improvement
5- Substitution of boiler with air source heat pump
6- Integration of UTAs with Mechanical Ventilation With Heat Recovery

The second type of strategies consists of:

7- Photovoltaic system introduction

All of the ways that can be taken to decrease the energy consumption, were useful to increase the autonomy time, overall value of self- sufficient time varied consistently from the baseline status to the retrofit one: respectively the value goes from 42 hours (less than two days) to 130 hours (5 days and a half).

Numbers make evident that passive strategies are not enough so there is the necessity to introduce a Photovoltaic system with a series of batteries in order to store energy. The energy produced allows to get through the time that was missing to reach the target.

In this way such project demonstrates how employing sustainable-related strategies is essential to reach the resilient status.

Moreover a secondary advantage that said retrofit bring along is the fact that through all of the actions taken bring to an Energy Use Intensity value that is low enough to meet the 2030 challenge (Energy Use Intensity lower than 39 kWh/m2/year).

For the specific Cascadia quake, Oregon’s seismic resilience could be achieved encouraging a culture of awareness and preparedness in relation to the seismic vulnerability of the energy sector.

If the above described process would be applied to selected buildings, it could create a net of constructions that have structure resistance, water and energy supply enough to go over stressing situations.

The core of the vulnerability to a Cascadia earthquake and to natural threats in general, is not the hazard itself, but the inadequacy of our built environment.

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