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Editor's note

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National energy security is a challenge for most countries. Developing countries in particular are dependent on foreign exchange for their energy supply and must struggle to manage fast-growing per capita energy consumption while minimizing environmental impacts. In many countries the problem is typically exacerbated by a legacy of an antiquated, under-invested and inefficient technological energy infrastructure

With accelerating climate change and rapid deterioration of finite natural resources, the need for research and development of sustainable energy pathways is therefore crucial and immediate in its urgency. In parallel, it is also very important and necessary to change consumer mindset to promote responsible consumption behaviours among us all as individuals. Technological solutions are fast becoming more economically viable and competitive compared with fossil fuels; however, they only provide part of the answer if we continue as individuals to use energy as if it were a free and infinite resource.

Editorial Board

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Content

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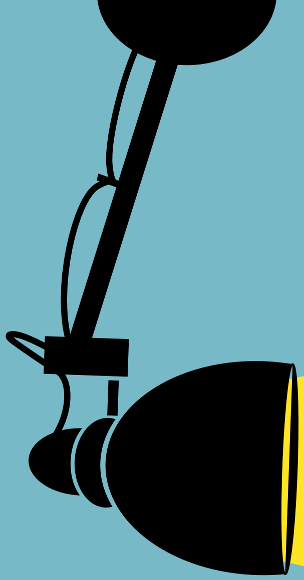

Smart Grid:

The Future of Power Technology

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Introduction

Nowadays, electricity is the main energy that drives the global economy and becomes one of the basic needs in human life. Without electricity, major activities, affecting human lifestyles, may be interrupted. Because production and transmission of electricity at present are simple and high efficient, it is widely used in many sectors. In the world amidst technologies like today, all human facilities require electricity. Electricity is the energy that can be easily produced and converted into other forms of energy that are easily used. It might be from solar cells that convert solar energy to electrical energy. Then, electrical energy can be converted into light in the light bulb, or converted into mechanical energy in the electric vehicle. However, currently, the technology in the production, transmission, and distribution of electricity is being changed. The main cause of the change comes from depletion of fossil fuels such as coal, oil and natural gas, used in electricity generation, together with these fuels create greenhouse gases leading to climate change and harmful pollution to human and the environment. Thus, renewable energy, which is considered as clean energy, is then received high interest. In addition, with the advancement of communication technology in which the internet plays important role in connecting, sending and receiving data in all sections related to the electricity system including generation, consumption and system supervision. It enables real-time information relating electricity to all relevant stakeholders. Therefore, the world is now entering a new era of electricity system creating possibility for electricity management with environmental friendly and more efficient in order to prepare and handle changes that will occur in the near future.

With human creativity combined with the research and development of various technologies and innovations, the world has been approaching the production and use of electrical energy to meet human needs while being environmental friendly.

Development of Thailand's Power System

The Electricity Generating Authority of Thailand (EGAT) is mandated to generate and distribute electricity nationwide. EGAT generates, transmits and then sells electricity to the Metropolitan Electricity Authority (MEA) in metropolitan areas, and to the Provincial Electricity Authority (PEA), which supplies the rest of the country. EGAT is also empowered to sell electricity directly to other major electricity users. Under the EGAT Act, EGAT also participates in other electricity-related businesses. Electricity is generated using a mix of coal-fired power stations, fuel oil, natural gas and hydropower. Several power plants using renewables such as wind and solar energy have also been established. But they make only small contribution to total supply compared with fossil fuel-based power plants. To meet the country's fast-growing demand and to have enough reserve in case of emergency, EGAT also purchases electricity from neighbouring countries, particularly hydroelectric power from Laos.

Thailand started using electricity in 1884 during the reign of King Rama V. Today's generation, transmission and distribution systems have not substantially changed since that time. EGAT supplies electricity to MEA and PEA through substations located around the country, that connect high-voltage long-distance transmission lines to local distribution systems. These substations control the flow of the power in the system and step down the voltage for distribution to households, commercial and industrial users. Officers monitoring the substations are responsible for issuing system notifications, sharing data and reporting problems (Figure 1).

In the past decade, electrical system or power grid has been changing as many new technologies had been introduced. It creates modern grid that enhances higher efficiency in energy management. Transmission System Operator (TSO) and Distribution System Operator

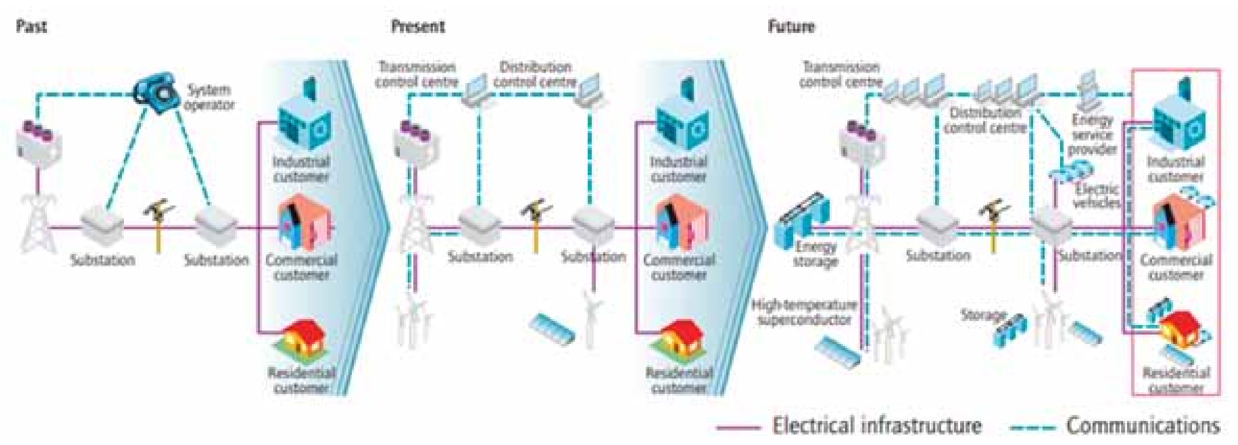

Figure 1 Development of the smart grid: past, present and future
Source: International Energy Agency (IEA) (2011)

(DSO) with automated communication and control devices have, by now, been mainstreamed to operate and control power grid. It can sometimes make automated decisions to optimize system efficiency and to balance loads. The data gathered from the devices allow real-time monitoring of the system. These technology-enhanced systems are often referred to smart grids.

Changes in consumer behaviour are also fuelling a trend towards distributed generation. Consumer which in the past can only buy electricity from utility now can produce electricity and sell back to power grid. One of the example is the use of rooftop solar panels at household level to reduce dependence on grid power and at the same time can sell surplus power back to the MEA or PEA. In the future, a customer to customer (C2C) business model may be possible for users in close proximity. Thus, consumer may become a *prosumer* who simultaneously produce and consume electricity (Figure 2).

Because electricity produced by prosumers using renewable energy is likely to fluctuate and leads to instability of the power grid. Main power grid needs to be more reliable and stable. Local energy storage systems are therefore important to ensure an uninterrupted power supply from wind or solar-powered sources. Moreover, households in the future may also be needed to install home energy management systems. Therefore, household consumption can flexibly response to fluctuation. Many smart homes might be connected to create "smart city". With more smart homes in a city, it becomes feasible to manage the city's electricity distribution through its own microgrid system. Then, the national grid is used only as a backup to maintain electricity security.

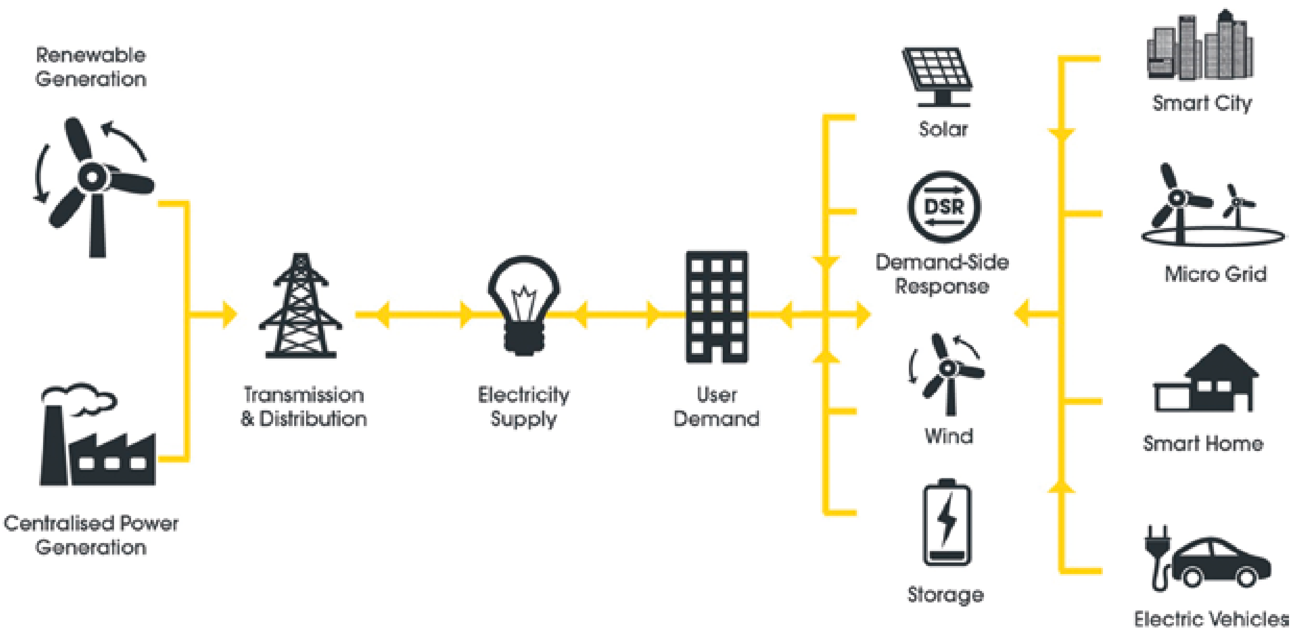

Figure 2 The New Energy Economy
Source: Clarke (2015)

The Smart Grid System

Thailand has began its preparations for smart grid technology since 2011. In 2012, the Ministry of Energy, together with Energy Research Institute, Chulalongkorn University developed a Thailand Smart Grid Master Plan 2015-2036 as a framework for development of a smart grid in Thailand. The Masterplan secured a Cabinet resolution, endorsed on 17 March 2015.

