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Editor's Note

In this issue of Technology Magazine we focus on Energy Efficient Infrastructure, exploring how innovation and sustainability are key to the future of our built environment. As authors who have contributed to this issue discuss in their articles, the need for energy efficient infrastructure has never been more urgent. Also, the rise in the global energy demand and the intensification of climate change has led to the research and innovation in development of integrated energy efficient technologies.

This issue also focuses on the implementation side of energy efficient infrastructure, which includes our conversation with Mr. Thanat Kriausakul, VP-Sustainability; CDO – Digital and Innovation, Pruksa Holding, where he elaborates on Pruksa's commitment to energy efficiency and renewable technologies. In another article, the authors share their experience in incorporating sustainable practices for planning and design of a new elementary school.

As presented in this issue, energy-efficient practices are essential in moving towards a resilient and sustainable future. And to drive energy efficient infrastructure, innovation in design, and application of advanced and emerging technologies are needed.

Our sincere gratitude extends to the contributors who have generously shared their experience and insights, enriching this edition. Thanks also to our editorial team for their efforts in developing this issue.

This magazine is a knowledge product of AIT Solutions, serving as a professional communication platform for experts and researchers, and providing readers a window to the latest technologies, events, and developments in the field.

Thank you for joining us on this insightful journey.

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Smart and Sustainable Roads: Integrating Energy Efficiency and Sustainability in Urban Road Transportation

Smart roads, integrating energy-efficient technologies like solar panels and Light Emitting Diode streetlights, reduce energy consumption, support electric vehicle adoption, and enhance resilience against climate impacts.

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Summary

Smart roads, integrating energy-efficient technologies like solar panels and Light Emitting Diode streetlights, reduce energy consumption, support electric vehicle adoption, and enhance resilience against climate impacts. By incorporating real-time monitoring and adaptive infrastructure, these smart roads can dynamically respond to changing conditions, ensuring safety and efficiency for all users. The innovations promote sustainability, optimize traffic flow, and contribute to economically viable and environmentally friendly urban transportation systems.

Introduction

Cities around the world are focusing on developing sustainable transportation system to tackle traffic congestion, emissions, air pollution, and the growing demand for energy. These challenges are significant hurdles to achieving energy efficiency and sustainability in road transport. To enhance transportation network efficiency and reduce environmental impact, innovative solutions are needed. Smart roads, with their advanced technologies and intelligent design principles, are paving the way for a sustainable future in urban transportation. By integrating energy efficiency and sustainability at their core, smart roads are key to creating a connected, eco-friendly future.

Smart roads come equipped with sensors, solar panels, Internet of Thing (IoT) devices, adaptive traffic management systems, and electric vehicle (EV) infrastructure (see Figure 1). These technologies work together to optimize traffic flow, minimize energy consumption, and lower carbon emissions, contributing to a cleaner, greener urban environment and improving the quality of life for city residents. Incorporating sustainable solutions like green spaces and promoting non-motorized transport helps reduce the carbon footprint of urban transportation and creates more livable urban spaces (Toh et al., 2020).

As cities continue to grow and evolve, implementing smart roads will be essential for creating resilient and sustainable transportation systems that meet future demands. Embracing a holistic approach that includes renewable energy sources, advanced technology, and sustainable urban design will enable cities to develop transportation networks that are both efficient and environment friendly. This forward-thinking approach ensures that urban mobility supports economic growth and enhances sustainable living for the future. The purpose of this article is to explore how smart roads can enhance energy efficiency, reduce environmental impact, and create more resilient and sustainable transportation systems.

This forward-thinking approach ensures that urban mobility supports economic growth and enhances sustainable living for the future.

Figure 1: Smart Road Technology & Energy Efficiency Integration

Source: *Toh et al., (2020)*

Energy-Efficient Infrastructure: The Foundation of Sustainability

Developing energy-efficient infrastructure for smart roads is crucial for creating sustainable, resilient and efficient transportation systems. By using suitable technologies and sustainable practices, smart roads can reduce energy consumption and environmental impact while improving transportation efficiency and safety. Technologies like solar roads, Light Emitting Diode (LED) street lighting, EV charging stations, and energy harvesting methods are becoming increasingly popular. Solar roads capture sunlight to generate electricity, while other roads use the vibrations from passing vehicles to produce power. This energy can be used to power streetlights, signs, and traffic signals, and can be stored or fed into the electric grid. The following are selected cases showing practical examples.

Case 1: Harvesting Energy from Roads

In France, the Wattway Solar Road is being tested across the country, including at motorway toll booths to power the gates and payment machines (see Figure 2). This technology captures unused ambient energy and converts it into electricity, which can be used for road infrastructure like lighting and signals. The energy can be stored in batteries for later use or sent to the power grid, all without needing extra land, as it uses the existing road network.

Figure 2: Wattaway created PV modules suitable for road placement

Source: *Wattway – LaRouteSolaire (2019)*

Case 2: LED street lighting

In the UK, Nottinghamshire County Council upgraded its streetlights from inefficient sodium lights to energy-saving LEDs (see Figure 3). This switch significantly reduced energy consumption and maintenance costs. Initially, turning off streetlights at night faced public objections, leading to the adoption of LED technology in 2013. By partnering with Salix Finance for interest-free loans, the Council replaced 10,000 lanterns annually, cutting energy usage by 48% and achieving substantial carbon savings. Key strategies included engaging stakeholders, meeting British Lighting Standards, and selecting Holophane Lighting for consistent quality and supply.

Figure 3: Hucknall bypass before and after upgrading LED streetlights

Source: *Midlands Net Zero Hub (2023)*

Pathways to Sustainable Road Transportation: Implementation of Clean Energy and Smart Mobility

The integration of transportation with energy, clean, and smart mobility signifies the merging of two crucial sectors within the wider energy transition and global climate action. Despite the existence of notable obstacles, progress in intelligent transportation and environmentally-friendly energy infrastructure is already transforming the way people move.

