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Sustainable Energy City: Learning from Japan's Model

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ABSTRACT

Rapid urbanization and rising energy demand in cities have stimulated research into sustainable energy solutions. The challenges reside in designing cities that not only meet energy needs but also reduce their environmental impact. This necessitates a comprehensive framework that integrates the necessary elements for the development of sustainable energy city. Japan has risen to the challenge by incorporating renewable energy, energy storage, and innovative energy management technologies into its urban planning. This study seeks to evaluate Japan's approach to sustainable energy city development and recommend a framework for Malaysia or developing economies alike on sustainable energy city deployment. Additionally, it suggests a business alliance between Japan and Malaysia to promote socioeconomic benefits and sustainability objectives in both countries. A visit to a sustainable energy city in Japan was conducted for on-site evaluation of infrastructures and technologies, as well as interviews with the management company. Japan's comprehensive approach to supportive policies and incentives has aided in the development of sustainable energy cities supported by public-private partnerships and active community participation. The key energy components of the Japan's case study include both energy management and resilience approach. The proposed cooperation between Japan and Malaysia has the potential to promote long-term growth, shared prosperity, and contribute to global efforts in combating climate change.

Keywords: solar energy, advanced energy technologies, sustainable smart city, public-private partnership, urban planning, climate change

NONMENCLATURE

Abbreviations	
ASCN	ASEAN Smart Cities Network
EE	Energy Efficiency
METI	Ministry of Economy, Trade and Industry
RE	Renewable Energy
SST	Sustainable Smart Town

1. INTRODUCTION

The pressing need to address climate change and move towards a sustainable future has garnered international attention, prompting nations to explore novel approaches for their urban areas (Klopp et al., 2017). The concept of Sustainable Smart City has become a crucial approach in tackling the environmental issues associated with urbanization, while simultaneously promoting economic development and societal welfare (Ozdamli and Nawaila, 2023). Sustainable Smart City is a city that utilize technical and digital advancements, alongside non-technological innovative approaches, to effectively tackle urban challenges, and continuously improve people's lives (Mosannenzadeh et al., 2017).

The need for sustainable smart cities is driven by the rapid pace of global urbanization, since more than half of the global population currently resides in urban areas, a proportion projected to increase to two-thirds by the year 2050 (UNDESA, 2018). According to UN Habitat, cities consume 78 per cent of the world's energy and produce more than 60 per cent of greenhouse gas emissions (UN Habitat, 2023). There are urgent needs for cities to increasingly adopt sustainable energy system, a component of smart sustainable cities. This concept incorporates renewable energy sources such as wind,

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solar, and hydropower; energy-efficient technologies, and innovative urban planning strategies (Chen et al., 2022). Sustainable energy cities offer a promising path to addressing urbanization's challenges and combating climate change by combining these elements.

Japan has emerged as a forerunner in the development of smart energy cities that demonstrate the integration of technology and urban planning (Kim, 2022). Originally, it is rooted from concern in energy security (Saneda, 2023). In 2010, the Japanese Ministry of Economy, Trade and Industry (METI) launched the "Next-Generation Energy and Social Systems Demonstration Areas" project, which aimed to create sustainable communities that incorporate renewable energy, smart grid technology, and other innovative solutions (Mah et al., 2013). The primary objective of the initiative was to demonstrate Japan's dedication to mitigating greenhouse gas emissions and fostering a culture of sustainable living. As part of this project, METI solicited proposals from private corporations to develop a sustainable community. Yokohama, Keihanna, Kitakyushu and Toyota City are good examples of the goals being set by Japan cities for innovation in energy. Since then, there are over 200 smart city projects in Japan, not just government-led initiatives, but local-government-led (over 500 local governments) and private sector led (Panasonic, Hitachi, Toshiba) smart city projects.

The success of Japan can be attributed to its strong dedication to innovation and sustainability, exemplified by notable endeavors such as the Yokohama Smart City Project (Suwa, 2020). The projects place significant emphasis on the integration of renewable energy sources, innovative energy-efficient technology, and forward-looking urban design, aligning with global efforts to combat climate change and enhance energy sustainability. Kitakyushu, which transformed itself into a model of eco-industrial development, and Toyota, which complement all local resources, are also compelling examples of Japan's expertise in this field (Pizzolo, 2023).

