# Toyama's Resilient Compact City Design with Underground Layered Decentralized Grid Architecture and Water Management Infrastructure

## City Overview

Sitting on an alluvial plain formed by the Jinzu and Joganjii Rivers and sandwiched between the Japanese Alps and the Japanese sea, 2119 Toyama boasts a population of 2,000,000. Meaning "rich with mountains," Toyama's traditional geographic isolation and historical recovery from WWII devastation lead to a robust entrepreneur economy with innovations in high tech robotics, nuclear and solar engineering, and pharmaceutical and glassmaking industries. This "City of Medicine" and past Rockefeller award-winning city became the world's elixir of resiliency due to its cultural heritage, compact city planning, and smart microgrid technologies.

Toyama's commitment to the Confucian Ideal of realization of oneself and others, coupled with its entrepreneurial spirit, and played out with communal, cross-generational bonding, produces resiliency at the heart of Toyama's people and culture. Toyama's government encourages mental and physical self-improvement and center-city living through its downtown rent-controlled elderly housing, discounted Odekake transit passes, and free memberships to Kadokawa health centers. Attaching senior citizen clubs to schools and daycares with community garden plots, and providing discounted senior admission passes to city museums when accompanied by young children helps to cultivate intergenerational relationships.

## Futuristic and Innovative Infrastructure

Compact City Design (CCD) and its infrastructural benefits lies at the heart of Toyama's resiliency plan. CCD consists of three phases:

- Phase 1: Establish a compact city around efficient public transportation (including through the city center) and concentrate residential living and city services within easy access to transportation
- Phase 2: Revitalize the downtown with improved cultural/civic amenities and economic development
- Phase 3: Improve energy generation, transmission, and distribution

City planning begins along centrally-located former Light Rail Lines where autonomous private Nextpods can link together, like a mass transit system, to transport citizens throughout the heart of the city. Amenities such as restroom or dining pods can link to basic travel pods, allowing uninterrupted and independent mobility for citizens throughout the city. Along major transportation arteries, concentrated residential living like Machinaka, one of many high-rise residential neighborhoods, places Toyama's population within convenient access to industrial, commercial, and cultural amenities.

Revitalization of downtown historical resources such as Toyama Castle, Hie Shrine, the World War II Peace Reconstruction Memorial & Statue of Tennyo, Grand Plaza, Kansui-park, Toyama Glass Art Museum and Institute, and other tourist destinations has unified the population around its shared heritage. Therefore, Toyama becomes a more educated and interconnected city.

Besides a compacted and culturally enriched downtown, Toyama's clean, sustainable, resilient, and responsible energy generation, distribution, and waste management solutions provide multiple infrastructural benefits to Toyama's society. The Shiraiwa Sabo Dam produces hydroelectricity but also controls river flooding by systematically releasing water into nearby rice paddy fields or into the Matsukawa underground water retention system (built in the 21st century to hold the excessive stormwater created by climate change). Geothermal heating drawn from magma chambers in Mount Tate heat city buildings but also melt snow on Toyama's mountain roads. In the downtown, Toyama utilizes solar roads, which transfer solar and pressure energy from photovoltaic paint and piezoelectricity through mutual induction plates to power vehicles. Vehicles' emergency reserve power comes from algae, a carbon neutral fuel and a dietary nutritional base for Toyama's citizens. Solar roads also power LEDs in solar tiles, which are programmed to efficiently direct traffic. Waste is managed through Toyama's Ecotown program, a government initiative, that educates the public to reduce, reuse and recycle and showcases new technologies like Kankyo Seibi's industrial plastic regeneration facility and waste to energy incinerators as well as its omniprocessor, which converts human waste into energy, ash fertilizer, and even fresh drinking water.

**City Services**

City services are highlighted by Toyama's educational philosophy and disaster response initiatives. Beginning in elementary school and throughout adulthood, Toyama instills the Japanese philosophies of  jijyo (self help), jyojyo (mutual help), and kojyo (public help) to nurture resilience within individuals and promote public service and intergenerational relationships. Post-secondary education in Toyama University features engineering internships with companies like Sumitomo Electric Nichiden Co., Ltd. and Nachi-Fujikoshi Corporation, manufacturing companies whose products help to manage and monitor Toyama's solar roadways and underground infrastructure. A collaboration of politicians, corporate CEOs and citizen volunteers develop and oversee the "Disaster Training and Awareness Program" (DTAP). Regional leaders are trained to disseminate information and educate volunteers, monitor local conditions and forecasts, and coordinate emergency rescues (including the location and extraction of vulnerable populations), manage shelters and evaluate results. The DTAP is a cross-generational example of Toyama's "helping" philosophy in action.