Key Pathways to Implementation:

Integration of Smart Grids and Renewable Energy Sources:

Integrating smart grids with renewable energy sources is critical for transforming road transport into a sustainable system. Smart grids enhance energy distribution efficiency and reliability by using digital technology to monitor and manage electricity flow in real time. This advanced system reduces energy losses, balances supply and demand, and supports demand response programs. When coupled with the transition to renewable energy sources like solar, wind, and hydro, smart grids significantly reduce Greenhouse Gase (GHG) emissions and provide a continuous, sustainable energy supply, resulting in long-term cost savings (Lu, 2016).

Support for Electric Vehicles and Public Transport:

In numerous aspects of smart roadways, the connection between renewable energy and smart infrastructure is readily apparent. For example, smart grids enable efficient EV charging, optimize charging times, and support vehicle-to-grid (V2G) technology, where EVs can supply power back to the grid during peak times (Mouyal, 2018). Additionally, the electrification of public transport, such as electric buses and trams, benefits from a stable energy supply managed by smart grids, with renewable-powered charging stations further enhancing sustainability. For instance, as local pathways shown in Table 1, advancing electric buses through technological innovation, enhancing infrastructure with smart grids and highways, and implementing policy measures like tax benefits to encourage the adoption of clean fuel vehicles are all aimed at creating a sustainable transportation system.

Table 1 Pathways and Measures to Supporting Public Transport Electrification through Smart Grids and Renewable Energy: A Case Study of Pathum Thani Province, Thailand

Category	Subcategory	Sustainable Path Development Approach	Selected Measures
Technology and Innovation	Energy and Automotive Technology	Electric Power	• Electric Buses
Infrastructure	Road infrastructure	Smart Highway System	• Real-time traffic reporting
		Smart Grid	• Standalone charging station • Fast charging station
Measures, policies and regulations	Policy to support the reduction of CO_2 from transportation	Tax benefits	• Tax cuts for clean fuel vehicles such as bio, electric and hybrid

Source: *Based on Focus Group Discussions (2024) and thematic area analysis*

Infrastructure Integration and Innovation:

Infrastructure integration, including smart traffic management and energy-harvesting roads, contributes renewable energy to the grid, supporting sustainable transport initiatives. A practical illustration of this integration can be as example in Case 3: Climate Smart City, where the Climate Street project demonstrates how sustainable urban infrastructure can effectively reduce carbon emissions.

Case 3: Climate Smart City

Climate Street is a pilot project in Amsterdam city's main shopping area aimed at creating a sustainable, carbon-neutral district. The project includes the installation of solar panels to generate electricity and the integration of smart meters to monitor energy consumption. To enhance energy efficiency, all streetlights have been replaced with LEDs, and BigBelly solar-powered trash cans have been introduced. The area uses electric garbage trucks from a single service provider, contributing to reduced emissions. Additionally, smart power plugs have been implemented to automatically control electrical devices, and a smart light pole system has been set up to optimize the logistics process (DEPA, 2024). These initiatives collectively reduce carbon dioxide emissions and exemplify the integration of sustainable practices in urban infrastructure, aligning with the principles of smart roads.

Synergizing Mitigation and Adaptation: Creating Resilient Transport Systems

This section emphasizes the importance of combining climate mitigation and adaptation strategies to create resilient transport systems that can withstand climate change impacts. It covers the technologies, materials, and design approaches used to enhance the resilience of smart roads and transportation infrastructure.

Integrating Mitigation and Adaptation Strategies in Smart Roads

An effective combination of mitigation and adaptation strategies is crucial for promoting holistic sustainability in smart road systems. Mitigation efforts focus on reducing GHG emissions and energy consumption, while adaptation ensures infrastructure resilience against climate impacts. These goals are achieved by incorporating energy-efficient technologies such as LED street lighting, solar panels, and energy harvesting systems. Additionally, infrastructure that supports EVs and smart traffic management plays a vital role in emission reduction. For instance, the enhancement of EV charging infrastructure through public-private partnerships in Bangkok and surrounding areas, and the deployment of smart traffic signs on highways in Bangkok, Thailand, exemplify these efforts (see Figures 4(a) and 4(b)).

Furthermore, using sustainable materials in road construction helps lessen the environmental impact. Adaptation strategies are equally important, focusing on climate-resilient infrastructure designed to withstand extreme weather conditions such as flooding, heatwaves, and heavy snowfall. Smart roads utilize real-time monitoring through sensors and IoT devices to track road conditions and environmental factors, enabling quick responses to climate events (Musa et al., 2023). Flexible design features also allow roads to be modified or upgraded as climate conditions change.

(a) charging stations

(b) LED board

Figure 4 (a)**:** EV charging infrastructure through public-private partnerships in Bangkok and surrounding areas; (b) Intelligent Traffic Signs in Bangkok

Source: *(a) Photo taken by Sutinee Choomanee (December 2022); (b) The Office of Transport and Traffic Policy and Planning, Thailand (2017)*

Examples of Adaptive Infrastructure Addressing Climate Risks

Smart roads incorporate adaptive infrastructure to handle specific climate risks, enhancing resilience against adverse weather effects. For instance, flood-resistant roads in flood-prone areas are designed with elevated roadways to prevent waterlogging and maintain accessibility during heavy rains (ClimateAdapt, 2023). Permeable pavements allow water to seep through, reducing surface runoff and flooding risks, while advanced drainage systems quickly channel water away from road surfaces. Heat-resilient roads feature reflective surfaces and cool pavements to reduce heat absorption and lower road surface temperatures, combating the urban heat island effect. Shaded roadways with trees and vegetation provide natural cooling, enhancing comfort for pedestrians and drivers. In snowy and icy conditions, heated roads with embedded heating elements can melt snow and ice, ensuring safer driving conditions, and durable materials that withstand freeze-thaw cycles without deteriorating maintain road quality during winter.

These adaptive infrastructure measures ensure that smart roads remain functional and safe under various climate conditions, contributing to overall urban resilience. By synergizing mitigation and adaptation strategies, smart roads create resilient transport systems that reduce environmental impact and withstand climate challenges. Through innovative designs and adaptive infrastructure, smart roads ensure sustainable and reliable transportation, contributing to the overall resilience and sustainability of urban environments.