Malaysia acknowledges the significance of creating sustainable smart cities as one of the next frontier approaches to address urbanisation and climate change challenges (The Star, 2023). While Malaysia has made significant strides in urban development and infrastructure over the years, the history of smart city development in the country is a relatively recent phenomenon. In recent years, Malaysia has taken steps to incorporate smart and sustainable elements into urban planning and development through the ASEAN Smart Cities Network (ASCN) (Association of Southeast Asian Nations, n.d.) and various other initiatives. Kuala Lumpur established the Kuala Lumpur Smart City Blueprint, which aims for a Smart City that is Safe and Secure, Clean and Green, Efficient and Sustainable (Dewan Bandaraya Kuala Lumpur, 2021). The city is implementing smart traffic management systems, smart waste management systems, and smart surveillance systems. Kota Kinabalu is implementing smart solutions focuses on smart transportation, smart waste management, and smart tourism (Bakthiar et al., 2023). Cyberjaya, committed to becoming the first smart and low-carbon city in Malaysia by 2030, is implementing smart solutions to enhance connectivity, sustainability, and quality of life for its residents (Cyberview, n.d.). Iskandar and Putrajaya are implementing their Smart City Framework, focusing on dimensions such as Smart Economy, Smart Governance, Smart Environment, Smart Mobility, Smart People and Smart Living (Iskandar Malaysia,2023; Perbadanan Putrajaya, n.d.).

These smart city projects demonstrate Malaysia's commitment to promoting sustainable development and leveraging smart technologies to address urban challenges. However, most are lacking flagship projects addressing the smart/sustainable energy components and lack of integrative approach in their framework. Interestingly, Malaysia government has just announced one of the energy transition flagship projects which include construction of a residential solar across 450 homes in Selangor, amounting to 4.5MW solar capacity with up to 10kW solar capacity per house via rooftop leasing (EPU, 2023). Malaysia can benefit in this endeavor by drawing inspiration from Japan's expertise in smart energy city development.

This paper aims to examine the case study of a smart sustainable city in Japan and draw lessons that are relevant in the context of sustainable energy city development. One notable case study is the Fujisawa Sustainable Smart Town (FSST), a pioneering project that exemplifies Japan's commitment to sustainable urban development (Fujisawa SST, n.d.). A case study analysis and interviews were used to extract valuable insights from Japan's sustainable energy city approach. This research paper is structured as follows: The first section presents an in-depth analysis of the Fujisawa SST, exploring its development process, concepts, and innovations. The subsequent sections provide a conceptual recommendation for Malaysia's sustainable energy city development and propose a Japan-Malaysia business alliance, leveraging Japan's expertise in smart energy city development to accelerate Malaysia's efforts

in building sustainable, energy-efficient urban environments.

2. METHODOLOGY

The Fujisawa Sustainable Smart Town (FSST) was used as the case study. This study relies on available documentation, reports, and case studies related to FSST, as well as interviews with the SST management company. A site visit was undertaken to FSST for a guided tour of the locality and observing incorporation of various energy components inside the town. The sustainable energy features such as solar installation, electric mobility, community solar, was also observed in addition to the daily lives of the residents. The tour began with a formal presentation on the town's history, design philosophy and technology, by the representatives of FSST Management Company. A semi-structured interview followed the tour, conducted at the Fujisawa SQUARE Centre. Information from the presentation, uptake from the conversations, and neighbourhood observations are synthesized from the case study.

3. CASE STUDY: FUJISAWA SUSTAINABLE SMART TOWN, FSST

The FSST is a smart city project located in Fujisawa City, Kanagawa Prefecture, Japan, developed by Panasonic Corporation in collaboration with consortium of 18 partners (Fujisawa SST, n.d.). It was built on a former site of a manufacturing facility, designed to be a sustainable and environmentally friendly residential community that serves as a model for smart, eco-conscious urban development. Its primary goal is to demonstrate how advanced technologies and sustainable practices can be integrated to create a more energy-efficient, low-carbon, and comfortable living environment. The project aims to reduce 70% carbon emissions with renewable energy usage of more than 30%. There are around 600 detached homes and 400 condominiums. FSST consists of several zones and incorporates residential, community, commercial and health facilities. The estimated cost of developing the 19 hectares site to cater for around 1,000 households was ¥60 billion. The town conceptual image is presented in Fig. 1.