The Thailand Smart Grid Master Plan 2015-2036 defined smart grid development as *"The development of power grid system to work smarter and more efficiently by doing more with less. The system is effective, reliable and safe, sustainable and ecofriendly. The smart grid is developed through adaptation of devices using Information and Communication Technologies (ICT), sensor technologies, data collection and automatic control technologies. These technologies enable communication within the power grid and allow it to make a decision and manage the network automatically. This process must happen throughout the system."* (Ministry of Energy, 2015).

Smart grid technology emerged from convergence of technlogical advances in three related domains: Electronics and Embedded Systems, System Control and Automation, and Information and Communication. Smart grid systems allow two-way flows of both energy and data, harnessing the power of ICTs to allow consumers to manage their energy use and home appliances

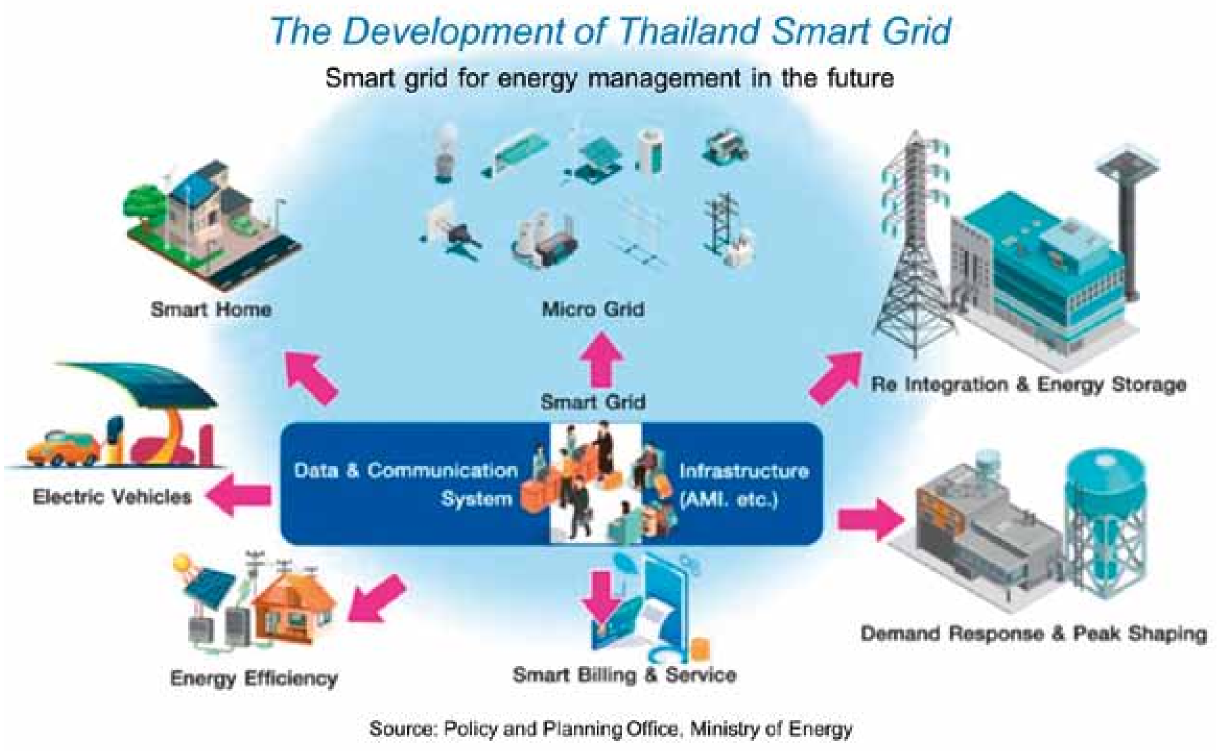

Figure 3 Smart Grid System for Future Energy Management
Soure: Prachachat (2019)

remotely through mobile devices. The essential technological components for the smart grid technology (Ministry of Energy, 2015) includes hardware and software that can send, receive and analyze data, and make real-time decisions in collaboration with power system and other devices. Examples include flexible power generation, transmission and distribution automation, Advanced Metering Infrastructure (AMI), demand response technologies and Energy Management Systems (EMSs) installed in households or Home EMS (HEMS), buildings and Building EMS (BEMS), factories or Factory EMS (FEMS), and communities or Community EMS (CEMS).

A smart grid system can transform the electrical system at both micro and macro levels, creating efficiences at all levels and elevating quality of life and hence contributing to national development. Connected to a suitable infrastructure and a compatible data and communication system, a smart grid can pave the way for smarter and more responsive power management at all levels. The potental is already within sight: smart homes, electric vehicles (EV), microgrids, renewable energy integration and energy storage, demand response and peak shaping, smart billing and services, and energy efficiency management for households, buildings, and factories (Figure 3).

Example of the Smart Grid Technology: The Smart Home

Smart homes use automation technologies to enhance the indoor and outdoor living experiences. The 'Internet of Things' or IoT allows control via the Internet over wifi-connected home appliances, lighting, music, air conditioning and security systems (Figure 4).

Figure 4 Using the Internet of Things (IoT) to control and operate a smart home
Source: Rabbit Today (2018)

Home owners can control these devices as an ecosystem via smartphones or other handheld devices, with clear benefits in terms of convenience, quality of life, energy savings, safety and security. Smart home systems cover a range of applications, including lighting control systems, shade and climate control, entertainment, energy management and security systems (SCG Home, 2015).

The increasing popularity of electric vehicles (EV) willl require the smart home to install dedicated vehicle chargers. When connected to the smart home, these vehicles can act as an energy storage for the home, augmented to the home local storage. Surplus energy generated from the installed solar rooftop or micro wind turbine is allowed to store and then consume or sell back to the grid later. Homeowners will be able to control and access to real-time data related to their power generation and consumption via applications on their smartphone or tablet that can provide accurate, real-time, or historical data of power generation, consumption, and storage, together with recommendation to optimize their home energy management.

Utilities as well as government organisations are already installing more versatile 'smart meters' and data concentrator units (DCU) that allow direct data transmission between homeowners and utilities. Using such systems, homeowners are able to monitor their real-time electricity usage and its cost, allowing homeowners to minimize their costs. For example, the homeowner may be able to reduce unnecessary use of electricity or shift their consumption to acheaper time slot.

The Future of Thailand's Power Grid

The development of the smart grid will affect the way EGAT, MEA, and PEA operate. They will be forced to improve their operations and services to customers. Such development will also lead to macro-economic benefits in terms of economic and industrial competitiveness (Ministry of Energy, 2015), including the following:

1) Increase reliability and quality of electricity delivered to consumers

2) Increase sustainability and efficiency of production and use of electricity

3) Improve operation and services provided by EGAT, MEA, and PEA to meet the needs of users and enhance quality of life for consumers

4) Ensure compatibility and interoperability among system components

5) Enhance the country's economic and industrial competitiveness in terms of new businesses related to smart grids

New technologies are leading to breakthroughs in generation, transmission, distribution and use of electricity, making it more effective, flexible, and eco-friendly, and gradually decoupling electricity from its dependency on fossil fuels. As global transformation of national power grids into smart grids is taking place, the following changes affecting demand and supply sides are expected to happen (Audomvongseree, 2019)

1) Demand side

- More self-generated electricity for self consumption
- More solar rooftops
- Increase in peer-to-peer selling of surplus electricity by households
- More small energy storage installed at household and commercial levels
- Increasing use of IoT to drive automation of households and business pemises

- More smart homes/buildings/factories that can perform demand response
- More electric vehicles and nationwide charging infrastructure
- Shifting of peak demand from daytime to nighttime

2) Supply side

- Slowdown in construction of large power plants
- More power generated from small community's power plants
- More power generated from renewables, particularly solar energy
- Liquified natural gas may be widely used to produce electricity, heat and cooling air and water using micro combined cooling, heat and power (Micro CCHP)
- The power grid will become smaller and turn into microgrid whereas the main grid will become a backup to ensure supply continuity
- The business model of EGAT, MEA, and PEA will change by introducing more products and services aside from generating and selling power
- Electricity tariffs' structure will change to cost and product based

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Article

Biodiesel Production from Plastic Waste and Biomass Pyrolysis

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Introduction

Plastic waste presents an ongoing environmental crisis because of its adverse and long-term impacts on humans, living things and the environment. The majority of plastic waste in Thailand is disposed of in landfills where it can take decades to decompose. The problem is exacerbated by the rapid growth in use of plastics, particularly single-use plastics, without any obvious cost-effective disposal strategy. Campaigns to raise awareness and reduce the use of single-use plastics have had limited impact on the plastic waste problem, which has reached crisis level in Thailand. It is therefore critically important to explore innovative approaches to plastic waste management and disposal.

One approach to mitigate the problem is to add value to the plastic waste or make it reusable. Transforming plastic wastes into liquid fuel via pyrolysis offers a potential solution. The liquid fuel produced can be used as a substitute for diesel to power agricultural machinery and help reduce costs for farmers. The liquid fuel can also be used to generate electricity. Wider adoption of such approaches should therefore be incentivized. Further research is needed in order to optimize technologies and processes to ensure sustainable outcomes.