Conclusions

Incorporating sustainability and energy efficiency into road transportation offers several advantages that enhance the quality, dependability, and environmental protection of transportation systems. Smart roads equipped with solar panels, LED streetlights, and energy-harvesting systems significantly reduce energy consumption, leading to cost savings and decreased grid load. These roads also contribute to lowering air pollution and GHG emissions by supporting the adoption of EV and implementing intelligent traffic control systems. Adaptive infrastructure solutions, such as heat-resistant and flood-resistant surfaces, provide resilience and safety during extreme weather events, thereby extending the lifespan of transportation infrastructure. Additionally, the use of environmentally friendly recycled materials in construction further promotes sustainability. Real-time monitoring and data collection optimize traffic flow, reduce congestion, and enhance safety for all road users.

The insights and strategies presented in this article can be leveraged for future academic research and practical applications. Academically, the framework for integrating sustainability and energy efficiency into road transport can serve as a basis for further studies on the impacts of smart infrastructure on urban development and environmental sustainability. Researchers can explore the long-term effects of these technologies on urban mobility patterns, infrastructure resilience, and economic outcomes. Practically, the implementation of smart roads can guide policymakers and urban planners in developing more robust, environmentally friendly, and financially viable transportation systems. Future projects can build on the principles discussed here to create even more integrated and adaptive urban environment that align with global sustainability goals.

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Energy Efficient Infrastructure: Pioneering Sustainability and Innovation

As global energy demands rise and concerns about climate change intensify, the need for energy-efficient infrastructure has never been more urgent.

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As global energy demands rise and concerns about climate change intensify, the need for energy-efficient infrastructure has never been more urgent. Energy-efficient infrastructure encompasses buildings, transportation systems, and urban planning strategies designed to minimize energy consumption and reduce environmental impacts. This article explores the significance, strategies, and innovative technologies that drive energy efficiency in infrastructure, highlighting its role in fostering sustainability and addressing contemporary environmental challenges.

The Significance of Energy Efficiency in Infrastructure

A. Environmental Impact

Energy-efficient infrastructure significantly reduces greenhouse gas emissions, a primary driver of global warming. Buildings account for approximately 40% of total energy consumption in developed countries, and improving their efficiency can drastically cut CO_2 emissions. Energy-efficient transportation systems, such as electric vehicles (EVs) and public transit, also play a crucial role in reducing air pollution and mitigating climate change.

B. Economic Benefits

Investing in energy-efficient infrastructure can lead to substantial economic savings. Reduced energy consumption lowers utility bills for consumers and operational costs for businesses. Additionally, it stimulates job creation in the green technology and construction sectors. Energy-efficient buildings and infrastructure can also enhance property values and attract environmentally conscious tenants and investors.

C. Social and Health Benefits

Energy-efficient infrastructure contributes to improved public health by reducing air and noise pollution. Enhanced indoor air quality in energy-efficient buildings leads to healthier living and working environments. Furthermore, energy-efficient public transportation and urban planning promote active lifestyles, reducing the prevalence of lifestyle-related diseases.

Strategies for Energy Efficiency

A. Building Design and Construction

Passive Design

Passive design strategies involve designing buildings that naturally regulate temperature and lighting without relying on mechanical systems. This includes optimal building orientation, effective insulation, natural ventilation, and daylighting. Passive design not only reduces energy consumption but also enhances occupant comfort.

High-Performance Building Materials

The use of high-performance building materials, such as advanced insulation, low-emissivity windows, and reflective roofing, significantly improves the energy efficiency of buildings. These materials help maintain indoor temperatures, reducing the need for heating and cooling.

B. Renewable Energy Integration

Incorporating renewable energy sources, such as solar panels, wind turbines, and geothermal systems, into infrastructure design can drastically reduce reliance on fossil fuels. Net-zero energy buildings, which produce as much energy as they consume, exemplify the integration of renewable energy in achieving sustainability goals.

Smart Grid and Energy Management Systems

Smart grids and energy management systems enable real-time monitoring and control of energy consumption. These systems optimize energy use, reduce waste, and enhance the integration of renewable energy sources. Smart meters, demand response programs, and energy storage solutions are key components of an intelligent energy infrastructure.

Transportation and Urban Planning

Sustainable Transportation Systems

Developing sustainable transportation systems, such as EVs, hybrid vehicles, and efficient public transit, reduces energy consumption and greenhouse gas emissions. Investments in EV charging infrastructure and public transportation networks are essential for promoting sustainable mobility.

Urban Planning and Green Spaces

Urban planning that prioritizes energy efficiency includes the development of compact, mixed-use neighborhoods that reduce the need for long commutes. Incorporating green spaces and green roofs not only enhances urban aesthetics but also improves air quality and provides natural cooling, reducing the urban heat island effect.

Innovative Technologies Driving Energy Efficiency

Energy efficiency requires policymakers to engage with a wide range of stakeholders, including end users, businesses, utilities, IT companies, ESCOs, and data providers. Crafting effective policies that are both impactful and tailored to these diverse groups demands comprehensive data and robust connectivity, which can be challenging and expensive to achieve. Digital tools offer a solution by facilitating easier access to necessary data and fostering the connections crucial for advancing energy efficiency policies as shown in Figure 1.