Fig. 1 FSST Conceptual image (Fujisawa SST, n.d.).

3.1 History of FSST

The conception of Fujisawa Sustainable Smart Town (SST) emerged because of the collaborative effort involving the Japanese government, commercial enterprises, and the municipality of Fujisawa. The FSST site initially served as the location for Panasonic's Fujisawa Power Plant. Panasonic partnered with eight other companies to form the "Fujisawa Sustainable Smart Town Consortium". The consortium worked closely with the city of Fujisawa to design and build Fujisawa SST. The Fujisawa SST broke ground in November 2011, signalling the start of construction and development. During this phase, modern infrastructure and sustainable technology were installed to support the smart town goal. The Fujisawa SST was officially opened in November 2014, and the first people began to move into the smart town.

3.2 Public-Private Partnership and Community Engagement

FSST is developed by the Panasonic-led consortium Fujisawa SST Council, consists of 18 public and private organizations, which include utility companies and leaders in real estate development, building, and home construction such as Tokyo Gas, Nippon Telegraph and Telephone East Corp, Panasonic Homes Corp, Koyama Medical and Welfare Group, Yamato Transport and Mitsui & Co., with the support of local governments and residents. FSST was financed by a combination of public and private sources, with the government providing grants and loans and private investors providing equity financing. Panasonic played a pivotal role in the project and provided expertise in energy-efficient technologies, solar panels, intelligent appliances, and battery storage systems. They were responsible for designing and integrating the community's smart energy systems. The local government of Fujisawa City provided the initiative with regulatory support. They worked with Panasonic to ensure that the development was consistent with the city's sustainability objectives and urban planning guidelines. Additionally, the initiative involves collaboration with academic institutions and other

Table 1. FSST Public-Private Partnership

Organization	Type	Role and Responsibilities
Panasonic Corporation	Private Company	Main private partner in charge of project development, energy-efficient home design, renewable energy technologies integration, smart energy systems, and providing expertise in sustainable technologies.
Fujisawa City	Local Government	Collaborated on urban planning and regulatory support, linked the project with the city's environmental goals, and participated in community outreach.
Residents and Community	Residents	Participated actively in the initiative, provided feedback, adopted sustainable practices, and utilized smart energy systems to optimize energy consumption.
Other Private Corporations	Private Companies	Contributed expertise in a variety of areas, including urban planning, infrastructure development, and technological solutions, in collaboration with Panasonic.
Research Institutions	Educational/Research Institutions	Participate in research, looking at how the project would affect urban development, sustainable living, and energy use.
Utility Companies	Utility Companies	Collaborated on integrating the smart grid and managing energy distribution inside the community.

organizations to create and implement sustainable policies. Each partner performs a unique role in the development and operation of the town as shown in Table 1.

3.3 Key Energy Components

The FSST is a case study in sustainable energy systems where two of its five town services focus on energy elements. FSST incorporates various sustainable features and technologies, such as energy-efficient homes, solar panels, residential fuel cell systems, storage batteries, advanced energy management systems, electric mobility and sharing, energy-saving equipment and community solar illustrated in Fig. 2.

FSST employed energy-saving devices for its detached houses such as LED lighting, energy efficient air conditioning, water saving toilet and water saving shower with energy saving technology and smart sensor system. The house is also designed passively to take advantage of natural ventilation and sunlight. By orienting homes to capture prevailing breezes and sunlight, residents can reduce their reliance on artificial heating and cooling systems, further lowering energy consumption. The town also utilizes solar powered LED streetlights with motion sensors, installed along major roads.

The detached houses are equipped with a solar power and a fuel cell generation system. Fuel cells are a highly efficient method to generate electricity through an electrochemical reaction between hydrogen and oxygen. Furthermore, the remaining heat residual is used to generate hot water.

The storage of energy in a home is achieved through a lithium-ion batteries which allows homeowner to conserve energy and ensure stable power supply. Electric power generated by respective systems can be used to meet household requirements and excess power can be sold.

