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How are Southeast Asia Countries Embracing Green Home Technology?

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Abstract
Physical development, which includes real estate activities, is currently very active in developing countries. This is especially true in Southeast Asian countries that aim to transform their countries into developed countries. Southeast Asia is rapidly industrialising and growing; this growth has resulted in a rise in energy consumption and environmental effects. Deforestation, landslides, pollution and the greenhouse effect have all been impacted by the global development process, which began in developed countries. Therefore, the idea of a green home or green building which embraces green technology has received attention. A green home is a set of household systems that reduce demand for natural resources and carbon emissions, resulting in improved human well-being, social equality, and a green economy. It incorporates eco-friendly strategies for water and waste management systems, such as rainwater harvesting and water recycling, in addition to energy-efficient structures. A green home is more than just a green building, but it symbolises a sustainable lifestyle based on environmentally friendly technologies and practices. This article aims to review the application of green technology in housing and to explore green homes in selected Southeast Asian countries. Secondary data was used for the purpose of this study. The review of articles found that Singapore is on the cutting edge of most technical advancements compared to Malaysia, Indonesia and Thailand. Meanwhile, Malaysia, Indonesia and Thailand are concerned about housing affordability as this is the foundation for the majority of housing initiatives in these three countries, especially in Malaysia and Thailand.
Keywords: Green Home, Green Technology, Sustainable Home, Sustainability, Southeast Asia

Introduction

The concept of a green home or sustainable home can be realised through a decision-making process that takes into account and combines environmental, economic, and social concerns. Sustainable housing, according to Gilkinson and Sexton (2007), is a type of affordable housing that uses ecologically friendly building materials and designs to reduce the negative impact that homes can have on the environment. Keall et al (2010) mentioned that sustainable housing is vital for human health, safety and sustainability. Meanwhile, López et al (2019) stressed that the three pillars of environment, society, and economics must be integrated into a sustainable home. Across all industries, there is a growing tendency towards environmental stewardship, and this is included in the built environmental sector. Therefore, green technology has become a trend, in which green technologies are a broad category of technologies that help to reduce human impact on the environment and promote sustainable development. Generally, a green home is a concept in which a house is built to use less energy, natural resources, and water, to offer better air quality and comfort, produce less waste, and offer sustainable development for a better lifestyle. Green homes are still less common than conventional homes (Jones & Laquidara-Carr, 2018), yet interest in a green home is progressively increasing (WBCSD, 2008). In addition, the COVID-19 pandemic has brought attention to the necessity for a healthy structure that can fend off the virus, where good air quality and ventilation, natural lighting, and green open space are features of a healthy structure.

a. **Application of Green Technology Adoption in Housing**

The Malaysian government encourages the use of green technology, particularly in buildings, such as solar energy, rainwater harvesting systems, and the use of the green building index (GBI), in order to achieve energy renewables, energy efficiency, and other goals (Suhaida et al., 2011). There are a number of green technology applications in housing, which include solar energy, wall technologies, green roofs, green water harvesting systems, green flooring, green flushing, green electronics, and others.

Solar Energy

The solar energy industry will become the world's greatest producer of renewable energy, surpassing water and wind energy producers, and as a result, the solar energy industry will generate more electricity than all nuclear power plants combined (Niekurzak & Kubińska-Jabcoń, 2021). Since Malaysia is located in the equatorial area, where sunlight is abundant throughout the year, solar energy will play a vital role in the country's future energy mix (Lee, 2017). Solar energy is one of the primary possibilities for meeting small and large-scale energy demands in a dependable, economical, practical and environmentally sustainable way (Shahsavari & Akbari, 2018). The solar system for homes consists of the use of photovoltaic solar panels that assist in offering sustainable electricity. The electrical output of a solar panel is affected by its orientation, efficiency, latitude, and climate. Roofs are frequently slanted towards the sunlight to maximise the effectiveness of solar panels. A true-south facing orientation maximises yield for any solar panel. If true-south alignment is not practicable, solar panels positioned within 30 degrees of south can produce enough electricity. The solar devices consist of a solar electric panel, LIPA meter, inverter and circuit breaker. The solar photovoltaic cells at the solar panel absorb the sunlight's rays and produce the form of electricity called Direct Current electricity. However, this form of electricity is inappropriate to be consumed by home appliances. Therefore, the central inverter receives the Direct Current electricity and is responsible for converting it into Alternating Current electricity so that the electricity can be consumed by appliances.

