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Enhancing disaster resilience by sustainable technologies

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ABSTRACT

This paper briefly surveyed the promising sustainable and renewable technologies for producing not only fuel but also food and water respectively by capturing air with sustainable energy in order to enhance disaster resilience. Metal–organic frameworks (MOFs) can be used to harvest water from the air, CO_2 and water from the air can be used to produce alternative sustainable protein by bacteria, and CO_2 from the air can be also converted to fuel by inexpensive chemical catalysts. This paper examines whether surveyed technologies with allow us to build sustainable and resilient societies against disasters for solving real risk problems. The investigated sustainable and renewable technologies can transform our society into a sustainable and renewable society that is truly resilient to natural disasters. No one has yet attempted to combine the three sustainable and renewable technologies to transform our society into one that is sustainable and resilient to natural disasters. The proposed approach will be tested and examined in Kaga City, Japan.

Introduction and rationales

In order to enhance disaster resilience, reducing stress-associated health impacts plays a key role (Sandifer & Walker, 2018). In order to reduce the stress, necessary and sufficient preparedness against natural disasters plays a key role. The preparedness includes fuel, food and water respectively. We must assume that there is no fuel, no food, no water in a serious situation during a disaster for a long time.

Hornyak (2018) stated clearly that due to a variety of natural disasters in Japan, the disaster research is a national priority for good reason. Japan has learned many lessons of a triple disaster in 2011: the biggest earthquake in Japan's history, the tsunami and nuclear disaster (Editorial, 2012). Based on experiencing such big earthquake and the tsunami in 2011, Ishigaki et al. (2013) reported preparation of power outages plays a key role in disaster medicine in severe situations.

Murphy (2011) disseminated that the big earthquake in 2011 caused 4 million household power outages in Tokyo. 4.4 million households in northeastern Japan were left without electricity and 1.5 million without water in 2011. In 2018, Linask (2018) reported massive earthquake causes power outage for 5 million in Hokkaido Japan. NASA in 2019 using Moderate Resolution Imaging Spectroradiometer depicted that the big typhoon Hagibis in 2019 caused widespread flooding, mudslides, power outages, and wind damage (NASA, 2019). BBC 2019 also reported more than 900,000 homes have been left without power after Typhoon Faxai in 2019. BBC 2019 disseminated to the world that Japan deploys 110,000 rescuers after worst storm in decades and that more than 7 million people were urged to leave their homes at the peak of the storm.

Based on the past lessons from earthquakes and typhoons in Japan mentioned in this paper, electric power plays a critical role in medicine under harsh situations. You may imagine that sustainable energy is equivalent to solar-powered energy or wind-powered energy. Solar-powered electricity generation is intermittent and vulnerable on cloudy or rainy days.

The recent wildfires gave us lessons on the problem of solar power generation. According to the US Energy Information Administration, in California in early September, solar power generation dropped off by nearly a third as wildfires darkened the sky with smoke and continuously disturbed the solar energy from the sun. In order to use solar power generation, you need a large battery. Wind-powered electricity generation is also intermittent and vulnerable on no-wind days.

The conventional sustainable power generations (solar or wind) are inherently intermittent. This paper shows that the sustainable fuel plays a key role in robust electricity generation regardless of the weather. Fuel is used for constantly generating electric power regardless of weather conditions. Remember that power outages can significantly influence disaster medicine and telemedicine under harsh situations.

This paper briefly introduces the promising sustainable technologies for producing food, water and especially fuel respectively by capturing air with sustainable energy in order to support disaster medicine or telemedicine. Three technologies are used for producing water-food-fuel respectively from the air:

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1 Metal–organic frameworks (MOFs) can be used to harvest water from the air.
2 CO_2 and water from the air can be used to produce alternative sustainable protein by bacteria.
3 CO_2 from the air can be also converted to fuel by inexpensive chemical catalysts.

This paper examines whether three technologies are feasible for achieving sustainable and disaster-resilient cities. This paper will contribute to the urban aspect of disaster resilience with the proposed airborne technologies.