Each houses adopt an energy management system, through a Home Energy Management System, a smart system that linked the energy-creation, energy-storage and energy-saving equipment. The main features of this system include real-time measurements of the consumption of electricity, water and gas. For electricity, the monitor displays the current state and the carbon dioxide balance of the entire house, estimated electricity charges as well as the ability to generate energy through solar energy or fuel cells. The different types of data, including the amount of charge of storage batteries, can be monitored through televisions, computers, smart phone screens and other displays. Other features include Artificial Intelligence and Smart Energy Gateway which is the control centre of the system, which allows

connection and control of electrical equipment and appliances in the home, and helps to increase energy savings.

Throughout the entire town, there is a 400 m long Community Solar Power Generation System, installed along the main road, supplying a total of 100 kW power for use in the common area and emergency. For consistent, reliable power supply, a special electrical storage facility can supply the entire community with three days of emergency power in the vent of emergency such as earthquake. Residents will have access to energy sources for use of mobile phones and tablets, and transportation such as electric vehicles (EV) and electric-assisted bicycles in such event.

The mobility service offered to FSST residents include the sharing of electric vehicles (EV) and electric-assisted bicycles and battery stations for renting rechargeable batteries. Electric vehicles and bicycles are available for renting using a touch card for authorization and tracking. There is an option to use a rental car delivery service to deliver a car near resident's home. The aim is to promote mobility and allow those without their own vehicle to be more active, while reducing the community's carbon emissions.

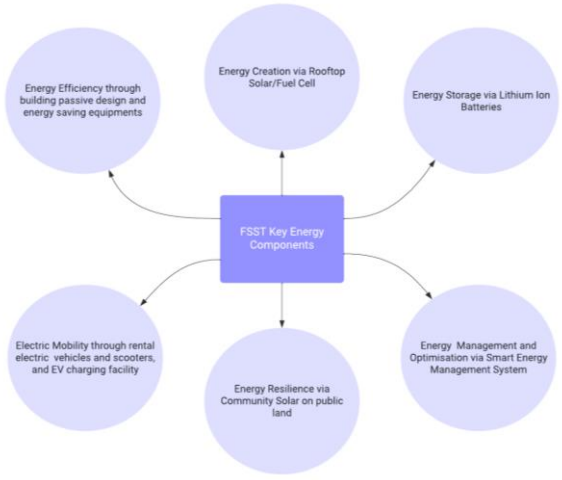

Fig. 2 FSST Key Energy Components

4. FRAMEWORK FOR SUSTAINABLE ENERGY CITY IMPLEMENTATION

The sustainable energy city conceptual framework is proposed in Figure 2 learning from Japan's experience. It starts with establishing a clear concept and quantifying the objectives to be achieved in the city, along with conducive regulatory and financial environment, supported by a strong public-private partnership in which an energy-literate community actively engage and participate for sustainable operation.

The supportive regulatory and financial environment refers to a set of policies, regulations, incentives, and funding mechanisms provided by government and relevant authorities to encourage and facilitate the development and adoption of sustainable energy practices and technologies within the city. This includes well-crafted energy and sustainability policies that set clear goals for renewable energy adoption, emissions reduction, low carbon/zero emission vehicles, efficient resource use, as well as robust town planning guidelines that incorporate energy-efficient infrastructure and green building standards. These examples showcase Japan's multifaceted approach to creating a supportive environment for sustainable energy, low-carbon and smart practices, in the city. This environment is crucial to provide a foundation for sustainable energy initiatives to thrive, creating a favourable landscape for businesses, residents, and organizations to invest in and adopt sustainable energy solutions.

The second layer involves forging strong collaborations between the public and private sectors, forming a synergy that drives sustainable development. The partnership includes multiple stakeholders such as industry, municipality, private companies, academia, etc. The FSST is a notable example of a strong public-private partnership of more than 18 partners as shown previously in Table 1.

The bottom layer of the framework is community engagement, where the active participation of residents, local organizations, and other stakeholders is essential. This activity encompasses of educating residents about energy conservation, sustainable living, and the benefits of renewable energy sources, involving the community in decision-making processes, such as selecting sustainable projects and providing feedback on initiatives and promoting behavioural change to reduce energy consumption and adopt eco-friendly practices. In the case of Fujisawa SST, its residents are actively participated in the project, providing feedback, engaging in sustainable practices, and using the smart energy technologies to optimize energy consumption. This community engagement is vital for the project's success.