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Production of Biofuel from Plastic Wastes and Biomass

Refuse Derived Fuel (RDF) is produced by converting wastes into solid fuel. This process involves segregation of plastic wastes with the appropriate heating value, moisture content, size, and density in order to process into fuel for boilers for power or heat generation.

This research used two main types of raw materials: plastic waste and biomass with different components (Figure 1), as follows:

1) Plastic waste, comprising:

- Polyethylene (PE), a polymer of ethylene (CH_2=CH_2). Polyethylene can be categorized into high-density polyethylene (HDPE), medium-density polyethylene (MDPE) and low-density polyethylene (LDPE). Polyethylene is a versatile material and is used to manufacture a wide range of products such as chemical and water bottles, containers, utensils, toys, battery parts, electrical insulation, bags, wrapping films, tables and chairs.

- Polypropylene (PP) is a thermoplastic polyolefin made from propylene. There are three types of polypropylene: isotactic polypropylene, syndiotactic polypropylene and atactic polypropylene. Products made from polypropylene include toolboxes, plastic covers and folders, cosmetic cases and boxes, home appliances, food containers, industrial containers, medical equipment, chemical bottles, oil cans, rice bags and fertilizer bags. Acrylonitrile-butadiene-styrene (ABS) and polyurethane (PU) are also included in this category.

- Polystyrene (PS) is used for products such as bowls, plates, glasses, spoons, forks, food artificial fruits containers, rulers, electronics, toys, medicine tubs and bottles, some types of furniture, refrigerator parts, packaging foam and heat insulation.

Plastic waste may be used to produce liquid, gaseous and solid fuels.

2) Biomass refers to organic matter derived from living organisms, that come in various forms such as agricultural waste (rice husk, bagasse and straw),

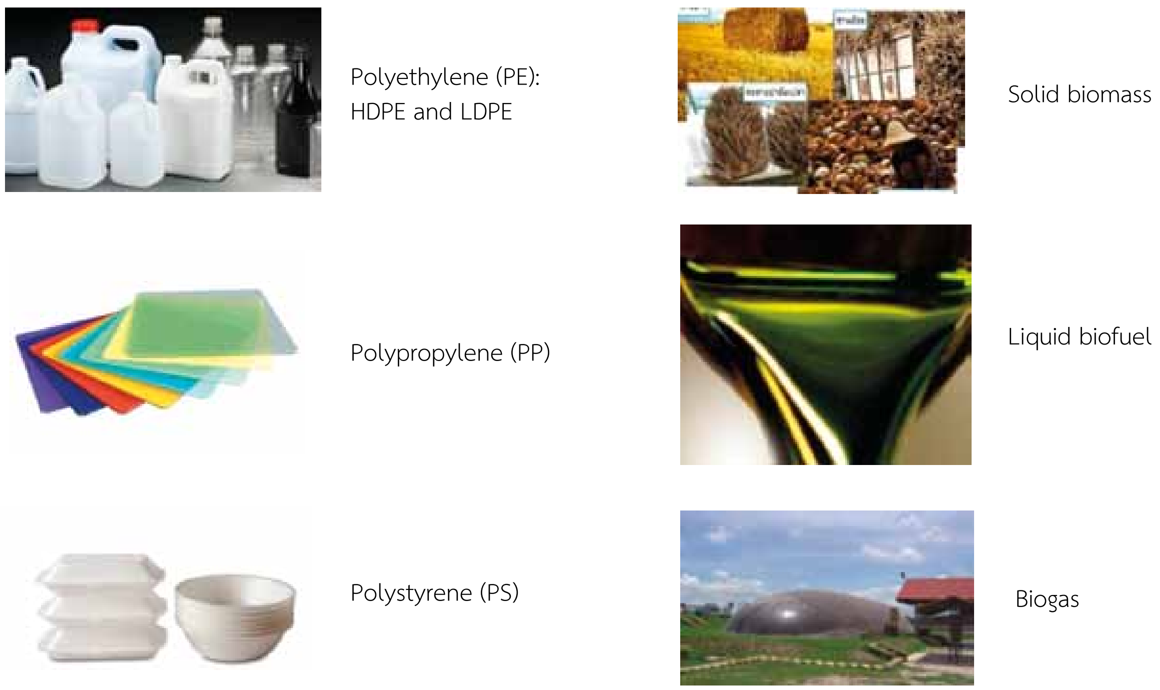

Figure 1 Raw materials for liquid biofuel production
Source: Chula Unisearch, Chulalongkorn University (2018)

rubbish, factory wastewater and manures. Biomass is a source of energy with three states of refinement:

- Solid biomass such as wood chips, wastepaper and seed shells
- Liquid biofuel produced from solid biomass including methanol, ethanol, and biodiesel.
- Biogas is fuel gas produced via pyrolysis of biomass under a temperature and pressure controlled process.

Materials used in this study were processed plastics suitable for conversion into biodiesel. It is relatively simple to process plastic into an energy-dense liquid state.

The Pyrolysis Process

Pyrolysis involves chemically decomposing organic materials at elevated temperatures in the absence or near absence of oxygen. The heat breaks the bonds in long molecular chains into short molecular chains. Some organic components decompose and volatilize, then condense into a liquid 'pyrolysis oil' which is similar in composition to fuel oil with a high heating value. It can be used as fuel in various industries such as glass production and cement manufacturing. Moreover, the oil can be refined to improve quality, enabling its compatibility with diesel -powered engines and power generators. There are two types of pyrolysis process:

1) Slow pyrolysis is the slow heating of organic feedstock material at slow heating rate (<10 °C/min) at less than 500 degree Celsius. Tar and char are released as the main products.

2) Fast or flash pyrolysis is the heating of organic feedstock material at a heating rate of 10-10,000 °C/min at temperatures between 400-1,000 degrees Celsius. Gas and liquid are released as the main products.

Temperature affects the quantity and composition of volatile products from pyrolysis. Pyrolysis takes place in three stages:

- The first stage is the heating of organic feedstock to 200-300 degrees Celsius. Small amounts of volatiles are released, in addition to carbon dioxide and water.
- The second stage is the heating of the organic feedstock to 300-500 degrees Celsius. The organic material is decomposed, releasing volatiles at 75% of the product.
- The third stage is the heating of the feedstock to 500-800 degrees Celsius. Gaseous products are released for the second time. The remaining carbon (char) product changes in this stage. Non-condensing gases such as hydrogen and methane are released.

Main Factors Influencing the Pyrolysis Process

Three main factors influence the pyrolysis process:

1) Types of raw material. Different types of feedstock contain different compounds and produce pyrolysis products with different characteristics and yields. Biomass feedstocks containing high levels of volatiles tend to produce higher yields of biofuel end-products.

2) Pyrolysis temperature. The composition and amount of end-products are strongly influenced by temperatures. For example, a used tire will yield different products at different stages of heating. At 150-310 degrees Celsius, tire additives such as plasticizers are slowly decomposed while the natural rubber itself is decomposed at 310-430 degrees Celsius. The remaining synthetic rubber is decomposed at higher temperatures of 350-490 degrees Celsius.

3) Heating rate. Rate of heating has a major influence on the type and quantity of pyrolysis end-products. Generally, a fast heating rate implies a temperature change of 103-105 degrees Celsius/minute.

Research on production of liquid fuel in the laboratory

In this study, researchers produced liquid fuel at laboratory scale (Figure 2) in order to determine the efficiency of the process at each stage and optimize the overall process. The study investigated material preparation methods, material ratios, efficiency and productivity of the system and end-products before considering scaling up for real-world implementation. The laboratory study began with material preparation: the preparation of plastic waste (Figure 3). The plastic waste was cleaned thoroughly to minimize contamination.

Figure 2 Pyrolysis Incinerator
Source: Chula Unisearch, Chulalongkorn University (2020)

Figure 3 Plastic waste used as pyrolysis feedstock material
Source: Chula Unisearch, Chulalongkorn University (2020)

Figure 4 The pyrolysis process
Source: Chula Unisearch, Chulalongkorn University (2020)

Figure 5 Liquid product from the pyrolysis process (pyrolysis oil)
Source: Chula Unisearch, Chulalongkorn University (2020)

Moreover, the moisture of the material must be below 20% in order to maximize pyrolysis efficiency. The material was then placed in an incinerator and the pyrolysis process initiated (Figure 4). The pyrolysis process generated solid, liquid and gaseous end-products. The study's findings revealed that using plastic waste as a feedstock resulted in 70-80% conversion to liquid oil (Figure 5). The liquid fuel product can be used as a fuel for electric generators, and 1L can produce 3-4 units of electricity.

One of the objectives of this research is to produce a liquid fuel suitable for small machines or agricultural machinery. The research team analyzed the properties and conducted a quality check on the end-products to ensure its suitability and compatibility for practical use in the agricultural sector. The analysis indicated that the properties of the liquid fuel produced by pyrolysis met the diesel quality standard (Table 1). The properties of the liquid fuel were similar to that of low speed fuel and were compatible to use as fuel for small engines or agricultural engines (Figure 6). From an environmental standpoint, the closed system pyrolysis incinerator does not cause air pollution: due to its low operating temperature, the gaseous products are non-toxic to humans or the environment. Even if the raw material contains contaminants such as heavy metals, these will be solidified at temperatures above 600 degrees Celsius, making them easier to remove than in the gaseous phase.

Road to energy stability and sustainability at community level

The research team would like to see the knowledge and technology generated by this study to be adapted and implemented at community level. This will require transfer of knowledge to the community with support from state agencies, the private sector and other actors who share the aim to enhance community-level energy sustainability. Management of plastic waste using the pyrolysis biomass incinerator at 450-600 degrees Celsius is economically feasible for this application due to the small size of the incinerator and its capacity to process from 200-1,000 kg per day of plastic waste from the community. Small community-level facilities are also more practical to build and install than a large-scale disposal facility which is typically resisted by adjacent communities. Thus, with an effective waste management system in pace, coupled with the process and technology to transform plastic waste into liquid fuel for local use in agricultural machinery or for power generators, this can bring economic benefits to the community as well as environmental benefits. The availability of pyrolysis oil also offers farmers and communities a buffer against spikes in diesel or electricity price spikes. The community's ability to produce its own fuel and energy greatly enhances its energy security.