Figure 1. Solar system for residential

Residential Rainwater Harvesting System

Water scarcity can occur almost everywhere in high demand water consumption areas and has become a key concern in sustainable development. The use of rainwater has been widely regarded as a reliable solution to lessen and mitigate the consequences of water scarcity. Rather than wasting rainwater as runoff, rainwater is collected and stored for later use (Lani et al., 2018). Arid climates and locations with limited water supplies are commonly associated with scarcity. It can also occur in locations with a lot of rain, either due to high population density or because of excessive residential-agricultural-industrial water usage (GhaffarianHoseini et al., 2016). A prior study in Brazil proved that water consumption was consumed the most by showers at 54.2%, followed by washing machines (21.3%), kitchen taps (9.3%), toilet flushes (9.2%), and washbasins (2.6%) (Maykot & Ghisi, 2020). Therefore, this emphasises the importance of providing continuing access to renewable water resources (Partzsch, 2009).

Rainwater harvesting is more than just collecting and storing water to supplement the growing need. Individuals rationing and managing water collection, storage, and consumption are also implications of a larger water management strategy (Abdulla & Al-Shareef, 2009). Rainwater harvesting in an urban area, in addition to its basic purpose, can assist in minimising urban stream deterioration and flooding by acting as a “buffer” for surplus water in the event of extreme precipitation (Farreny et al., 2011). It also helps to reduce the nutrient load on waterways (Lani et al., 2018). There are several basic steps for a rainwater harvesting system. Firstly, it must collect and transport rainwater from catchment areas. A water harvesting system’s catchment is the area that receives direct rainfall, such as the rooftop, the terrace, or the courtyard of a building. Meanwhile, the pipelines that convey rainwater from the catchment or rooftop to the collecting system are known as conduits. Next is the filtering process, in which a filter unit is a chamber filled with a filtering tool that filters debris and filth out of the water before it enters the storage tank. The collected water can now be stored in storage tanks that are designed to meet society’s water needs for immediate use. Figure 2.0 shows the process of the rainwater harvesting system.

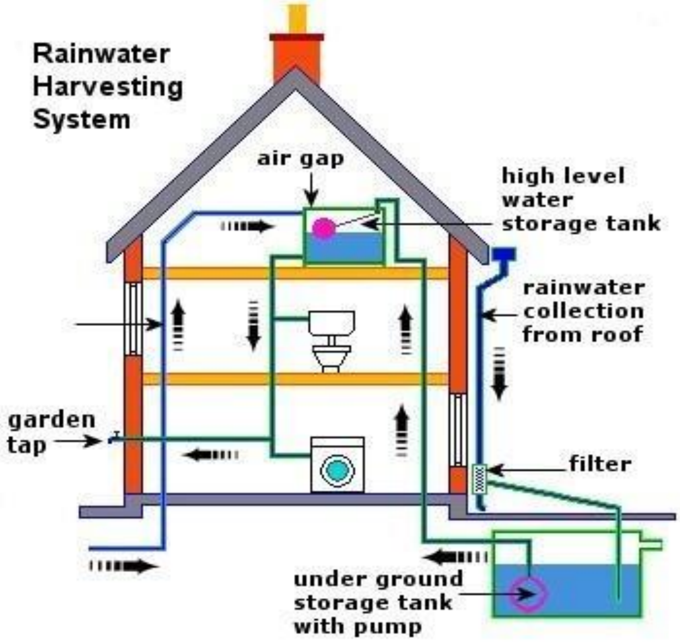

Figure 2. Rainwater harvesting system
Source: Waterways Environmental, n.a

Sustainable Flooring

Traditional flooring industries use a variety of environmentally hazardous materials, whether through energy-intensive manufacturing, pollution, or non-biodegradable trash that poisons the environment for decades after the flooring has been discarded. Petroleum products are the most common of them, especially polypropylene which is used in the production of carpets and other backing materials, as well as adhesives and protective coatings. According to the OECD report, sustainable plastics are defined as plastic materials used in products that provide societal benefits while enhancing human and environmental health and safety across the entire product life cycle. Furthermore, the OECD also defines sustainable materials management as an approach to promoting the use of sustainable materials that integrate actions aimed at reducing negative environmental impacts and preserving natural capital throughout the life cycle of materials while also considering economic efficiency and social equity (OECD, 2021). There are a variety of options for installing sustainable flooring, and bamboo, cork, natural linoleum and wood from sustainable plantations are the most popular eco-friendly flooring options. Reclaimed wood, natural plant fibre flooring (e.g., sisal carpets), recycled metal tiles, recycled glass, and recycled carpet, as well as stone flooring from properly-managed quarries, are all less popular and typically more expensive possibilities.

