The Resilient City: Kaifukuryoku

こんにちは (*Kon'nichiwa*)! Welcome to Kaifukuryoku (resilience), a vibrant island city of pristine beaches, lush mangroves, verdant hilltops, and sparkling, marine coral reefs. Located in the Prefecture of Okinawa, on the East China Sea, Kaifukuryoku rises from the remains of Miyakojima, which was destroyed by a devastating tsunami in 2033. The island is located in a sub-tropical zone, and the climate is warm and humid. In 2118, Kaifukuryoku is home to 55,000 people with a median age of 65. (Residents live to the age of 120).

Kaifukuryoku draws tourists, scientists, and engineers for luxurious resorts, engineering schools, and traditional celebrations. These include Miyakojima Tsunami Remembrance Day, Cherry Blossom Festival, and Buddha's Birthday. Their economy has flourished from the tourism and textile industries.

Kaifukuryoku’s infrastructure and resources are protected by the Tsunami Intelligent Protection System (TIPS). TIPS is a multifaceted system comprised of mangroves to dampen waves, coral reefs to disrupt waves, vertical evacuation buildings, evacuation pods, seismic sensor networks that provide data to the early warning system, and the Tsunami Protection Gate (TPG). Buildings are either elevated off the ground to let the water flow through or turned at an angle to direct water away.

Residences/commercial buildings, transportation, and energy are intelligent and linked. Single-family houses and condos, with *hogyo* (pyramid) roofs and *engawas* (outer corridors), are nestled in hilltops, natural barriers from tsunamis. Houses have catchment systems, smart meters, efficient solar panels, energy storage systems, and integrated smart home networks. Kaifukuryoku's intermodal transportation includes Battery Backup Pods (BBP). BBPs are green, operating without an internal combustion engine. They charge instantaneously during off-peak times and travel autonomously on local roads and elevated superhighways. They learn citizens' personal schedules and preferences and can also be used for evacuation. As a bonus, BBPs can be used as an emergency power source to microgrids.

Kaifukuryoku's state-of-the-art healthcare and education technology make it a safe place to live. Residents are injected with a biologically powered chip at birth that monitors health and location. Kaifukuryoku's education includes robotic teachers, virtual-reality classes, and planetary field trips.

Kaifukuryoku's innovations and resilient elements include rotating vertical farms and the TPG. When a tsunami is detected by the early warning system, the TPG closes to protect the city. Rotating vertical farms provide fresh local produce, increase food production, provide year-round crop production, and provide optimum sunlight for plants.

The city addresses resiliency beyond power grids through innovation. Homes are resourceful, integrated, and inventive. They have catchment systems, battery storage, and solar paneled roofs/windows. Houses learn owner's preferences and predict power consumption based on current and historical data and provide this data to the grid. Furthermore, TIPS is an example of resilient planning. Components of TIPS are vertical evacuation, elevated buildings, evacuation pods, early warning system, TPG, and tsunami building codes. In addition, reseeding coral reefs, planting tsunami forests, and cultivating mangroves are environmental components of TIPS. These slow down the effects of a tsunami, prevent destructive damage, provide shelter, and preserve the beauty of Kaifukuryoku.

These innovations were a direct result of the destructive 60-foot high tsunami that shackled the city in 2033. That day more than 18,000 people were killed, 20,000 were injured, and 200 went missing. Many were homeless. The remaining families lived in damaged, powerless homes. The power grid was devastated. Nuclear plants stopped running and leaked radioactive waste into the environment. Transmission and distribution lines were decimated. Without transportation, people who needed help could not get to the hospitals and succumbed to injuries. The elderly and handicapped, the most vulnerable, were less mobile and could not seek shelter. Fortunately, Kaifukuryoku has brilliant engineers, TIPS, and microgrids to protect the city from a disaster ever occurring again.

Kaifukuryoku's advanced microgrids, Resilient Induction Smart Energy System (RISES), are self-healing, cognitive, resilient, and reliable. Components include infrastructure, information systems, and a smart protection system. RISES is a series of self-sufficient microgrids that draw power from on-site/localized generation. Individual consumers within each microgrid generate energy through the use of solar or wind and store it in a high capacity and durable home or commercial battery. Geothermal (constant) and/or tidal (variable) energy power the battery reserves and serve as a spinning reserve to industrial/commercial users that draw more power. This is the exact opposite of the obsolete centralized grids of 2018, which had multiple single points of failure, inefficient power distribution, and, in the case of Japan, different current frequencies. In Kaifukuryoku, geothermal/ tidal generated energy is sent to advanced substations to increase voltage and step down current for delivery of power over long distances before the voltage is stepped down for safety.