Conclusion

The ***"The Study and Development of Waste-to-Energy System,"*** generated knowledge and validated the technology for community-level production of biodiesel from plastic waste and biomass via pyrolysis. The study outcomes can be applied more widely and at a national level, should be considered as a mitigation strategy for plastic waste management, which is emerging as a global and national environmental crisis. Effective implementation of waste-to-energy processes to meet community needs carry potential to bring major benefits to local communities as well as the environment.

Successful implementation will depend on the government's recognition of its full potential and its commitment to incentivize its wide-scale adoption, working together with local government agencies. Success will also require efficient management, technology support and systematic monitoring.

Table 1 Properties of pyrolysis-derived liquid fuel

No.	Specification	Upper/Lower limit	Diesel High speed	Diesel Low speed	Method	D.1	D.2	D.3	D.4
1	Specific Gravity at 15.6/15.6 °C	No lower than No higher than	0.81 0.87	- 0.92	ASTM D 1298	0.8165	0.809	0.8388	0.8008
2	Cetane Number (Calculated Cetane Index)	No lower than	50 50	45 45	ASTM D613 ASTM D976	48.1	64.4	58.2	-
3	Viscosity, cSt 3.1 at 40°C 3.2 at 50°C	 No lower than No higher than No higher than	 1.8 4.1 -	 - 8 6	ASTM D445	 1.785	 2.568	 3.105	 2.32
4	Pour Point, °C	No higher than	10	16	ASTM D97	-6	6	-9	21
5	Sulphur, %wt.	No higher than	0.01	1.5	ASTM D2622	0.04546	0.06692	0.3	0.0185
6	Copper Strip Corrosion	No higher than	No. 1	-	ASTM D130	1a	1b	1a	1a
7	Oxidation Stability, g/m^3	No higher than	25	-	ASTM D2274	N/A	N/A	N/A	N/A
8	Carbon Residue, %wt.	No higher than	0.05		ASTM D189	0.11	0.27	0.05	0.053
9	Water and Sediment, %vol.	No higher than	0.05	0.3	ASTM D 2709	0.025*	N/A	0.025*	0
10	Ash, %wt.	No higher than	0.01	0.02	ASTM D 482	0	0	0	0
11	Flash Point, °C	No lower than	52	52	ASTM D 93	36	40	31	25
12	Distillation, °C (90% recovered)	No higher than	357	-	ASTM D 86	330.9	354.6	397.5	374
13	Polycyclic Aromatic Hydrocarbon, % wt.	No higher than limit	11 High speed	- Low speed	ASTM D 2425				
14	Colour 14.1 Hue 14.2 Intensity	 No lower than No higher than	 Yellow - 4	 Brown 4.5 7.5	 ASTM D 1500	 Yellow >5	 Yellow 1.2	 Yellow >5	 Yellow 3*
15	Methyl Ester of Fatty Acids, %vol.	No lower than No higher than	4.5 5	- -	EN 14078				
16	Lubricity , Wear Scar mm	No higher than	460	-	CEC F – 06 - 96				
16	Additives	Refer to the regulation of Department of Energy Business							

Source: Energy Research Institute (2014)

Figure 6 Using pyrolysis oil for agricultural engines
Source: Energy Research Institute (2014)

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Article

The Low-carbon City Movement to Achieve the Sustainable Development Goals

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Introduction

In the past decade, the effects of climate change have become more apparent from more severe natural disasters and increasing frequency. Scientists believe that climate change is both natural and anthropogenic in its causes. Whilst natural causes take a long time to manifest, anthropogenic greenhouse gas (GHG) emissions have rapidly accelerated the process. Scientific evidence since the 1980s concludes with certainty that GHG emissions from human activities have triggered the recent acceleration in climate change which is now recognized as a global crisis. To combat its causes and impacts, UN Member States and other parties signed the United Nations Framework Convention on Climate Change (UNFCCC) which was adopted on 9 May 1992 and entered into force on 21 March 1994.

Climate change is also one of the 17 Sustainable Development Goals (SDG), established as overarching global development goals for the next 15 years. The goals for climate change are the same as those set out in the Paris Agreement, focusing on policies and mechanisms at international and national policy levels of mitigation and adaptation to climate change. It also emphasises the need for international collaboration to raise funds for instruments such as the Green Climate Fund (GCF) to support efforts by developing countries to reduce GHG emissions.

The low-carbon city

Recognizing the reality of climate change and its pervasive impacts, many countries have introduced the concept of a *'Low-carbon Society'*, later given greater geographical focus through the *'Low-carbon City'* concept, which aimed to curtail the carbon footprint of cities.

The concept of low-carbon cities has widely accepted in many cities around the world. Today there are 1,050 low-carbon cities in the United States, 40 in India, 100 in China and 83 in Japan (Tan et al., 2015). These cities use different approaches to achieve a common goal. Reports from the Cities Climate Leadership Group (C40), the world's megacities network, indicated that 92% of the countries in the C40 network succeeded in curtailing their carbon footprint by a large amount (Tan et al., 2017). Megacities such as Nogoya (Japan), Växjö (Sweden) and Brussels (Belgium) have set clear outcomes for each of their mitigation actions, including the following:

- Incorporating nature into the city by building community areas close to railway stations to increase walkability and encourage cycling instead of driving
- Improving basic infrastructure by promoting green buildings and using eco-friendly public transportation system
- Powering the city using renewable sources such as solar energy, biomass and waste-to-energy instead of using fossil fuel
- Supporting a low-carbon lifestyle and low-carbon business to reduce carbon emissions
- Turning urban agricultural areas into organic agricultural areas and encouraging sustainable consumption such as buying from responsible sources and promoting allotment for residents to grow their organic vegetables.

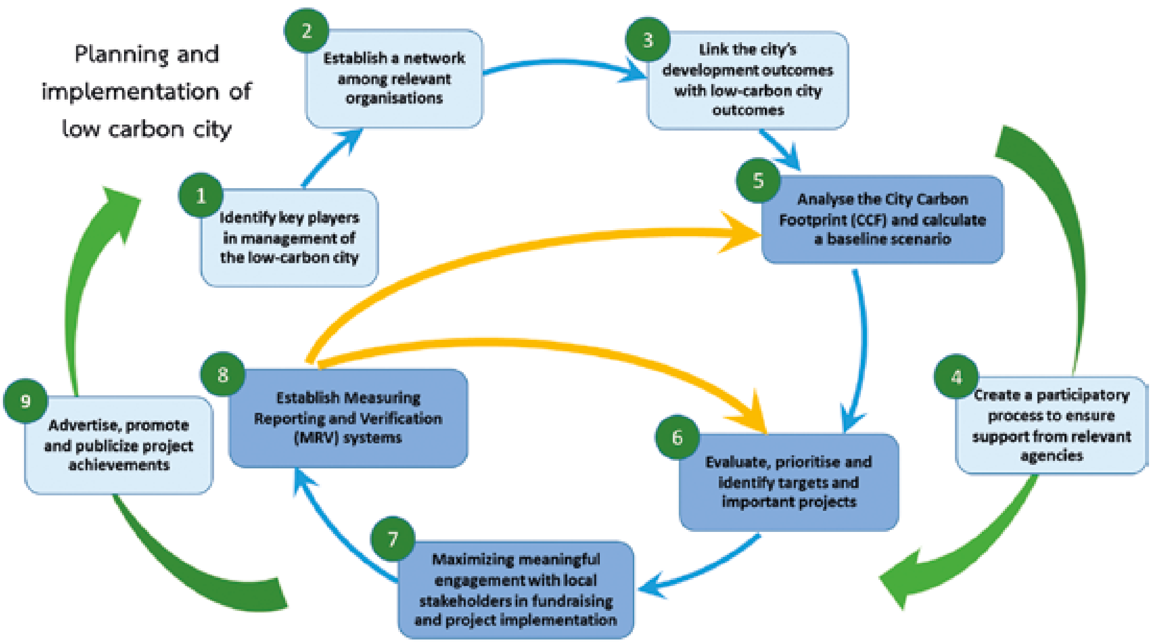

Figure 1 Planning and implementation for development of a low-carbon city
Source: Thailand Greenhouse Gas Management Organization (2019)

Planning and implementation of the low-carbon city

The Plan-Do-Check-Act (PDCA) cycle (Figure 1) is the driving mechanism behind low-carbon city development. The process includes:

1) **Identify key players in management of the low-carbon city** to act as anchors for planning and implementing low-carbon mitigation measures as well as coordination among local stakeholders.
2) **Establish a network among relevant organisations** to ensure cooperation from different sectors including public organisations, private sector and the general public. A well-established network is one of the most important components for effective long-term development of a low-carbon city.
3) **Link the city's development outcomes with low-carbon city outcomes** to ensure that development of the low-carbon city contributes as part of the solution to the city's problems. Such a link will thus become the main motivator for collaboration among local stakeholders to kick-start low-carbon city initiatives.
4) **Create a participatory process to ensure support from relevant agencies** from planning and design of mitigation measures, to implementation.
5) **Analyse the City Carbon Footprint (CCF) and calculate a baseline scenario** to predict baseline and future greenhouse gas emission scenarios with and without mitigation measures.
6) **Evaluate, prioritise and identify targets and important projects** as a crucial step in the planning process. Prioritising by a range of defined criteria will help ensure optimal utilization of resources to reduce emissions.
7) **Maximizing meaningful engagement with local stakeholders in fundraising and project implementation** is crucial for effective implementation of low-carbon city initiatives in real-world situations.
8) **Establish Measuring Reporting and Verification (MRV) systems** to monitor and report outcomes of interventions under low-carbon city initiatives. Project monitoring during implementation is vital to ensure effective implementation and allow course corrections, while ex-post evaluations help to quantify economic and social returns against agreed indicators. Following the MRV process, a review of the plan must be conducted if outcomes fall short of meeting agreed development goals, in order to refine the development plan to suit specific local requirements.
9) **Advertise, promote and publicize project achievements** to share successful models and encourage wider adoption of the low-carbon city concept by other cities.