Methods

Three sustainable technologies for producing food, water and fuel are introduced respectively: sustainable food from the air, sustainable water from the air, and sustainable fuel from the air. We will use these technologies to verify whether we can truly realize resilient cities in the near future.

Sustainable food from air

Recent sustainable food research has introduced a method of producing bacterial proteins using solar power by capturing CO_2 from the air (Molitor et al., 2019; Sillman et al., 2019). Protein-rich food can be produced by taking CO_2 directly from the air in a closed system which is also climate-independent by helping of H2 oxidizing bacteria with renewable power. During the proof-of-concept experiment, Molitor et al. (2019) can produce a carbon yield of 25% as yeast biological material with a protein mass fraction of 40–50%. Microbial proteins (single-cell proteins, also known as SCPs) are obtained by growing proprietary bacteria harvested from nature in a bioreactor specially designed using gas fermentation (Carleton, 2019). Based in Finland VTT Technology Research Center and Lappeenranta Institute of Technology (LUT), Solar Foods is in the preliminary stage for production and the company can currently produce 1 kg of protein-rich powder called "Solein" per day by using solar power electricity (Carleton, 2019).

Since the average adult needs a minimum of 0.8 g of protein per kilogram of body weight per day, a person with 70 kg may need about 56 g of protein per day. Solar Foods did not show a bacterial protein production device, but their device can provide enough protein for 18 adults.

Sustainable water from air

According to Wikipedia, an atmospheric water generator is an AWG device that extracts water from the humid surrounding (ambient) air. Condensation can extract water vapor in the air. That is, cool the air below the dew point, expose the air to a desiccant, or pressurize the air (XYZ, 2022).

However, Fathieh et al. (2018) can energy-efficiently produce water from desert air. One of Metal-organic frameworks, MOF–801 device was experimented in the laboratory and reexamined later in the desert of Arizona of the United States. In the desert, by only using natural cooling and ambient sunlight as an energy source, MOF-801 1 kg device can harvest 100 g of water in a day-night cycle.

The MOF device is capable of harvesting 2.8 L of water per kilogram of MOF daily at relative humidity levels as low as 20% (Kim et al., 2017).

According to the study on human water requirements, they are estimated to be about 2.3 to 2.5 L/day for people with low activity levels and about 3.3 to 3.5 L/day for people with high activity levels (Sawka et al., 2005). 2 kg MOF can harvest enough water for a single adult forever.

Sustainable fuel from air

Thomas Rayder encapsulated a pair of catalysts like enzyme in a zirconium-based MOF device to accelerate a series of reactions that can convert gaseous CO_2 to the fuel methanol in the form of liquid (XXYZ, 2022).

Rob McGinnis is aiming to utilize renewable solar energy to convert carbon dioxide and water to liquid gasoline (Service, 2019). The key component of McGinnis' machine (household-sized refrigerator) lies in black-boxed carbon nanotube-based filter that can separate fuel molecules from mixed water without using the large electric energy input conventionally needed for this task. The optimized machine by Rob McGinnis can produce 20 L of gasoline per week (Service, 2019).

Xu et al. (2020) reported a catalyst composed of carbon-supported copper that can be synthesized by using an amalgamated Cu–Li scheme, which can achieve a single-product Faradaic efficiency (FE) of 91% at −0.7 V and onset potential as low as −0.4 V for electrocatalytic CO_2-to-ethanol conversion.

A typical gas-powered portable generator of 1000 W can consume 4.16 L of gas for 5 h. Thus, if you use 20 L of gasoline per week, you can generate 1000 W for 24 h. In other words, it can continuously generate 143 W of electricity.

Discussions

The conventional sustainable power generations are inherently intermittent and vulnerable depending on the weather where cloudy or rainy days influence the solar-powered generation and no-wind days produce no power by the wind-powered generation respectively.

However, as far as we know, the proposed sustainable fuel is one and only one method for constantly generating electricity, regardless of the weather. Since the captured fuel is from air, the sustainable power generation is based on zero CO_2 emission.