5. PROPOSED JAPAN-MALAYSIA PARTNERSHIP

Japanese businesses could play an important role in in sustainable energy city development in Malaysia through their expertise in renewable energy technologies and project management. Japan is a world leader in renewable energy, energy efficiency, and smart

systems and appliances, and has developed advanced technologies in this field. Japanese companies could bring their knowledge and experience to Malaysia, where this development has great potential. Japanese companies could benefit from the growth of the renewable energy market in Malaysia, as the country aims to increase its share of renewable energy in its energy mix by 40% by 2035 and the recent Malaysia Energy Transition Roadmap announced several flagships solar projects which include one residential solar [EPU, 2023].

Japanese companies could collaborate with Malaysian companies and government agencies in the form of providing financing, technical expertise, and project management support for the development projects. These partnerships would contribute to job creation and economic development in Malaysia, while Japanese investors may see returns on their investments. In addition, this collaboration can strengthen diplomatic ties and enhance bilateral relations, extending beyond that of energy sector.

From an environmental standpoint, Japan could support the emission reduction and promote sustainable practices in Malaysia. Malaysia could gain recognition for its commitment to sustainable development. Sustainable energy city can help Malaysia to reduce its carbon emissions and promote sustainable urban development practices, such as energy-efficient buildings, waste management, and water conservation, which can help to