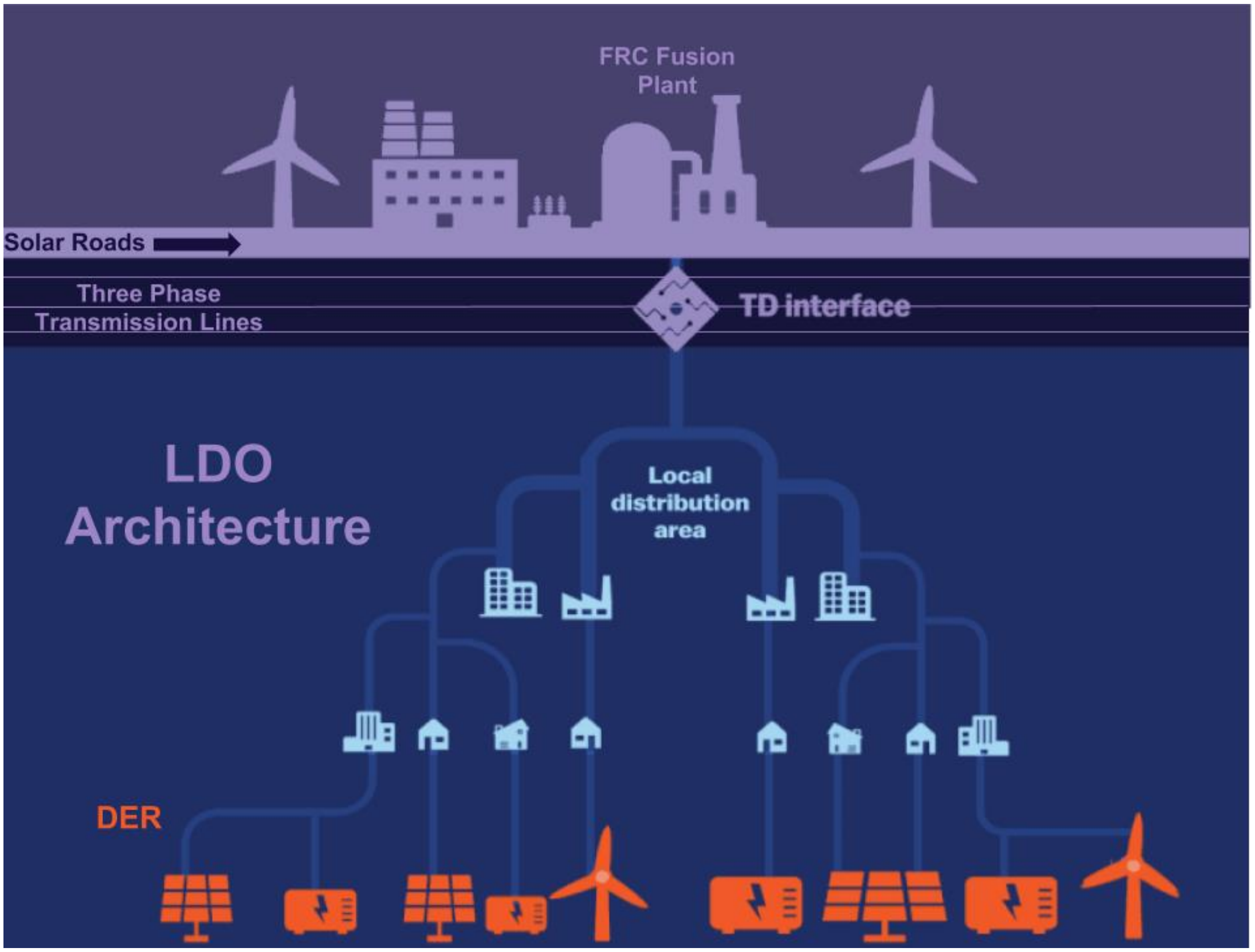
**Problem Definition**

Excessive winter snowfall and spring melting with historical rainfall has threatened lives and damaged infrastructure, including Toyama's power grid. Short-term damage from flooding includes swollen rivers, washed out roads, power outages, and the inaccessibility to particularly vulnerable (sick, young, elderly) populations. Traditional power lines are susceptible to falling, leaving live wires exposed and the possibility of electrocution. Long-lasting effects include the excessive costs of ongoing infrastructural repair, damage to residential living, commercial businesses, and tourist attractions that are necessary for quality of life and local economic prosperity. Although past flooding was prevented with the construction of Shiriwa Sabo Dam and rerouting the Jōganji River, climate change in the 21st century brought excessive rain that required even more innovative solutions.