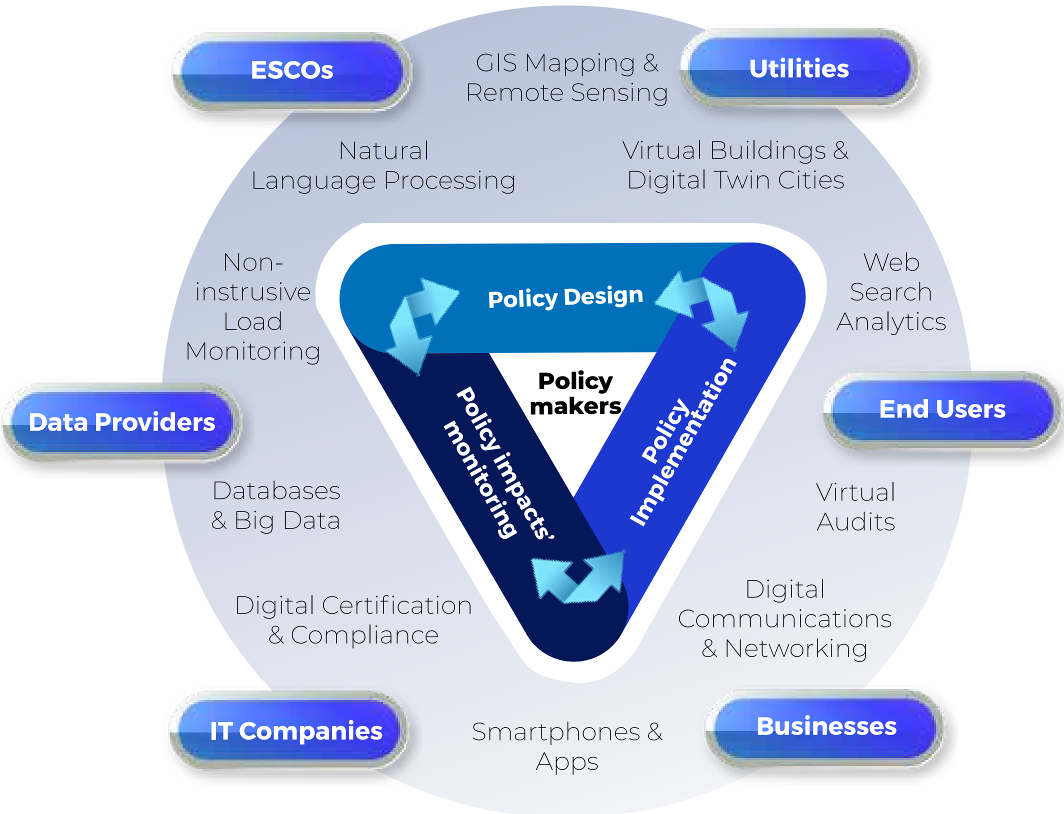

Figure 1: Digital tools for energy efficiency policy ecosystem

Source: *https://www.iea.org/articles/better-energy-efficiency-policy-with-digital-tools*

Internet of Things (IoT)

The IoT enables the creation of smart buildings and cities, where interconnected devices optimize energy use. Smart thermostats, lighting systems, and appliances can adjust their operation based on occupancy and environmental conditions, significantly reducing energy waste.

Advanced Building Automation Systems

Building automation systems (BAS) integrate various building functions, such as heating, ventilation, air conditioning (HVAC), lighting, and security, into a single, cohesive system. Advanced BAS use artificial intelligence (AI) and machine learning to predict energy demand and optimize system performance.

Energy-Efficient Appliances and Equipment

The development and adoption of energy-efficient appliances and equipment, such as LED lighting, high-efficiency HVAC systems, and energy-star rated appliances, contribute significantly to reducing overall energy consumption in buildings and infrastructure.

Green Building Certifications

Certifications such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) promote energy-efficient practices by setting benchmarks for sustainable building design, construction, and operation. These certifications encourage the adoption of best practices and continuous improvement in energy efficiency.

The IEA has developed the Readiness for Digital Energy Efficiency (RDEE) framework, which outlines key policy considerations for enhancing the use of digital technologies in energy efficiency. This framework offers crucial guidance on the necessary physical, social, and regulatory infrastructure to help policymakers maximize the benefits of digitalization in energy efficiency initiatives as shown in Figure 2.