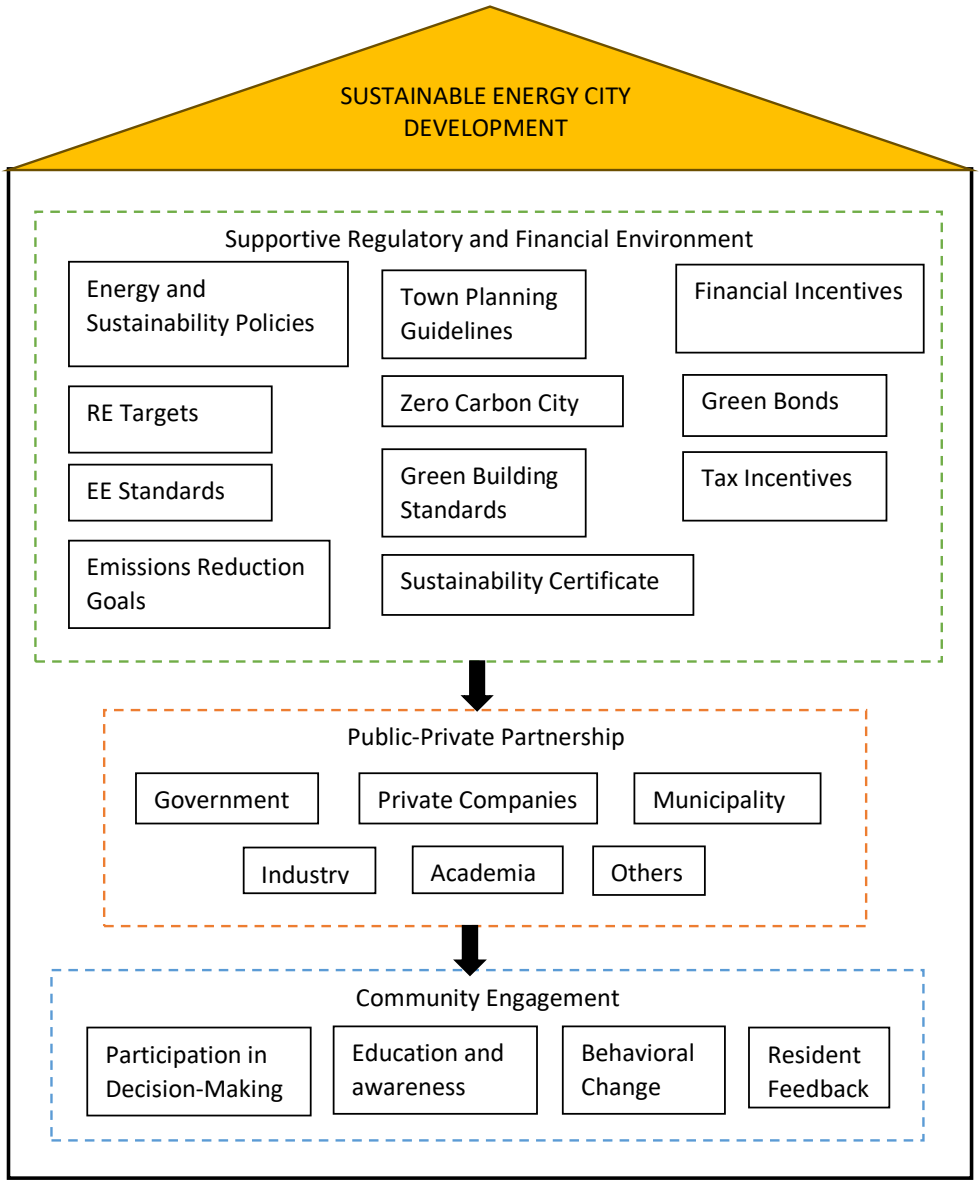

Fig. 3 Sustainable Energy City Framework

create livable and healthy communities for Malaysian citizens.

Overall, the Japan's involvement in the sustainable energy city development in Malaysia could bring significant benefits to both countries. Table 2 highlights both Japan's and Malaysia's roles and contributions across various aspects of sustainable energy city projects, emphasizing collaboration and mutual support in the development process. This mutual alliance can help generate new business opportunities and create jobs for both Japanese and Malaysian workers, helping to strengthen economic ties between Japan and Malaysia and advance the sustainable development goals in both countries.

Table. 2 Japan-Malaysia Alliance Roles

Aspect	**Japan's Parts**	**Malaysia's Parts**
Financing and Investment	Funding for sustainable energy city projects Financial advice to developers Invests in renewable energy projects in Malaysia	Identifies local funding opportunities and incentives Collaborates with Japanese partners to secure funding and investments Manages local financial institutions and incentives to attract investments
Technical Expertise	Shares knowledge on renewable energy technologies Provides technical training and support to local partners Develops new renewable energy technologies for the projects	Develops local expertise in renewable energy technologies Establishes training programs and collaborations with local technical institutes Engages local research institutions and universities in technology development
Project Management	Manages and oversees the project construction Ensures the timely completion of the projects Coordinates and supervises the operation and maintenance of the projects	Coordinates local project management teams Monitors project progress and timelines Manages local maintenance and operation teams
Collaboration and Partnership	Collaborates with Malaysian companies to develop sustainable communities Establishes partnerships with Malaysian universities and research institutions Shares resources and expertise with Malaysian companies to advance sustainable development	Engages local businesses and industries in the development process Collaborates with local educational institutions to promote sustainable practices Facilitates knowledge exchange and technology transfer between Japanese and local entities
Knowledge Sharing	Shares information on sustainable development practices Hosts workshops and seminars on sustainable development Creates educational materials and resources on sustainable development	Disseminates project progress and best practices within Malaysia Organizes local workshops and seminars to raise awareness and build capacity Develops local educational materials and resources that align with sustainable development goals

6. CONCLUSION

This study shed light on the lessons learned from the Fujisawa SST case study in Japan on sustainable energy city model and their relevance to development in Malaysia, harnessing the valuable insights gained from Japan's experiences. The concept of a sustainable energy city in Japan, which includes solar PV installation, fuel cell, energy storage, a smart energy management system, electric mobility, energy efficient buildings and

infrastructure, and other new advanced technologies, is an essential part of the country's sustainable urban development. Japan's sustainable city and energy regulations, as well as fiscal incentives, have helped to the rise of renewables, smart and energy-efficient technologies, and innovative technology, accelerating the country towards the net zero GHG target. A successful public-private partnership is required to foster sustainable growth, with active engagement from energy-literate residents. Malaysia can learn from Japan's model through an implementation framework that includes setting urban energy targets, developing policies and regulations, promoting public-private partnerships, creating financial instruments, investing in R&D, and educating the public about the benefits of sustainable energy. Japan-Malaysia business collaborations in sustainable energy city development would give both countries considerable economic benefits while helping global efforts to combat climate change and promote sustainable development. By leveraging the experiences and achievements of Fujisawa SST, Malaysia can accelerate its own transition toward a sustainable future in the context of sustainable energy and smart city.

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DECLARATION OF INTEREST STATEMENT

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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