Eco-efficient Toilets

Improving the eco-efficiency of water-using residential appliances and fixtures requires technological innovation. In this vein, water-saving fixtures like dual flush toilets and high-efficiency toilets can be a significant asset in areas where water is scarce. Toilets that waste water through the usage of obsolete syphon boxes should be avoided, as flushing is the most common source of water waste, and in terms of domestic consumption, it ranks first as it consumes between 25% and 35% of total water consumption in the household (Zaied, 2018). As a result, encouraging the construction and usage of these water-saving toilets makes sense. A dual-flush toilet is a type of toilet that flushes varying volumes of water using two buttons or a handle mechanism. This mechanism's aim is to reduce the amount of water utilised to flush various forms of trash. The design makes use of the fact that flushing liquid waste uses less water than flushing solid trash. The dual flush toilets included two different buttons, one for a tiny (1.45 gpf) flush for liquid wastes and the other for a substantial (2.9 gpf) flush for solid wastes. However, later the dual flush toilet became more efficient, as now it only uses 1.6 gpf for a large flush and 0.8 gpf for a small flush (Arocha & McCann, 2013).

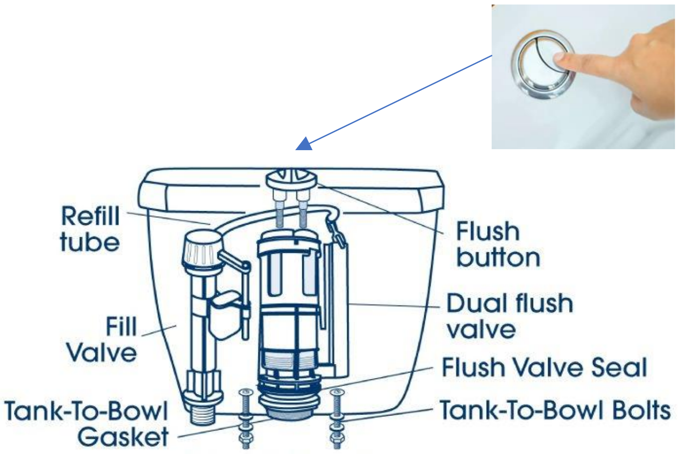

Figure 3. A dual flush toilet

Besides the dual flush toilet invention, the new idea of a U-shaped trapway toilet has also helped to reduce water consumption. Flushing water drives blackwater through the back zone and into the exit pipe in classic lavatory installations. The weight of some water from the flushing box is used in the study by An et al (2014) to tilt down a U-shaped trapway. It contains a spring positioned in a huge corrugated flexible tube that compresses prior to flushing to maintain a certain slope due to the elastic strain energy of the spring. When flushing begins, a particular volume of water flows into the flexible corrugated tube. When the inflowing water's mass exceeds the spring's elastic energy, the flexible corrugated tube relaxes to the bottom, making the trapway's slope horizontal and allowing waste to be discharged easily. However, a new approach by Zaied (2018) has been simplified, where the trapway is rotatable, which means it may be tilted down to allow blackwater to flow directly out of the bowl. Therefore, the flushing water is merely used to reduce friction and clean the route. This method is explained as shown in Figure 4.