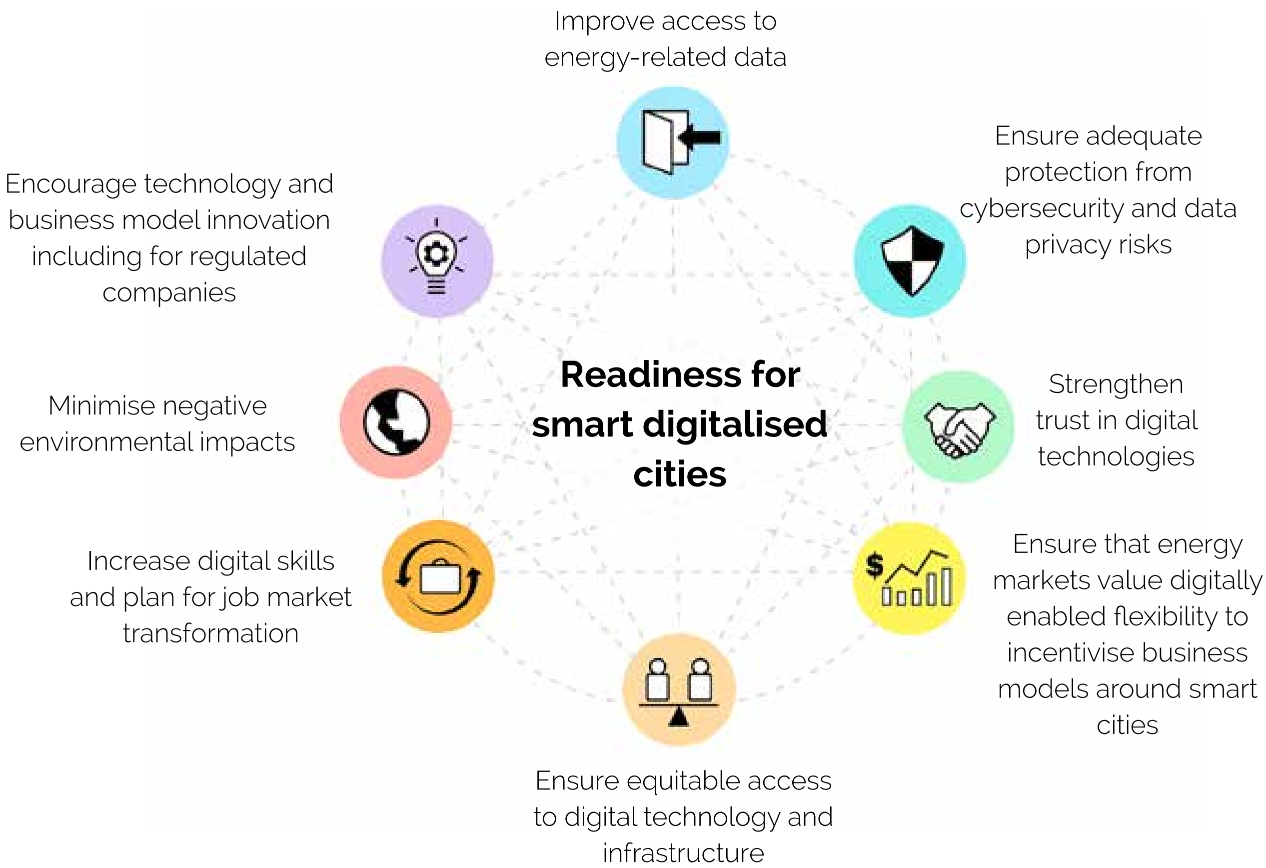

Figure 2: IEA Readiness for Digital Energy Efficiency framework

Source: *https://www.iea.org/articles/better-energy-efficiency-policy-with-digital-tools*

Case Studies

A. The Edge, Amsterdam

The Edge in Amsterdam is one of the world's most sustainable office buildings. It utilizes a combination of solar panels, an aquifer thermal energy storage system, and IoT technology to achieve a net-zero energy status. The building's smart systems optimize lighting, heating, and cooling based on occupancy patterns, significantly reducing energy consumption.

B. Masdar City, Abu Dhabi

Masdar City is a planned city project in Abu Dhabi that aims to be one of the most sustainable urban communities in the world. It incorporates passive design principles, renewable energy sources, and advanced transportation systems, including a personal rapid transit system. Masdar City serves as a model for integrating energy-efficient practices into urban planning.

Challenges and Future Directions

Initial Investment Costs

The upfront costs of implementing energy-efficient infrastructure can be a barrier. However, long-term savings and environmental benefits often outweigh these initial expenses. Innovative financing models and government incentives can help overcome this challenge.

Technological Integration

Integrating new technologies into existing infrastructure can be complex and costly. Ensuring interoperability and addressing cybersecurity concerns are critical for successful implementation.

Policy and Regulation

Supportive policies and regulations are essential for promoting energy efficiency. Governments must establish clear standards and provide incentives for the adoption of energy-efficient technologies and practices.

Future Trends

Future trends in energy-efficient infrastructure include the continued development of smart cities, advancements in renewable energy technologies, and the proliferation of AI and machine learning in energy management. Collaborative efforts between governments, businesses, and communities will be crucial in driving these advancements.

Conclusion

Energy-efficient infrastructure is pivotal in addressing the dual challenges of rising energy demand and environmental sustainability. Through innovative design, renewable energy integration, and advanced technologies, energy-efficient infrastructure not only reduces environmental impacts but also offers economic and social benefits. As the world continues to urbanize and face climate challenges, pioneering sustainable and energy-efficient practices will be essential in creating a resilient and sustainable future.

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Pruksa's Commitment to Energy Efficiency and Renewable Technologies

Q&A with

Mr. Thanat Kriausakul

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Q **How is Pruksa prioritizing energy efficiency in its projects?**

A Pruksa is committed to achieving carbon neutrality by 2050 and aims for a 30% reduction in its carbon footprint by 2030. This commitment involves addressing both Scope 2 emissions, which pertain to internal energy usage, and Scope 3 emissions, which involve the carbon footprint of the products delivered to clients. To achieve these goals, Pruksa focuses on enhancing energy efficiency within its operations and throughout the lifecycle of its properties. This includes implementing energy-saving measures in its construction processes, utilizing energy-efficient materials, and ensuring that the buildings they develop are designed to minimize energy consumption. By integrating these strategies, Pruksa aims to significantly reduce its environmental impact and contribute to global sustainability efforts.

Q Could you highlight some cutting-edge technologies or design principles Pruksa integrates to enhance energy efficiency in its properties?

A In 2024, Pruksa will launch its energy-efficient homes, certified by the Green Building Institute. These homes will incorporate advanced design principles and technologies to maximize energy efficiency. Key features include insulated walls to minimize heat transfer, high-reflectance coatings to reduce cooling needs, upgraded glass for windows to enhance thermal insulation, and innovative roof designs to improve overall energy performance. Additionally, Pruksa is exploring the integration of smart home technologies that optimize energy usage based on real-time data, ensuring that their properties are not only energy-efficient but also comfortable and sustainable for residents.

Q How does Pruksa address the challenge of balancing the initial costs of energy-efficient technologies with the long-term benefits for homeowners and the environment?

A Pruksa addresses the cost challenge by offering a modular approach to solar energy systems. They provide small solar panel sets priced below 50,000 THB, which can be expanded as homeowners' energy needs grow. This DIY solar system is designed for easy installation and use, offering a plug-and-play solution that is simpler and safer compared to traditional string inverter systems. By lowering the initial investment barrier, Pruksa enables more homeowners to adopt renewable energy, reducing their long-term energy costs and environmental impact. This approach ensures that energy efficiency is accessible and financially viable, encouraging broader adoption of sustainable technologies.

Q What role do renewable energy sources play in Pruksa's current projects, and how do you see this evolving in the future?

A Since 2023, Pruksa has integrated renewable energy sources into its projects by establishing a solar roof company. This initiative includes installing solar panels on common facilities such as clubhouses, sales offices, and wastewater treatment plants in every village they develop. By prioritizing the use of solar energy, Pruksa not only reduces the carbon footprint of these facilities but also sets a precedent for future projects. Looking ahead, Pruksa plans to expand the use of renewable energy, including exploring advanced storage solutions like home battery systems, which will allow them to further enhance energy efficiency and move closer to achieving net-zero buildings.

Q Could you share examples of Pruksa projects that have successfully implemented energy-efficient solutions and the impact these have had on their communities?