The planning and development of the low-carbon city begins with documenting the City Carbon Footprint (CCF) to pride a baseline for action. The CCF document reveals the ratios of GHG emissions from different economic sectors in the city. This baseline can be used to project future GHG emission trends as well as establish realistic mitigation targets based on empirical evidence.

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (World Resources Institute et al., 2014) is a globally accepted protocol to document and report GHG emissions at the city level. It is a transparent methodology covering all major sources of urban emissions. The GPC protocol was published jointly in December 2014 by the World Resources Institute and Local Governments for Sustainability

(ICLEI) and has been endorsed by the World Bank, the United Nations Human Settlement Programme (UN-HABITAT) and the United Nations Environment Programme (UNEP).

GPC is a standard protocol for documenting and reporting GHG emissions of any city. The protocol does not specify a particular methodology to calculate emissions. Instead, the protocol provides a standard outline to document and report emission data transparently and continuously. The protocol categorises GHG emissions into five types (Figure 2) as follows:

1) Stationary energy refers to emissions from burning fuel for heating and electricity generation. Stationary energy also includes energy from other sources such as gas leakage from the natural gas supply.

2) Transportation including travel by road, rail, sea and air, including both domestic and international travel. Emissions include both direct, as a result of burning fuel to power vehicles, or indirect from power generation.

3) Waste refers to the generation and discharge of waste and wastewater. Waste generated in urban areas is typically transported to other areas outside the city to manage or dispose of. Emissions result from incineration, transportation and aerobic or anaerobic decomposition in landfills.

4) Industrial Process & Product Use (IPPU) refers to GHG emissions from industrial processes and product use that does not necessarily relate to electricity generation or consumption. IPPU also includes emissions from fuel consumption that does not necessarily relate to electricity generation or consumption within the city boundary.

5) Agriculture, Forestry & Land Use (AFOLU) refers to GHG emissions from agriculture, forestry and land use that includes methane emissions from enteric fermentation of ruminant livestock and emissions from land use change (e.g. deforestation).

City activities generate GHG emissions both inside and outside the city's boundaries. The GPC Guideline is used to scope types of GHG emissions according to the emission areas. Scope 1 refers to emissions from sources located within the city boundary. Scope 2 refers to

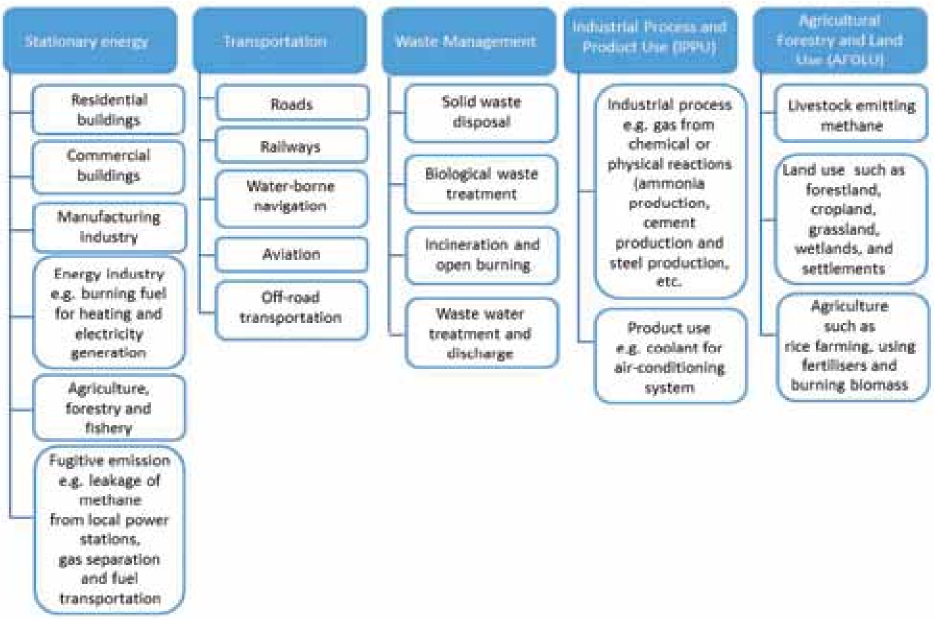

Figure 2 Sources of GHG emissions
Source: Thailand Greenhouse Gas Management Organization (2019)

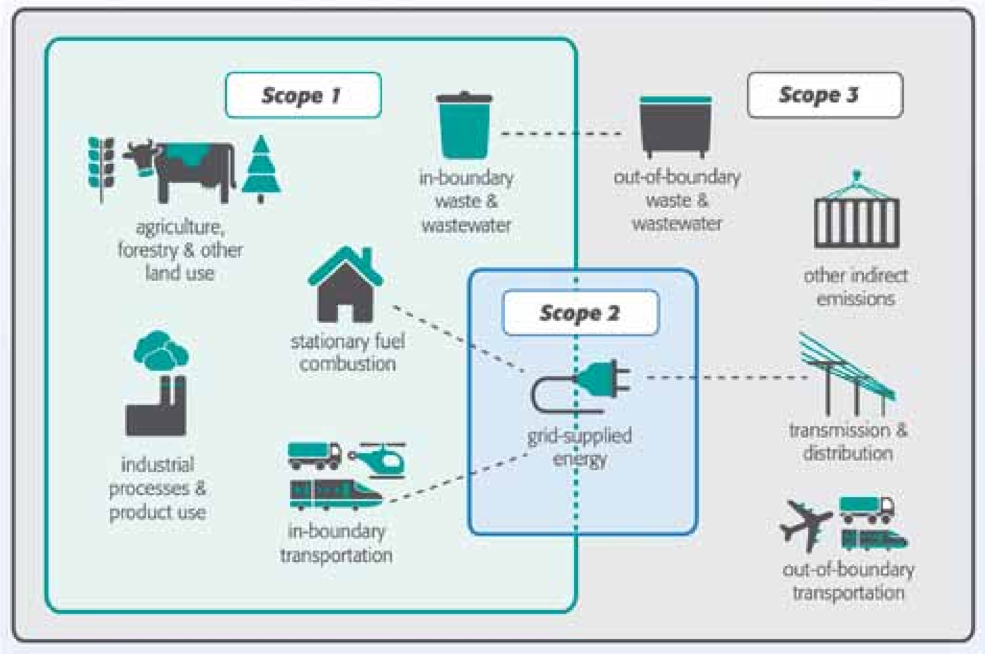

Figure 3 Definitions of GHG emissions at the city level
Source: World Resources Institute et al. (2014)

emissions occurring as a consequence of the use of grid-supplied electricity. Scope 3 refers to all other emissions occurring outside the city's boundary as a result of activities occurring within the city boundary (Figure 3).

According to the Greenhouse Gas Protocol for Accounting and Reporting Standard, GHG is calculated from Activity Data (AD) and Emission Factor (EF) as follows:

$$GHG = AD \times EF$$

Given GHG as GHG emissions (kg of GHG)
AD as Activity data of GHG emission (unit)
EF as Emission factor of an activity (kg of GHG/Unit)

The amount of emissions from each type of activity is calculated as carbon dioxide equivalent (CO_2 equivalent (CO_2e) unit using the metric known as Global Warming Potential (GWP) as follows:

$$CO_2e = GHG \times GWP$$

Where CO_2e as Carbon dioxide equivalent ($kgCO_2e$)
GHG as GHG emission (kg of GHG)
GWP as Global warming potential ($kgCO_2e$/kg of GHG)

The GPC framework allows cities to select among three GHG reporting levels: BASIC, BASIC+ and Expanded. The BASIC level covers GHG emission sources located in every city such as stationary energy, transportation and emissions from waste. The BASIC+ level covers industrial processes and product use (IPPU), agriculture, forestry & land use (AFOLU) and transboundary transportation. Data collection and calculation requirements are more challenging for this level of assessment. However, if the data sources are significant and relevant to the city, the BASIC+ level

Table 1 Global warming potential (GWP) values of GHG gases

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265

Source: World Resources Institute et al. (2014)

should be used to report. The Expanded level provide a full report with comprehensive and detailed coverage of emissions from all activities and boundaries.

Reducing GHG emissions within the city boundary

1. Mitigations and technologies for reducing emissions within the city boundary

Main mitigation measures available for each emission sector are listed as follows:

1) Stationary Energy: Available technologies for this sector depend on the sub-sector. Emissions in this category are generated mostly from residential and commercial buildings and facilities.

1.1) Frameworks for energy in buildings

There are two major approaches to regulating in-building energy management:

1.1.1) Compulsory frameworks refer to enforcement of sets of regulations such as building codes which include building types, structures, standards, rules and designs for energy saving.

1.1.2) Voluntary frameworks offer certificates of compliance for buildings that follow specified non-regulatory standards for energy saving. Nowadays, many buildings in Thailand are certified, both at an international and national levels, for their designs and their capabilities in energy management. Key certification and standard-setting agencies are the Leadership in Energy and Environmental Design (LEED) and Thailand Rating of Energy and Environmental Sustainability (TREES). Buildings certified by such organizations are not only able to achieve significant savings in energy costs, but also add value to the building utilisation and enhance public perceptions and corporate image.

1.2) GHG reduction technologies for residential and commercial buildings

1.2.1) Energy management technologies are integrated technologies to maximise energy management in buildings. Examples include the Building Energy Management System (BEMS), Home Energy Management System (HEMS) and Demand Response.