With the proposed catalyst power generation, it can continuously generate 143 W of electricity. 2 kg MOF can harvest enough water for one adult forever. With the proposed bacteria-based protein production, the device can supply enough protein for 18 adults.

The proposed sustainable airborne technologies as presented in this paper could be used in the future not only in disaster areas but also in urban areas where the poor people are marginalized for improving urban governance (Creţan et al., 2020; Méreiné-Berki et al., 2021). Based on the evidence of non-electric airborne technologies such as harvesting water from the air, producing bacteria-based protein from the air, and harvesting fuel from the air, the proposed sustainable airborne technologies could be the perfect solution for improving urban governance including urban poverty alleviation and urban disaster resilience, as long as air is available.

Reu Junqueira et al. (2021) proposed green infrastructure for alleviating urban climate change risks. Carlos et al. (2022) studies data science technologies for enhancing urban resilience against disasters. Didier et al. (2022) proposed data-driven city strategies for urban transportation resilience. However, to the best of our knowledge, no airborne technology has been proposed to alleviate urban poverty from an urban governance perspective as well as to strengthen urban disaster resilience. The advantage of the proposed airborne technologies lies in that they do not use electricity. In other words, the proposed airborne technologies are extremely sustainable. Therefore, the contribution of this paper is significant for the improvement of urban governance.

Based on the proposed airborne technologies, several cities in Japan will implement sustainable and renewable technologies and examine the capabilities and cost-effectiveness of these technologies in the near future.

Conclusion

This paper revealed that cities with the proposed airborne technologies can enhance unban disaster resilience. Using the promising sustainable technologies mentioned in this paper, capturing air with renewable energy can produce food, water and fuel respectively in severe natural disasters for robust telemedicine and disaster medicine in order to enhance disaster resilience. Use in hospitals requires improved technology performance and reduced costs. Their disaster medicine mitigation technology helps them survive disasters by using sustainable energy and capturing air. Fuel captured from the air can play an important role in generating electricity for robust telemedicine or disaster medicine under harsh conditions.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research: cyber-security, neural computing, energy harvesting, IoT, AI, applied mathematics, science/health policy, disaster management.

He authors 40 books and more than 800 scientific articles with supervising more than 40 PhD. students. He is one of pioneers on neural computing. His-team won the AI championship of 2017 NIPS in Quiz Bowl Question Answering with 309 cited.

He has published 210 eLetters and 1 report in Science (the report is entitled "A near-optimum parallel planarization algorithm" published in 1989 with 128 citations that is the world's first application based on neural computing), 1 correspondence in Nature on science policy, and 1 correspondence in NEJM on herd immunity.

His-book entitled 'Neural network parallel computing' published in 1992 has influenced many researchers in the world with 335 cited.

He coauthored a paper entitled "Functional Link Net Computing: Theory, system Architecture and Functionalities" published in IEEE in 1992 which was cited by 676 articles.

On artificial intelligence and security, he has been advising more than 50 profit and non-profit organizations including Food Service Association in Japan since 1992 and introduced technologies on sustainable protein alternatives published in Trends in Food Science & Technology.

He is currently Docent Professor at IT Department of Jyvaskyla University in Finland and economic advisor to governor of Shandong in China since March 2019 and to Weihai mayor in China since 2018. He was a former advisor of air force research in the US.

He has been developing AI systems using ensemble machine learning, neural computing with IoT devices for solving real intractable problems in our society. The prototype robots outperform super-skilled human engineers in civil engineering and construction. One of his prototypes is currently used in construction of underground-tunnels in Central Shinkansen in Japan.

He is one of the world's famous inventors (mobile phone's camera), Euro banknote validators (BV-6000: 12,000 units installed in Europe as of 2009), AI-embedded drilling machines for linear shinkansen in Japan, and Nintendo's Gameboy camera, and others.

He has been educating more than 10k students in universities and professional engineers in industries since 1980. He is selected by Times Higher Education as reputation evaluator for world university rankings.