A Pruksa has successfully integrated energy-efficient solutions in several of its projects. For instance, they have implemented solar roof systems as standard in new homes, ensuring that these properties generate a portion of their own energy from the outset. Additionally, solar street lighting has been installed on most internal roads within their developments, enhancing safety and reducing energy consumption. In their precast concrete factories, a 700kW solar roof installation significantly reduces reliance on the power grid provided by the Provincial Electricity Authority. These initiatives have led to lower energy costs, reduced carbon emissions, and increased sustainability within the communities Pruksa serves.

Q How does Pruksa foresee the evolution of energy-efficient infrastructure over the next decade, and what role will your company play in this transformation?

A Pruksa envisions a future where energy-efficient infrastructure is the norm, driven by advancements in renewable energy technologies and smart home systems. The company is actively seeking affordable home battery systems that can store solar energy for use during non-daylight hours, which is crucial for achieving net-zero buildings. By pioneering the adoption of these technologies, Pruksa aims to lead the transformation towards more sustainable living environments. They are committed to continuous innovation and investment in energy-efficient solutions, ensuring that their projects not only meet current standards but set new benchmarks for sustainability in the real estate industry.

Sustainable Practices for the Planning and Design of a New Elementary School

The aim of the project is to provide students, teachers, and surrounding communities with a smart, energy-efficient, and sustainable learning and teaching environment that aligns with the United Nations Sustainable Development Goals

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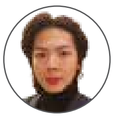

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A new elementary school is currently under construction in Nanzih District, Northern Kaohsiung. To accommodate the anticipated increase in educational demand resulting from population growth, driven by shifts in urban planning and the arrival of TSMC, an international semiconductor giant, the school is required to open for enrollment by 2026. The school comprises 48 classrooms and covers an area of approximately 3 hectares, featuring an open campus and preserving more than one hundred old trees. It is designed to be powered by a photovoltaic (PV) green energy system and employs an ultra-low energy consumption strategy. In addition to meeting the scheduling constraints, the aim of the project is to provide students, teachers, and surrounding communities with a smart, energy-efficient, and sustainable learning and teaching environment that aligns with the United Nations' Sustainable Development Goals (SDGs). The panoramic and close-up simulations of the campus are shown in Figure 1 and Figure 2, respectively.

Figure 1: The panoramic simulation of the campus

Figure 2: A close-up simulation of the campus

To meet the aims of the project, the new campus is designed to derive its power exclusively from a photovoltaic (PV) green energy source that harnesses sunlight to generate electricity using solar panels. The PV energy source creates a highly efficient and resilient energy ecosystem by pairing with a smart grid and energy storage device. The smart grid, as an advanced electrical grid infrastructure, utilizes digital technology, two-way communication, and intelligent devices to manage electricity generation, transmission, distribution, and consumption. The energy storage device addresses the inherent variability and intermittency of solar power generation, and provides the functions including excess power storage, grid stabilization, energy load shift, power backup, voltage regulation, and more shown in Figure 3.

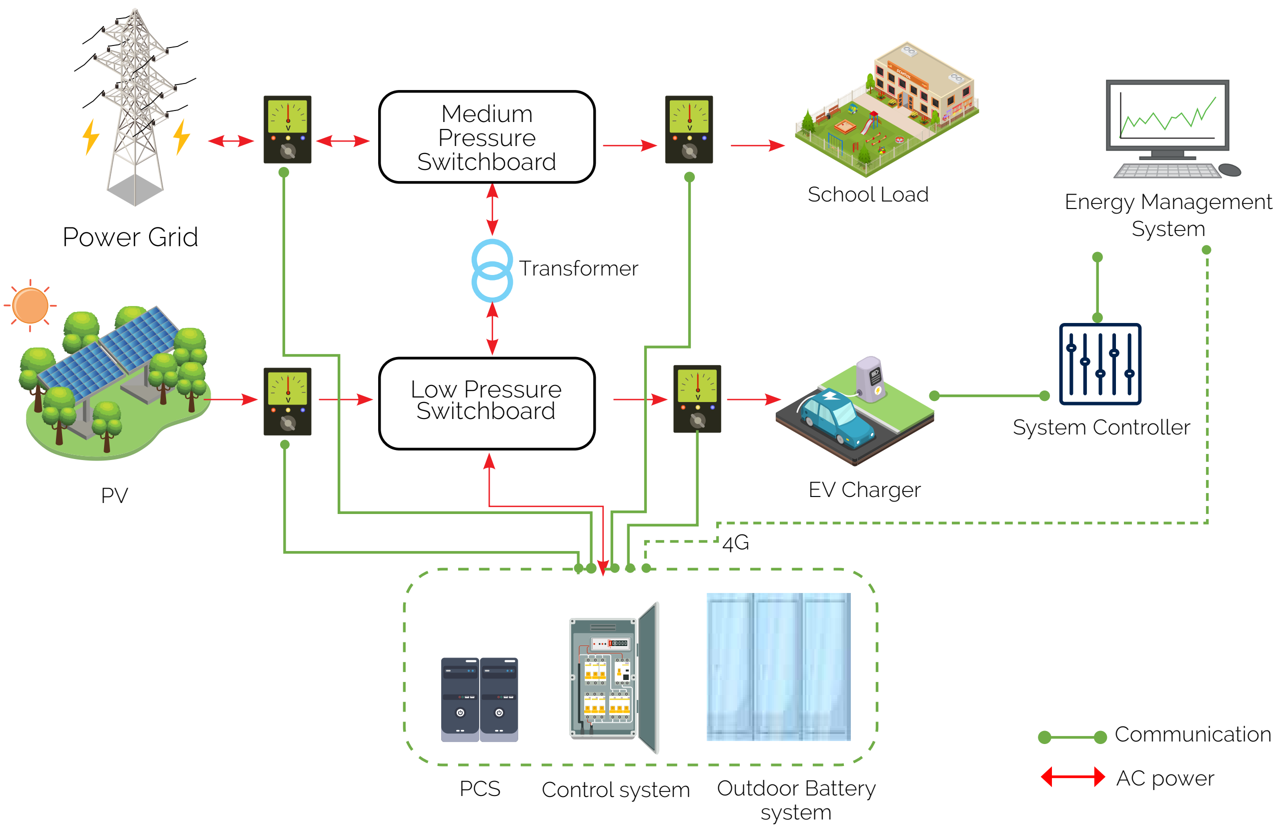

Figure 3: A close-up simulation of the campus

The integrated PV solar source, energy storage device, and smart grid system will create a low-carbon and intelligent campus. To ensure a sufficient and uninterruptible power supply, the photovoltaic panels are designed to maximize coverage area. Figure 4 shows an example designed to meet this design criteria, where the area covered by photovoltaic panels extends to the entrance plaza of the campus. The energy storage device and smart grid allow for centralized management, enabling the campus to be fully powered by the solar system. This approach reduces carbon emissions and promotes a sustainable and healthy campus.