1.2.2) Energy Efficiency refers to methods of using less energy to perform the same tasks more efficiently. A range of technological advances are used in energy-intensive systems such as air conditioning, heating and lighting and other systems located in the building.

1.2.3) Renewable Energy refers to renewable energy systems installed in commercial and residential buildings such as solar rooftop and solar water heaters.

2) Transportation Four key factors affect emissions for this source: activity (A), mode share (S), fuel intensity (I) and fuel choice (F). This model is called *"ASIF"*. Four main approaches to reduce GHG emissions and save energy for transportation are summarized as follows, using the same acronym (ASIF):

2.1) Avoid refers to the need to reduce or avoid unnecessary travel by improving the efficiency of the transportation system and city planning. This includes the developing compact area, working from home, building government offices and department stores in the area and introducing road pricing or congestion charges.

2.2) Shift refers to a transition from private transport to more efficient and environmentally friendly public transport and non-motorised transport (cycling and walking). This approach includes promoting the use of energy-efficient public transport and developing safe infrastructure for non-motorized transportation.

2.3) Improve focuses on improving vehicle fuel efficiency as well as optimising transport infrastructure such as improving energy saving vehicle technology, using energy-efficient vehicles and promoting use of electric vehicles. Example of the *Improve* approach include car labelling, mandatory ceilings for vehicle fuel economy and CO_2 emission standards.

2.4) Fuel Switch refers to switching the type of fuel to reduce emissions. Each type of fuel, benzine, diesel and natural gas, has a different GHG emission rate. Promoting the use of alternative low-emission fuels such as natural gas and biofuel is recommended for this component.

3) Waste refers to disposal of waste in a way that is appropriate for the city. Each waste management system has different advantages and disadvantages. In order to select the most appropriate method, planners should consider the amount and the components of waste generated in the city and the distance between pick-up point and location of treatment or disposal. The Recycle, Reuse and Reduce (3Rs) maxim should always be followed in order to minimize the volume of waste production at the pickup point as follows: separating glass, plastic and metal scraps for recycling and upcycling; wash glass bottles for reuse and reduce the amount of waste at the origin. There are four main approaches to implement technologies to mitigate emissions caused by waste management, as follows:

3.1) Collection and transport of wastes is more environmentally friendly if low-emission fuels e.g. natural gas instead of diesel, are used to transport wastes. Optimal management of logistics is also key to minimize transportation distances and fuel requirements.

3.2) Landfills should be sanitary landfills, in which the waste is physically isolated from the local environment until it has completely degraded, and thus cannot contaminate adjacent land and water resources. A number of systems can accomplish this. Aside from physical barriers, bulldozers and compactors can be used to spread and compact solid wastes before covering and compacting again with soil. Moreover, landfills are also able to generate power (known as landfill gas to energy), further reducing uncontrolled emission of methane, a potent GHG, from the landfill site.

3.3) Incinerator is a waste treatment process involving high-temperature combustion of wastes, where the heat is also converted into energy.

3.4) Separating wastes for reuse (Mechanical and Biological Waste Treatment) includes Refuse Derived Fuel (RDF), a clean technology that produces fuel from various types of waste using technologies such as pyrolysis and gasification. Fuel produced using this method can be used directly to generate power or stored for future use. This technology can be developed in the country. Composting is another method to reduce the volume of organic materials entering landfills. A composting plant can be built at the city's boundary, with the compost used for agriculture and horticulture. Separating other wastes before the composting process will yield other materials (e.g. glass, metal) that can be recycled.

2. Prioritising approaches and technologies to reduce GHG emissions

Selecting an appropriate approach and technology for the development of low-carbon city and infrastructure

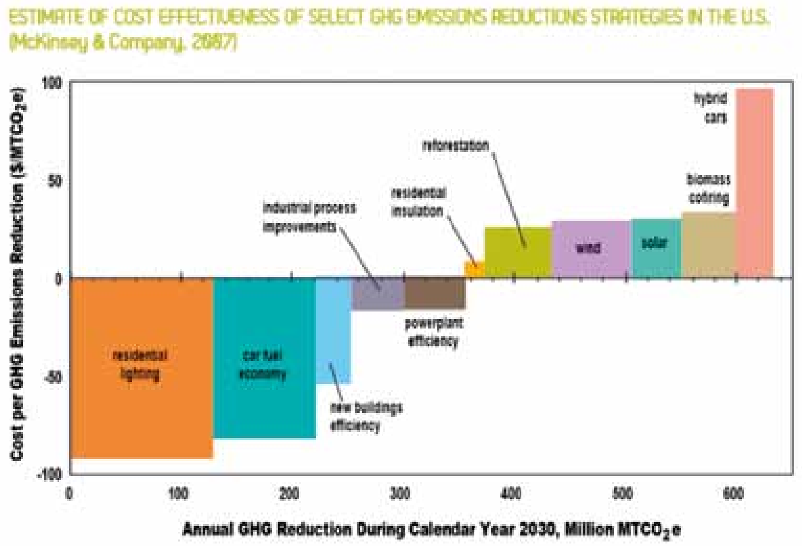

Figure 4 Using MACC to prioritise strategies
Source: Thailand Greenhouse Gas Management Organization (2019)

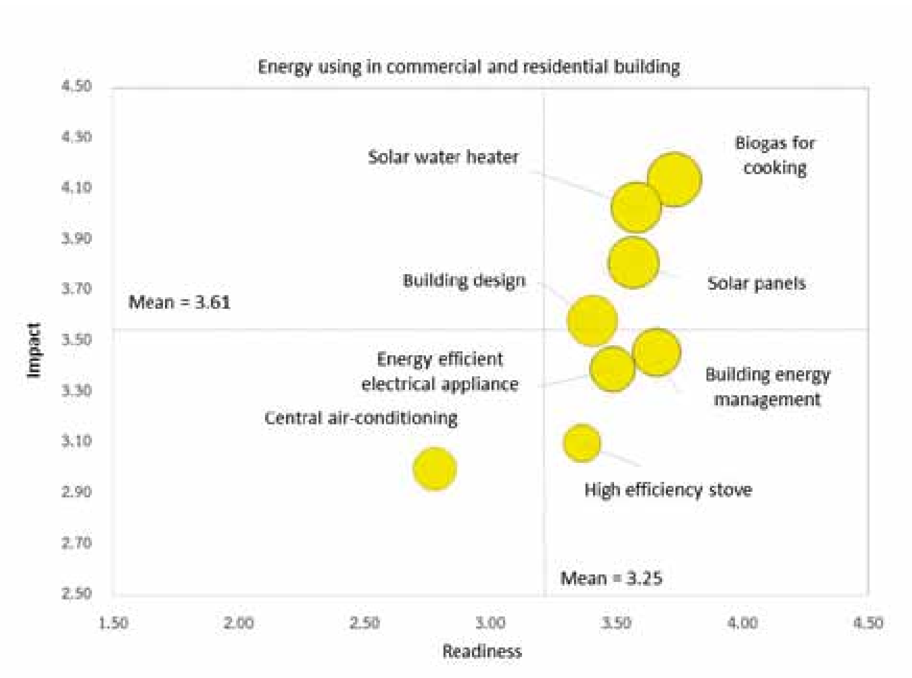

Figure 5 Prioritisation of GHG emission technologies in commercial and residential buildings using the MCA method
Source: Thailand Greenhouse Gas Management Organisation (2019)

planning is a crucial step. Identifying projects aiming to lower GHG emissions means providing solutions to the city's problems and setting clear goals. There are many ways to prioritise the approach, but there are two most common ways:

1) Marginal Abatement Cost Curve (MACC) is a tool to analyse and select the appropriate approach by considering *"economic cost of emissions abatement"* and *"capacity to reduce GHG emissions"* of each strategy. The least-cost strategy is normally chosen as the top

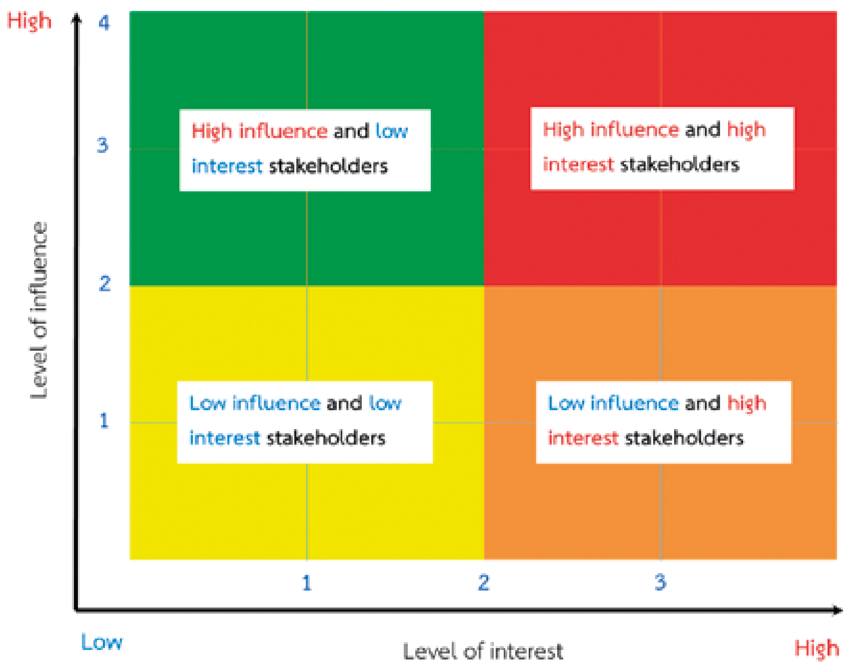

Figure 6 Stakeholder Prioritization using Influence and Interest
Source: Thailand Greenhouse Gas Management Organisation (2019)

priority followed by those with higher costs, until the goals can be met. The key strength of this strategy lies in is its effectiveness in managing different tools that can directly link to the overall low-carbon city development goals.