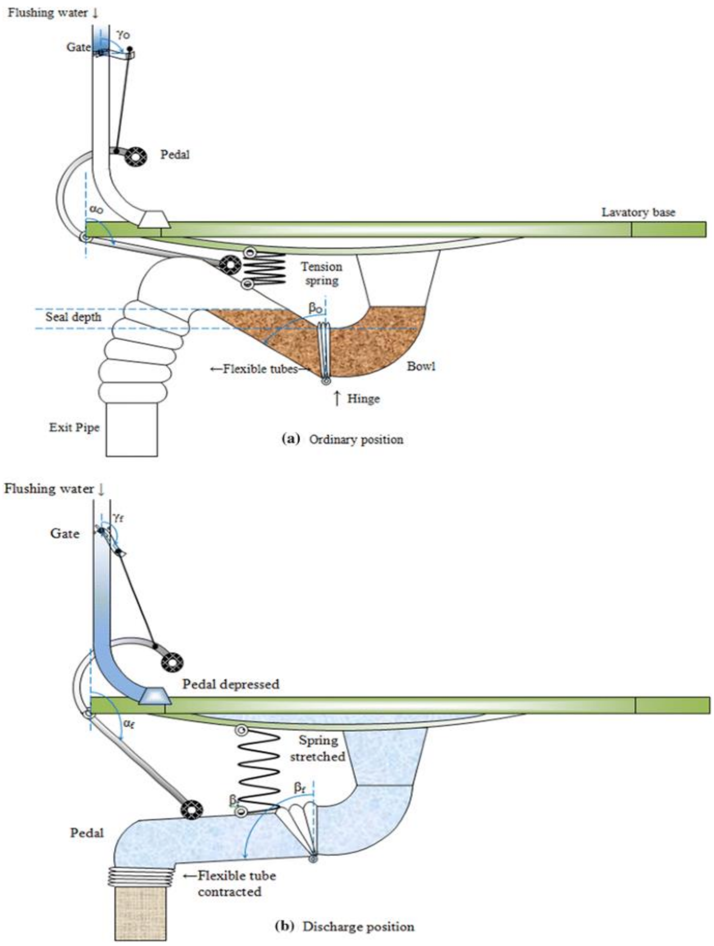

Figure 4. Comparison of traditional lavatory and rotatable trapway system
Source: Zaied (2018)

Green Home in Southeast Asia

Southeast Asia has enormous renewable energy potential, but these resources have been largely overlooked in the past. This is particularly true in Indonesia and the Philippines, where the region offers a lot of geothermal potential. Meanwhile, other countries in the region, such as Vietnam, Cambodia, Laos, and Myanmar have the capacity to harness hydropower on a large scale, and the bloc's location means that the 12 hours of sunlight it receives each day could easily be converted into solar energy. In Southeast Asia, wind power offers similar potential.

Singapore

Singapore is at the forefront of most technological developments, so it is no surprise that they are also at the forefront of green technology. Thus, in bridging sustainable living, the Housing and Development Board (HDB) of Singapore has designed the HDB Greenprint into existing HDB estates, where this framework is used to create Green Neighbourhoods, Green Flats, and Green Communities. The HDB Greenprint was first implemented in Jurong's Yuhua estate, where 38 blocks of flats were converted into a Green Neighbourhood. The prototype HDB Greenprint programme in Yuhua was launched in 2012 with the goal of bringing energy-efficient, water-management, and waste management elements to this estate, which works for various initiatives such as enhancing existing cycling and pedestrian networks, securing bicycle parking facilities, skyrise greenery, vertical greenery, pneumatic waste conveyance system, solar photovoltaic system, energy-efficient LED lightings and outdoor LED street lighting with sensing control, elevator energy regeneration system, and sub-metering (HDB, n.a).

Figure 5. The HDB Greenprint
Source: HDB (n.a)

Besides that, the Green Home at North West is a programme designed to encourage residents of the North-West district to embrace Green Living at home by implementing eco-friendly habits and acquiring energy-efficient appliances. The government has set criteria where the home has to meet at least three points to qualify as a Green Home. The criteria are (1) have an air-conditioner with a 3-ticks rating on the new energy label, (2) a refrigerator with a 3-ticks rating on the new energy label, (3) a washing machine with 3-ticks on the water-efficiency label, (4) a television with a five-ticks energy efficiency rating, (5) a recyclable collection corner at home, (6) an instantaneous water heater and (7) natural ventilation in the common living space (North West Community Council, n.a). Another initiative for Green Homes is the Green Homes Package, where the household received a rebate on energy-efficient appliances purchased. Meanwhile, elevator energy regenerations are applied in the lift systems to reduce energy consumption, which allows for the recovery of 20% of the energy utilised by lifts without impacting lift operations (HDB, n.a). For Green Commuting, two initiatives have been taken, including a cycling path network and a dual bicycle rack system at all new HDB developments, to ensure the residents enjoy a greener and healthier way. The invention of a dual bicycle rack allows two parked bicycles to be safely and securely stacked.