Locally generated microgrid power is distributed wirelessly via magnetic induction inspired by Nicola Tesla's rotating magnetic induction field. Energy not used is stored in batteries. The microgrids are autonomously monitored from multiple control stations for redundancy. It auto adjusts/predicts load and learns/balances individual energy consumption with two-way communication from homes and businesses to the control stations (Figure 1*).* Control stations communicate with homes and businesses to reduce consumption, avoiding brownouts.

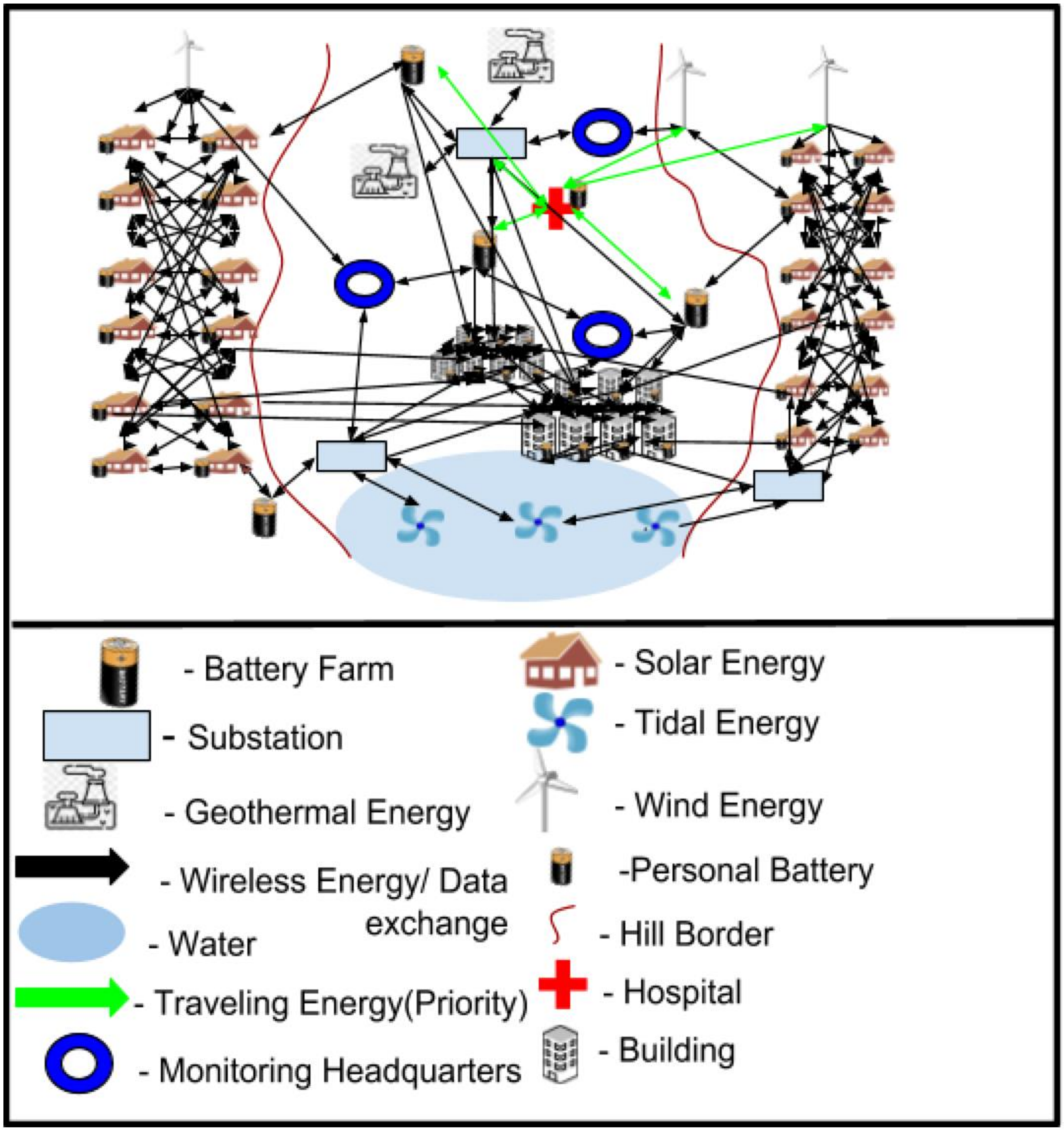

Figure 1. RISES

The two ways our grid can withstand and recover from the disaster are the Tsunami Protection Gate (TPG) and energy storage (battery farms, BBP storage, and home storage). The TPG, located at the shoreline, utilizes tide buoys and shore-based tide gauges to activate saving the grid and lives. If power generation is disrupted in one part of the microgrid, the microgrid will self-heal and automatically reroute power from one of multiple energy sources. BBPs can also automatically service affected areas in an emergency. Microgrids, around critical infrastructure (hospitals, etc.), ensure that these areas are isolated from the grid and remain online in case of a catastrophe. Multiple energy generation sources distribute energy to microgrids. For example, homes generate and store energy via solar panels, solar paint, and transparent cells located in windows so they can power themselves, charge home batteries, and provide power to microgrids.

Two possible disruptions to the power grid are cyber attacks and natural disasters. Since the power grid is distributed, there are many access points for cyber attacks. To prevent attacks, computer engineers designed robust firewalls and software that delivers critical security updates multiple times per day providing cyber resiliency.

Natural disasters and tsunamis pose threats to RISES. Because of TPG and TIPS, the grid is prepared for a tsunami up to 80 feet–the best-case scenario. In the worst-case scenario, the tsunami may exceed the height of the gate and flood the city. However, the gate will slow the impact and lessen the damage. The tidal turbines could be damaged or go offline. To compensate for the loss of a major generation source, RISES has the ability to draw/reduce energy from non-essential devices (appliances, storage batteries, etc.) and deliver power to critical infrastructure (hospitals, communication systems, transportation systems, etc.). This will only be temporary because the microgrid will identify, isolate, and repair the damage.