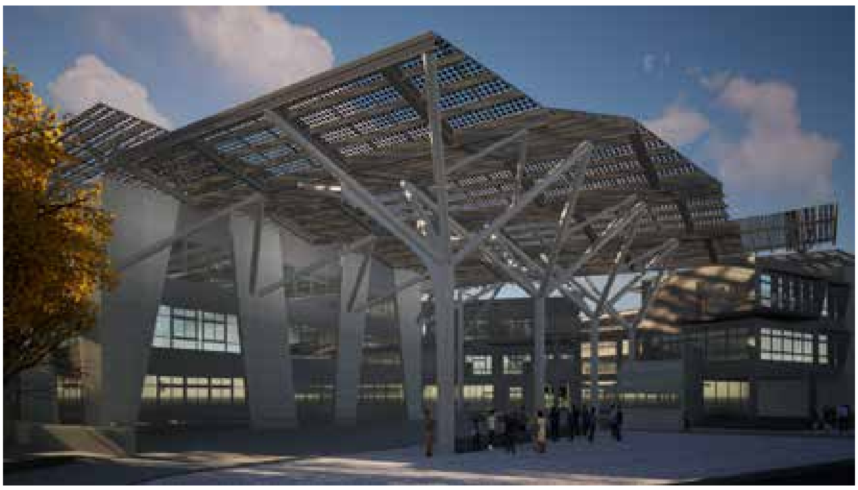

Figure 4: The entrance plaza covered with photovoltaic panels as part of the design to maximize the coverage area

In this project, carbon emissions are further reduced through the ultra-low energy (ULE) consumption approach. ULE consumption can be achieved through three steps. The first step is to identify the most comfortable or optimal state between the building façade and its surroundings through daylight simulation and computational fluid dynamics (CFD) analysis, based on observational results of natural airflow and sunlight. The next step involves planning and designing the air conditioning system, mechanical ventilation, and lighting as complementary measures to the identified optimal state. Finally, the intelligent management system, which integrates the smart grid, energy storage devices, and photovoltaic panels and is aimed at ultra-low energy (ULE) consumption, is incorporated into the energy management for the operation of the campus.

To create an aesthetic balance that represents a harmonious fusion between sustainable technology and design principles, the photovoltaic panels are seamlessly incorporated into building roofs, facades, and structures, further enhancing the visual appeal and functionality of the space. This approach essentially transforms the campus buildings into energy-efficient entities. Opting for material recycling and waste reduction, steel frame structures with partition walls and exterior wall panels made of cement composite honeycomb panels have been chosen as the pattern of the buildings for the entire campus. All construction materials conform to the principles of sustainable construction. The construction process emphasizes factory prefabrication and on-site assembly, eliminating the need for water to effectively manage the construction schedule.

As a smart, energy-efficient, and sustainable campus, the new elementary school aligns with the following Sustainable Development Goals (SDGs) of the United Nations:

Goal 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" – The project involves providing and improving educational facilities that are suitable for children, individuals with disabilities, and sensitive to gender considerations.

Goal 7: "Ensure access to affordable, reliable, sustainable, and modern energy for all" – The campus can be fully powered by photovoltaic green energy and managed by an intelligent power management system to provide reliable and sustainable energy for all learning and teaching needs.

Goal 11: "Building inclusive, safe, resilient, and sustainable cities and rural areas" involves providing safe, inclusive, accessible, and green public spaces.

Goal 12: "Ensure sustainable consumption and production patterns" –The project promotes efficient use of photovoltaic green energy resources and reduces waste by employing a steel frame structure, emphasizing factory prefabrication and on-site assembly.

Goal 13: "Take urgent action to combat climate change and its impacts" –The campus sets an example for enhancing education and awareness of climate change mitigation and adaptation, impact reduction.

Moh and Associates, Inc. along with RHT Architects and Associates, serve as the project management and construction supervision consultant (PCM) for the project, tasked with realizing a vision of a green, smart, and low-carbon building. The PCM is required to work closely with the owner to define design principles guiding the project towards establishing a low-energy consumption campus from the outset. During the design and construction phases, the PCM is responsible for conducting design reviews and providing construction supervision to ensure the new campus aligns seamlessly with the predefined goals.

This project sets several milestones for sustainable development in Taiwan, including being the first low-carbon campus with ultra-low energy consumption and self-sufficient green energy. Instead of conventionally being placed solely on rooftops, the photovoltaic panels are also integrated into the facades and structures of the campus buildings to achieve an aesthetic balance between sustainable technology and design principles. The groundbreaking for the construction of the new elementary school took place in May 2024. Student enrollment is scheduled to begin in 2026. It is anticipated that the smart, energy-efficient, and sustainable new elementary school will not only provide an excellent learning and teaching environment but also integrate with the surrounding communities to foster a more sustainable environment for all.

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Energy Efficient Infrastructure and Sustainability

With noticeably rapidly rising urban temperatures, making living somewhat unbearable, energy efficient methods must be adopted to provide conditions pleasant for living.