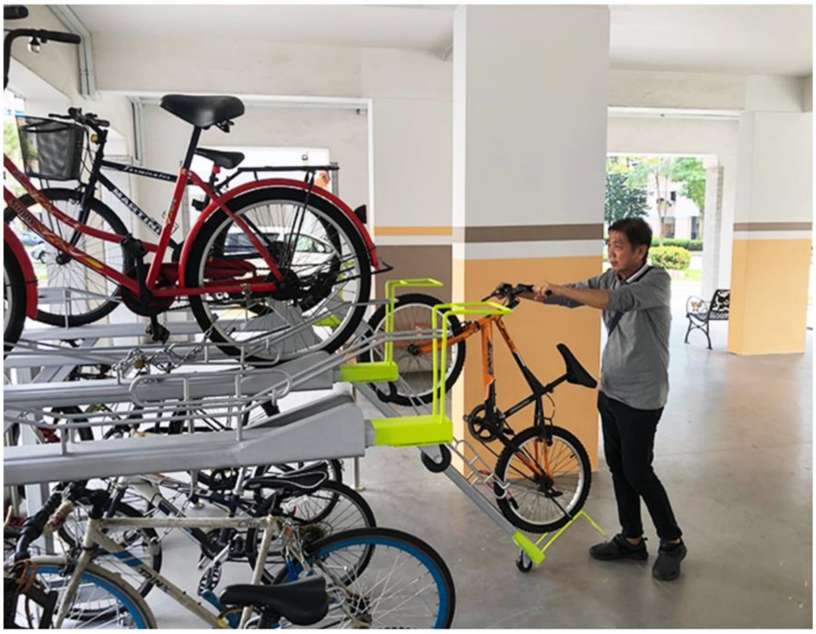

Figure 6. Dual bicycle rack system
Source: HDB (n.a)

Singapore also will be using the rainwater harvesting system, which was successfully piloted utilising Membrane Technology to improve water resource efficiency in public housing. This rainwater harvesting system would reduce the amount of water used for block cleaning at void decks, garbage chutes, and corridors (HDB, n.a).

Malaysia

In 2009, the Malaysian government established the Green Building Index to promote a sustainable approach to development and safeguard the environment (Shafiei et al., 2013). The GBI is a rating system that is used in both residential and non-residential buildings, in which six criteria are considered: (1) energy efficiency, (2) indoor environmental quality, (3) sustainable site and management, (4) material and resource, (5) water efficiency and (6) innovation. However, embracing the green aspect in residential development has experienced some barriers, where house developers face greater construction expenses as a result of incorporating green features to get a Green Building Index (GBI) certification. A while ago, the lack of demand for green homes was the major issue facing green home developers in Malaysia (Alias et al., 2010). However, the green home has recently become popular in Malaysia. Many green home projects have been launched in different areas of Malaysia, such as the Avantas Residences in Kuala Lumpur, Tropez Residence in Johor Bharu, and the Light Point in Penang. These and many other green residential developments have proven that the green concept is increasing in popularity and is widely embraced by the public (Goh et al., 2021). According to the GBI council’s statistics, 333 new residential construction projects in Malaysia have been registered under GBI by September 30, 2020 (GBI, 2020). Prior studies proved that the green features of energy efficiency aspects have a higher contribution, and this is in line with the Malaysian government, which has implemented regulations to encourage residents to install solar photovoltaic panels from January 1, 2019 (Carvalho et al., 2018). Meanwhile, water-efficient green features contribute less to residential energy savings, albeit the feature helps to save costs and reduce water consumption for Malaysia's water tariff (Chan, 2009). In Malaysia, private housing developers take responsibility for providing green homes, while the government focuses on providing affordable homes.