There are many benefits to a distributed wireless and resilient power grid that keep citizens safe and happy. This includes reliable and sustainable energy, which reduces the frequency of power outages and produces better quality power. Renewable energy reduces the carbon footprint, improves air quality and, likewise, improves residents' health. Consistent energy ensures that communication and transportation systems will be constantly operational, resulting in fewer injuries from accidents. Hospitals will not be threatened by power loss. Consumers can monitor/control their monthly energy usage resulting in low/no electric bill. In addition, a smart power grid requires more tech workers; this opens up job opportunities.

Two risks to RISES include cyber attacks and privacy concerns. Cyber attacks pose a threat to the grid (generation, transmission, distribution, and storage). Computer engineers designed multiple firewalls (cryptography, detection, and authentication techniques) to protect the microgrids. Furthermore, the integrated nature of RISES poses both a risk and a trade-off since each house will have a smart meter that records energy usage and learn occupants' schedules, medical needs, and habits to send to the energy provider. However, the benefits outweigh the risks with the grid's ability to auto-adjust power generation to provide more resilient power. Another tradeoff is cost and adoption of the new technology. Building a smart grid will require upgrading houses with efficient appliances/devices. Tech-savvy citizens may adopt the idea of a smart house/meter easier. Homeowners must be educated about the investment benefits of a smart house/meter (cost-effective, energy efficient, interconnectivity, etc.) Tax incentives, grants, and rebates would entice people to invest in RISES.

Smart grid engineers and computer engineers worked together to create RISES. Smart grid engineers gathered specifications, supervised construction of microgrids, analyzed failure rates, and supervised reliability-centered maintenance. They guarantee that equipment/processes operate safely and efficiently and supervise building of turbines and the distribution system. Computer engineers evaluate needs of the user/system and create communication software that connects homes, generation plants, transportation, and warning systems. They analyze the reliability of the grid and failure protection, test for system vulnerability, and evaluate security/protection system.

RISES and brilliant engineers all light the way for Kaifukuryoku's resiliency.

(1500 Words)

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