2) Multi-Criteria Analysis (MCA) is a qualitative prioritisation tool using a scoring system and criteria for each level of development. The advantages of MCA are *"flexibility"* and *"diversity"* when selecting criteria. For MCA, the *"economic cost of emissions abatement"* criterion may be surpassed by other more important criteria for that particular city such as community acceptance as well as regulatory constraints. Moreover, the weighting of each criterion can be adjusted based on multiple-criteria considerations.

Moving forward with the low-carbon city

Stakeholder analysis is an essential step for planning and implementation of any low-carbon city plan. It is crucial to ensure full and meaningful participation and engagement of stakeholders from all levels and sectors. Engaged and committed stakeholders affected in some way by the plan will be motivated to inclusively support, promote and take part in different GHG reduction activities according to the development plan and ensure its long-term success.

The stakeholder analysis considers numerous criteria. In this case the criteria are *Influence* and *Interest*. Once the stakeholders have been analysed using the criteria, they will enter the stakeholder prioritization process (Figure 6). The outputs of the stakeholder prioritization process are categorised in four zones.

Stakeholder engagement is a second essential process to identify appropriate methods to engage and persuade stakeholders to participate in development and design of the low-carbon city and work together to set and achieve common goals. The intensity of the engagement method differs according to where the stakeholders are situated within the four zones following the stakeholder prioritization analysis (Figure 6).

Zone 1 (Red Zone) refers to stakeholders who have high influence and interest in the development of the low-carbon city as well as its development strategies and engagement methods. This zone requires establishing a multidisciplinary working committee with agents from different organisations, formal meetings, small group discussions and seminars. Strategies for stakeholders in Zone 1 are to identify operation processes and distil lessons learned from implemented experiences.

Zone 2 (Green Zone) and **Zone 3 (Orange Zone)** refer to strategies that promote engagement such as interviews, seminars, consulting and public hearings and completing questionnaires.

Zone 4 (Yellow Zone) refers to engagement strategies such as establishing communication by sending advertisements and publications to relevant sectors or via online platforms such as local government websites, e-mails and other online news outlets.

Conclusion

The world is suffering increasingly from adverse impacts of climate change, and the threats will be even more severe in the future. Reducing GHG emissions is an essential tool to mitigate climate change and ensure sustainable development for the next generation.

The development of low-carbon cities is a crucial component of any national mitigation strategy and is relevant to cities of all sizes and stage of development. Major strategies include improving energy efficiency, incentivizing a switch to renewable energy at household and municipal levels as well as for transportation and industrial activities, improving efficiency of industrial processes and waste management and increasing forested areas.

Implementing such strategies require appropriate analysis and prioritisation since each city is unique in its context, sectoral mix and development goals. Systematic planning and execution is necessitated as well as transparent monitoring and evaluation. It is recommended to follow the Plan-Do-Check-Act (PDCA) guideline and consider stakeholders' opinions at every single step of the development journey in order to ensure sustainable development of the city.

Acknowledgements

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Article

Status of Green Government Buildings and How to Improve:

A Case Study of Faculty of Science, Chulalongkorn University

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Introduction

Climate change is the world's greatest challenge. The primary cause of these problems is the emission of greenhouse gases (GHGs), resulting in rising global temperatures. Reducing energy consumption and conservation is therefore important to mitigate emission of GHGs. The United Nations has launched numerous initiatives focusing on environmental and energy management for buildings through the *'Green Buildings'* concept. Many countries around the globe have embraced the concept as a contribution to sustainable development and placing social and environmental responsibility on owners and users.

Thai agencies led by the Pollution Control Department, Ministry of Natural Resources and Environment, are well aware of the issue, and have implemented the green government building project to minimize environmental impact. This project has improved the environmental performance of government buildings. To support government policy and promote the university's global competitiveness, Chulalongkorn University has also implemented the policy to become a green university. More budget has been allocated for physical resources management.

The Faculty of Science has the largest number of personnel and students and the largest building space. Therefore, modification of the Faculty's buildings could be instrumental in transforming Chulalongkorn University into a green university. Such an accomplishment would contribute to the university's strategic plan of *"happiness"* as well as the Faculty of Science's own strategic plan to improve its physical efficiency and use of space according to the University's Master Plan.

Given the need for an effective master plan and feasibility study to demonstrate cost effectiveness of intended improvements, the planning stage took four years to collect in-depth data, assess existing conditions and benchmark with other survey results. A study is also needed to define a new set of standards for new buildings. This study therefore aims to identify an approach and standard for designing new buildings or modifying future buildings that are suitable for the Faculty of Science and compliant with national and international standards.

Preliminary building assessment results

This research study was conducted to collect data for all buildings at the Faculty of Science and to assess them against the green building standard set by the Pollution Control Department and LEED (Leadership in Energy and Environmental Design) (Figure 1). After that, a pilot building was selected to conduct a detailed study of the modification approach, expected results, feasibility, and cost-effectiveness. The preliminary results are summarized below.

1) Preparedness of the environmental management department: Some parts of the buildings have no record of water consumption nor sub-meters for each category of consumption. Therefore, post-implementation results cannot be measured at that level of detail. However, the buildings have electricity meters to measure consumption by each department. However, what is lacking is a system to aggregate all data on energy efficiency according to general standards e.g. comparison with electricity consumption with the Ministry of Energy standard.

2) Building management: Staff at the Faculty of Science do not understand how to use the majority of the building space to save energy, or to ensure basic building maintenance to conserve energy. Additional staff should be hired from a third-party company with appropriate equipment to perform periodic efficiency examinations and make recommendations. Alternatively, training should be provided to staff on energy-efficient building usage. Also, a building management manual should be developed.

3) Layout of green space: The Faculty of Science is located at the center of the university, and is easily accessible via mass transit, with two train services nearby (BTS and MRT) as well as a well-developed bus service. The surrounding area (Sam Yan) is well-equipped with facilities such as shopping centers, restaurants, libraries, sport grounds, parks and shops. However, watering the gardens at the Faculty of Science depends mainly on city water. It is recommended that more recycled water be used.

4) Energy saving: Most faculty buildings are old, without heat insulation on roofs or outside walls. The buildings are full of heat releasing machines such as heating chambers and refrigerators in the laboratories and air conditioners in offices. Heat from the latter further adds to their load, increasing their power consumption. The Faculty of Science should immediately check if some of these machines are strictly necessary, and if they are properly maintained. Also, it is advisable to consider replacing outdated equipment with newer, more energy-efficient equipment.

LEED standard (Leadership in Energy and Environmental Design)
Source: www.usgbc.org

กรมควบคุมมลพิษ
Pollution Control Department

Pollution Control's green building label
Source: www.pcd.go.th

Figure 1 Logos of the assessment standard
Source: as cited in Sreshthaputra & Sirithummapiti (2016)

5) Building's internal environment: The interior in most rooms lacs adequate ventilation both in terms of CFM per head or per area and positive pressure for manned rooms and negative pressure for chemical storage. It was generally observed that chemicals can be leaked to manned rooms, presenting a serious health hazard to staff.

6) Waste management: The trashing area at the Faculty of Science is poorly managed, resulting in odor and pest problems including rats, birds and cockroaches.

7) Power consumption and lighting: Most faculty buildings are not equipped with modern energy-saving lighting systems such as dimmers, automatic lighting control sensors and energy-saving LED lighting. Building automation systems (BAS) can be used to control the timing of operation of lighting and air conditioners from a central control room. The system can also prevent lights or air conditioners from being operated when no one is present in the room.

8) Air conditioning: The cooling tower in the buildings at the Faculty of Science is inadequately maintained and the presence of *Legionella pneumophila* has been reported. Poor maintenance of air conditioners also results in vented hot air causing disturbance to passers-by. Most laboratories have a simple ventilation system to release exhaust or smoke from experiments without treatment as required under green building standards. The system allows polluted air to be released to outside courtyards or outside of the building, presenting adverse health risks to staff and students.

9) Water consumption: Buildings at the Faculty of Science do not have onsite storage tanks for rainwater or wastewater recycling systems for watering lawns and gardens, floor cleaning or flushing toilets. Most buildings are not equipped with separate water consumption meters or separate meters for specific points of use such as restrooms, classrooms, laboratories, landscaping work or building utilities.

10) Wastewater treatment: Buildings at the Faculty of Science do not have effective wastewater treatment systems. Wastewater from laboratories should be separated from the main wastewater of the buildings. The treated water should be checked for quality before releasing to the university's common drainage system.

Approaches to building modification

In this study, two green building standards are used as a basis to modify buildings at the Faculty of Science, namely the Green Building Standard, set by Thailand's Pollution Control Department, Ministry of Natural Resources and Environment, and the LEED Standard, established by the U.S. Green Building Council (USGBC) in the 1990s. LEED has gained popularity due to its broad use as a benchmark for construction of office buildings. Building design based on the LEED Standard includes criteria covering green area, gardens and lawns, water saving, energy saving, material saving, livable environment, natural light, and clean air. The aforementioned are the LEED criteria for New Construction & Major Renovation (LEED NC). The green building assessment results of the Faculty of Science were compared with the results of government buildings nationwide (Sreshthaputra and Pinit, 2013; Lertsakwiman and Sreshthaputra, 2017) as shown in Figure 2. The assessment scores for Thai governmental buildings ranged from 2 to 55, with 6% of the buildings scoring 31 points. In comparison, buildings at Chulalongkorn University had lower scores than typical governmental buildings in the country. Around 10% of buildings at the university scored 25 points on the green building scale. Those at the Faculty of Science had a narrower range of scores, between 18–35 points. Some buildings (4%) passed the green building standard, with a score of 46 points.