Indonesia

Indonesia's regional administrations encounter many challenges in estimating population growth or decline, and in providing enough housing facilities, particularly in densely populated areas. Therefore, the quantity of houses is prioritised over the quality (Larasati et al., 2007). In certain areas in Indonesia, such as Medan City, the green home is not well recognised, where people mistakenly believe that a green home is simply a house surrounded by trees (Fachrudin & Fachrudin, 2017). However, Indonesia has taken action by embracing the concept of a green home. For this article's purpose, a number of green homes in Indonesia are named, such as the *Kampung* Improvement Program by the Indonesian government, the eco-house by the Institute of Technology Surabaya, and the eco-house by *Pusat Penelitian Lingkungan Hidup* (Environmental Educational Center), Sololiman, East Java. According to these green homes, there is a set of requirements for Indonesian green homes. The first point is the need to apply a passive design strategy to reduce energy use in a domestic setting. In hot, humid conditions, a passive design strategy aims to limit the usage of power for lighting and avoid the use of air conditioners. The interaction of daylight, radiation, and ventilation is included in the design, and the design should allow sunlight and draughts into the structure while avoiding outside heat (Pandjaitan, 1998). Additionally, the design of a natural ventilation system needs an understanding of the mechanisms of airflow through buildings, as well as the elements that influence airflow patterns within (Bhatia, 2015). Next, Larasati et al. (2007) suggested increasing the use of alternative or local materials, such as using bamboo as a building material, while Nurdiah and Juniwati (2020) mentioned that bamboo has a lot of potential as **a** sustainable resource and can be utilised for the primary building material. Noia (2015) supported the idea that bamboo is convenient to cultivate, handle, harvest and mobilise. The suggestions for improvements in the housing sector for infrastructure (environmental services such as site and water) are frequently not planned ahead of time, and are only installed after the homes are constructed (Larasati et al., 2007). This circumstance frequently results in the emergence of unstable housing facilities, which results in unpredictable energy and resource usage.

Figure 7. Green Village in Indonesia uses bamboo
Source: National Geographic (n.a)

Thailand

The National Housing Authority (NHA), a state-owned enterprise under Thailand's Ministry of Social Development and Human Security, has adopted the New Urban Agenda (NUA) to end poverty and ensure that no one is left behind by ensuring safe and equal access to physical and social infrastructure, basic services, and adequate and affordable housing. NHA is also focused on incorporating sustainable urban housing concepts and practices into its assets in order to provide people, particularly those from low-income households, with affordable and sustainable urban housing and community development. NHA has formed a strategy for green homes, which includes (1) an energy-efficient green home design and labelling scheme, (2) an incentive mechanism for promoting energy-efficient homes and (3) raising awareness and building capacity for promoting energy-efficient homes (Arunpreechawat & Pont, n.a). NHA has created a Sustainable Finance Framework for affordable housing with the goal of using its investments to eliminate inequality in housing access for Thai residents, while also contributing to inclusive growth and promoting the creation of a sustainable future. The Sustainable Finance Framework of the National Housing Authority corresponds with the following SDGs:

Table 1
Alignment of Thailand National Housing Authority's Affordable Housing and Socioeconomic Empowerment Goals with the United Nations Sustainable Development Goals.

Eligible Categories	Sample Eligible Projects	UN SDG Alignment and Commitments/ Contributions
Affordable Housing	• Increase in number of affordable and decent homes available for target populations.	1 No Poverty; 7 Affordable and Clean Energy; 10 Reduced Inequalities; 11 Sustainable Cities and Communities
Socioeconomic Advancement and Empowerment	• Empowering target populations especially women to capable to generate income for their living and paying for affortable housing. • Good community environmental management.	3 Good Health and Well-Being; 5 Gender Equality; 9 Industry, Innovation and Infrastructure; 12 Responsible Consumption and Production; 13 Climate Action
Green Building	• Increase in number of energy and water efficient homes available for target population. • Contribution toward a net zero carbon society through reduction of greenhouse gas emissions. • Increase number of eco-friendly construction products and/or appliances to market.	7 Affordable and Clean Energy; 11 Sustainable Cities and Communities; 12 Responsible Consumption and Production; 13 Climate Action

Source: National Housing Authority (2021)

Conclusion
It can be difficult for the typical individual to recognise a green home and green features. A green home saves energy and water, consumes fewer natural resources, produces less waste, and is healthier and more comfortable for its inhabitants. In a word, green elements in a home will significantly decrease or eliminate negative environmental impacts. Green features in a home will often result in cheaper energy bills and improved indoor air quality.

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