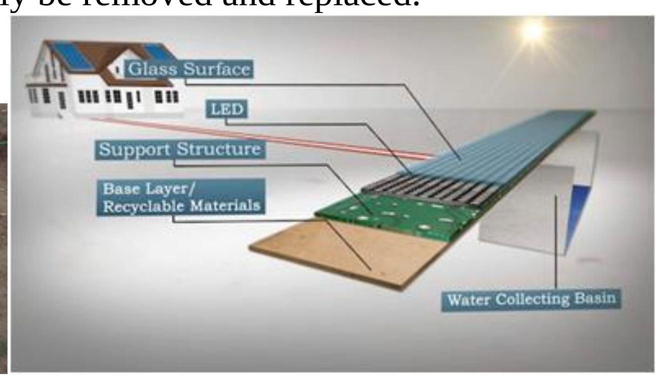
**Solutions**

Toyama solved historic flooding with improved underground water management and energy infrastructure. Toyama redirects excessive water not contained by Shiriwa Sabo Dam and surrounding rice paddy fields into storm channels built along roadways and into the banks of the Jōganji River and to Matsukawa underground water retention tanks, where it is stored for water consumption or controlled releasing into Toyama Bay.

Toyama's power is transmitted within protected trenches along solar roadways. Generated high voltage electricity travels from a Field Reversed Configuration (FRC) Nuclear Fusion plant through underground three-phase transmission lines to water-sealed substations, where transformers downsize voltage before it is consumed. Toyama's grid utilizes Layered Decentralized Optimization (LDO) architecture, a microgrid bottom-up approach that manages energy supply and demand at the local level. Capable of working independently from the transmission grid, autonomous local energy producers called Distributed Energy Resources (DERs) within each microgrid generate the majority of Toyama's energy needs. DERs are incentivized to maximize production and minimize costs and usage. Excess energy is exchanged upward at a single point of contact, in transformer stations along the TD interface and to the transmission grid under solar roadways.




Solar roadways are constructed with tiles containing a conductive electrode painted with a mixture of titanium oxide, cadmium nanocrystals, alcohol, and water and generate electrical current from sunlight and moving vehicles. A layer of strong, shatter-resistant glass houses LEDs, sensors and other electronics within the tiles. Once installed, solar road repairs are also less costly and intrusive to traffic, as any damaged panel can quickly be removed and replaced.




Stored energy is drawn from a man-made reservoir in Mount Tate, and released back into Matsukawa's storage tanks during high energy demand. Besides pumped hydroelectric, Toyama stores additional energy in white-hot molten silicon-filled graphite containers, which are heated by Toyama's underground magma chambers.

Toyama's Quantum Communication System (QCS) provides instant emergency notifications, managing and tracking of infrastructure. QCS monitors urban radar, rainwater estimation, and outflow systems which detect cumulonimbus cloud formations, rainwater intensity and its predicted effects on the stormwater management system. QCS sensors also monitor vibrational changes and fluctuations in electrical output and command LEDs in road panels to alert the public to water and grid hazards, to redirect traffic as necessary, and to provide emergency vehicles priority access to any situation.

In addition to providing safer and more efficient transportation, power distribution and consumption, and emergency management, Compact City Design with QCS-monitored underground infrastructure, including LDO microgrid architecture provides a multitude of benefits: a scalable, locally controlled, and optimized electric grid, a cleaner environment, a revitalized downtown with improved accessibility for the elderly, higher public transit usage, less traffic and more time efficiency, improved intergenerational relationships, a more cultured and educated citizenship, and increased tourism.

## Trade-Offs and Engineering Disciplines

Inverting the grid structure with LDO architecture and installing solar roadways was a time-consuming and costly endeavor that led to short-term market fluctuations in energy prices. Excavation and solar tile installation disrupted traffic. Expanding storm drains and installing underground transmission lines, stations, and sensors at DER sites added further cost and time. Toyama's solution also required working through the bureaucratic legislative process as the construction of solar roadways and LDO inversion required new legislation from Japan's central government.

Toyama utilized biomechanical, mechatronic, and electrical engineers to design, develop and program the Photovoltaic cells, algae biofuels, solar roadways, and microgrids.  Automotive engineers designed the Next Pod transportation network. Civil and geotechnical engineers developed the compact city design, road layout, and underground infrastructure. Social engineers created Toyama's intergenerational educational programs. Through compact infrastructural design, Toyama's engineers utilized innovative energy generation, distribution, and transportation to make its city like its people, a model of resiliency.

Text minus title = 1467 words

3 Graphics = 29 Words

1496 Total Words

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