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Energy efficiency infrastructure

This is a huge undertaking and encompasses the gamut of entire town planning, industries, population control, balancing growth and politics. With noticeably rapidly rising urban temperatures, making living somewhat unbearable, energy efficient methods must be adopted to provide conditions pleasant for living. A colossal task! Nevertheless, within the realm of rational thinking many things can be done, keeping sustainability as the mantra, as explained in this article.

Energy Efficient Infrastructure and Sustainability are synonymous.

In 1987, the United Nations Bruntland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

To this end, energy efficient infrastructure contributes positively to the climate change agenda and encompasses the entire construction industry.

Sustainable Development Goals

The UN Sustainable Development Goals (SDGs) were born at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. And, on 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development officially came into force.

These Goals universally apply to all countries, who will mobilize efforts to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind. With only 6 years to go, the race is on to achieve maximum results.

Climate Change

More than being one of the UN Sustainable Development Goals (SDGs) 2030, climate change is a harsh reality that can no longer be ignored. Particularly with large-scale undertakings, adopting sustainable practices has been proven to be good for the environment as well as an organisation's bottom line. When done systematically, it can dramatically lower both the construction and operating costs of real estate.

Sustainable construction

The definition of "Sustainable Construction" is when people use sustainable materials.

"Green building (also known as **green construction** or **sustainable building**) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition. This requires close cooperation of the

Reference un.org

contractor, the architects, the engineers, and the client at all project stages".

Materials used in the construction of buildings already account for around nine per cent of overall energy-related CO_2 emissions.

Released at the round of climate talks in Egypt, COP27, the 2022 Global Status Report for Buildings and Construction finds that the construction sector accounted for over 34 per cent of energy demand and around 37 per cent of energy and process-related CO_2 emissions in 2021.

Philosophy

- The construction and real estate industries must implement zero-carbon strategies for new and existing buildings.
- The building materials and construction industries must commit to reducing their CO_2 emissions throughout their value chain.
- Develop cottage industry, such as brick-making.
- Encourage use of local expertise, for example, the country of Laos has excellent carpentry skills which must be kept alive.
- Use solar energy.
- Use locally available resources, including.
    - Local labour
    - Local contractors
    - Local materials

Constraints

Growth is outpacing efforts on energy efficiency and reducing energy intensity. The increase in global gross floor area between 2015 and 2021 is the equivalent to

the total land area covered in buildings in Germany, France, Italy, and Netherlands; if it were built on one level, at around 24,000 sq. km.

Governments, especially cities, need to implement policies that promote the shift to 'circular material economies'. Fast-growing countries and economies need investment in capacity-building and supply chains that promote energy-efficient designs and low-carbon sustainable construction.

The cement industry is one of the main producers of carbon dioxide, a potent greenhouse gas.

Why demolish old structures?

Under the guise of "development", old structures are being continuously razed to the ground and it's in place, building multistorey towers with massive construction. Is this sustainable? Of course, profit and greed play an important role in this so-called "development", leaving the climate change agenda and sustainability to the background.

Retaining old structures, albeit with restoration and repairs, also retains the fabric of the town/city, which is so important from heritage and cultural perspectives. The allied advantages are many, such as avoiding overcrowding, balancing the existing infrastructure and utilities, especially water and power supply, etc.

Green Building Certifications:

Certifications are a means to an end, but not the be-all and end-all. Often, obtaining and prominently displaying a Green Building plaque is considered more important than the route to this effort. Education is crucial here.

Here it is important not to simply utilise the certifications available because of their prominence in the building industry. Each certification has its uniqueness depending upon its geographic location and suitability of the climate and urban development. Moreover, the design and application knowledge differs greatly from region to region. For example, the Building and Construction Authority (BCA) Green Mark system from Singapore, is a prevalent rating tool for projects in Malaysia, Thailand, China, and Vietnam. It is established as most suitable for the urban tropics of South-East Asia, like the tropical monsoon climate of Laos.

Some of the issues to tackle are:

- To negotiate with the reviewer that the country is still a developing country.
- Its cities do not have separated bicycle lanes or such infrastructure as per green building requirement. However, despite this, people use bicycles for commuting.
- For example the data in 2017/18 showed that 22.5 percent of total traveling trips in Yangon, Myanmar use bicycles.
- In this case, if the reviewer allows roads to be used as a bicycle network, the credit can be complied as it connects to both diverse uses and/or rail stations.

The availability of assessors for face-to-face interaction and guidance plays a very crucial part in understanding the constraints and addressing credit-related compliance issues.

Education

This is by far the most important contribution to energy efficiency. And, it is best done by starting at the kindergarten level. We see the challenges faced in various forums to arrive at a consensus of opinion and the young generation is raising its voices against the powerful and greedy, each with its own vested interests.

Hopefully the toddlers of today, with effective education in the field of sustainability and climate change agenda (and therein lies a challenge as well!) will save the world for themselves!

AIT Solutions

Services

AIT Solutions is one of the outreach centers in Asian Institute of Technology, Thailand. The solutions and services provided by AIT Solutions are built upon the extensive research and development conducted by its experts in Asian Institute of Technology.

Wind Tunnel Testing

We conduct wind tunnel laboratory testing to assess the wind loads and responses of building sand structures in a controlled environment using an atmospheric boundary layer wind tunnel, with a working section of 2.5m x 2.5m x 23m.

Structural Health Monitoring

Our expert team uses advanced analysis technique to monitor the health of instrumented structures and assess their safety and reliability.

Structural Failure Investigations and Retrofit Design

Our expert team investigates and evaluates the causes of structural failures and develops retrofit designs to enhance the safety and reliability of existing structures.

Performance-based Seismic Design

We use advanced analytical methods to ensure the safety and performance of structures during earthquakes.

Software Development & IT

Creating customized desktop, web, mobile, and cloud-based applications in various fields, including structural engineering, mobile computing, knowledge products, construction monitoring and management.

Computational Modeling and Analysis of Complex Structural Systems

Our expert team uses state-of-the-art software and modeling techniques to simulate various scenarios and assess the performance of structural systems under different conditions.

Structural System Development & Code-based Design Review

To ensure that our clients' structures are designed to meet their specific needs while being safe and compliant with local codes and regulations.