Modification of pilot buildings

The survey results informed the selection of, one building at the Faculty of Science to serve as a pilot to monitor the modification process, potential problems and expected results from the modification in terms of green building scores, energy savings and environmental impacts. It was required that the pilot building had both classrooms and laboratories.

"Mahamakut Building" (Figure 3) was selected on this basis as the pilot building, as its main purposes are both teaching and research. The space in this building is divided among different departments. The problems faced, such as ventilation and chemicals management, are common to many buildings.

Environmental assessment for the pilot building

The modification of Mahamakut Building was based on the LEED Standard and that of the Pollution Control Department. The priorities for modification were those issues affecting users of the building, such as air quality and toxic materials, and environmental issues such as green area, water saving and waste management. These modifications provide indirect rather than direct financial benefits. For example, rental values are higher for buildings with a good work environment. Since some benefits generated are subjective, valuation and objective comparison can be challenging.

1) Layout and landscape

According to the LEED Standard, the layout and landscape of the Mahamakut Building achieved almost a full score. The building is located in a developed area with easy access to various modes of transportation, including BTS and MRT. The areas that did not achieve a full score, such as exterior space management and common areas of the University, are under the supervision of the University's central administrative unit.

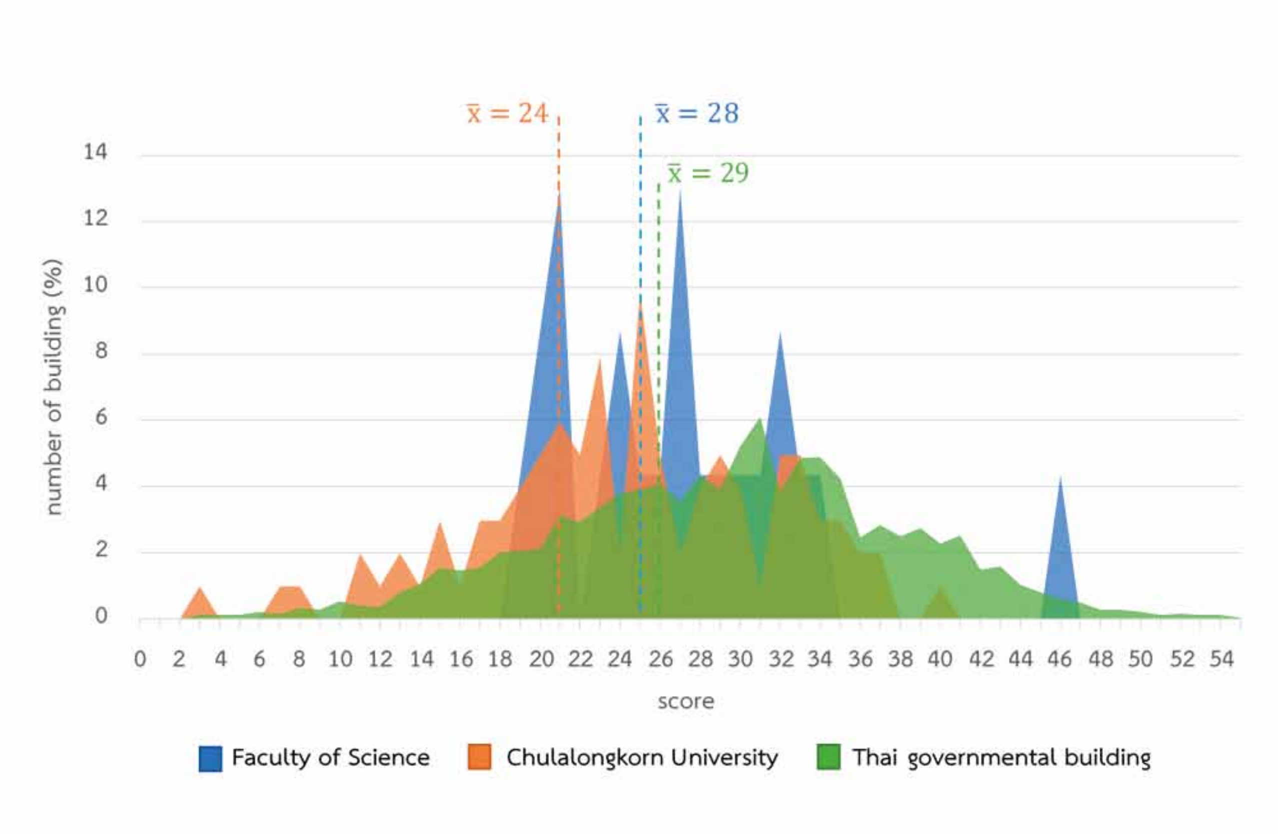

Figure 2 Assessment scores for green buildings at the Faculty of Science compared to governmental buildings nationwide
Source: Sreshthaputra and Sirithummapiti (2016)

These areas are thus beyond the Faculty's control (except for a small garden). Therefore, management of exterior space and landscape was excluded from the scope of this study.

2) Water saving

The building survey found that most sanitaryware in the toilets are water-saving models. Therefore, the building passed the preliminary criteria. However, despite this, the building could not save water better than the criteria set for green buildings. Replacement of sanitaryware was expensive, yet the benefit was low. Toilets would generally only be replaced to replace those out of order, and thus the Faculty does not consider upgrading of sanitaryware as a priority. Furthermore, Mahamakut Building is not equipped with a water consumption meter. The retrospective check with Sanitary Group, the Physical Management Office, revealed that the building did not have internal water meter, but shared the meter with a nearby building. Currently, it is therefore impossible to measure the building's actual consumption, which is a minimum standard for all green buildings.

In addition, Mahamakut Building does not have a sub-meter, which is inexpensive to install, but it could record water consumption in the building by different areas e.g. system room, restrooms, laboratories or classrooms. Installation of sub-meters would allow water consumption monitoring and planning, as well as the impacts and benefits of renovations.

3) Energy consumption and the atmosphere

The green buildings standards require all buildings to have an energy management plan and be regularly maintained. The plan forms the basis for training and system analysis, finding ways to save energy and calculating the cost effectiveness of system improvements to inform future energy planning. The plan also helps select system inspectors to test the building's internal system and enables analysis of energy consumption and building renovation planning. According to the infrastructure survey, Mahamakut Building has 4 meters to measure energy consumption, but relevant staff did not know the coverage of each meter.

Figure 3 Mahamakut Building
Source: Sreshthaputra and Sirithummapiti (2016)

Sub-meters should be allocated to different functional areas e.g. system works, water pumps, elevators, air conditioners, and other main sources of energy consumption in the building. Installation of sub-meters will be important in future energy planning as a means of monitoring impacts of renovation works and identify opportunities for achieving further energy savings.

4) Materials and resources

According to the LEED Standard, Mahamakut Building achieved a relatively high score for materials and resources because procurement is environmental-friendly, especially for consumable goods and durable goods. Only a few issues were identified as needing improvement, including management of waste from consumables, where opportunities to reuse and recycle should be identified and implemented.

5) Quality of building's interior environment

Scores for this attribute were relatively low. First of all, the rooms have inadequate ventilation as assessed by for the green building standard for clean air ratio per area and air pressure. The building survey found some rooms were equipped with ventilation fans while others were not. When air is vented to the exterior to maintain negative pressure, it is impossible to control the source of clean air. As a result, new air entering into the room could be bad air drawn from the nearest restrooms or laboratories. The ventilation fans blow out the inside doors to the hallway. During the survey, some rooms with scientific experiment were found to have Air Class 2 per ASHRAE criteria (Air Class 2 is the air in factories and laboratories that have chemicals or substances not found in office or residential buildings). Some of the ventilation fans even blow exhaust into the hallway, resulting in Air Class 1 (Air Class 1 is defined as unpolluted clean air, suited for classrooms, office buildings and houses). These buildings should not contain any Air Class 2.

Air from laboratories is not treated in compliance with green building standards before venting to the exterior of the building. Most laboratories have ventilation holes to extract exhaust directly to the exterior. Moreover, experiments with dangerous aerosols are conducted in fume hoods, with the exhaust collected and piped to the central piping system, which merges with pipes at the corner of the building and finally vented from the rooftop without treatment. There should therefore be a cleaning plan for classrooms and offices, requiring use of environmentally friendly surface cleaning products and equipment. Chemicals must also be properly stored. Cleaning staff should undergo appropriate training on handling and use of chemicals. Satisfaction of building users should also be assessed in terms of the comfort of their work environment (temperature, humidity, light and noise levels, odors and air quality) to elaborate an air quality management plan for the building.

Despite its cost, renovation of ventilation systems is essential because it directly affects the health and wellbeing of building users. The use of volatile hazardous chemicals in laboratories in the building presents serious long-term health risks to staff and students. Therefore, the ventilation system should be prioritized for renovation under the green building campaign. Although the cleaning plan and satisfaction survey are a secondary priority, they are a low-cost action that could easily be implemented.

Renovation of the pilot building in term of energy consumption

Energy consumption of Mahamakut Building was conducted via computer modelling using VisualDOE 4.1. This software is commonly used by architects and engineers to calibrate energy consumption and assess a building's energy efficiency. Its calculations cover a wide range of building utility systems, including artificial light, air conditioning, water heating, the building shell and the use of natural gas in the building. To use this program, the calculator needs to input the design of the building, its construction materials, architectural components, efficiency of utility systems, location, layout direction, date and time of use, number of users, and frequency of use. Using these data, the program can calculate hourly energy consumption, providing a precise forecast of future energy consumption. Calibration using predicted and observed energy consumption data yielded very similar results, indicating the reliability of the model.

1) Building shell

Structurally, Mahamakut Building has a central pillar, surrounded by classrooms, laboratories and offices. There are holes around the building, resulting in a high window to wall ratio (WWR). The roof around the building is around 2 meters long, covering all the perimeter of

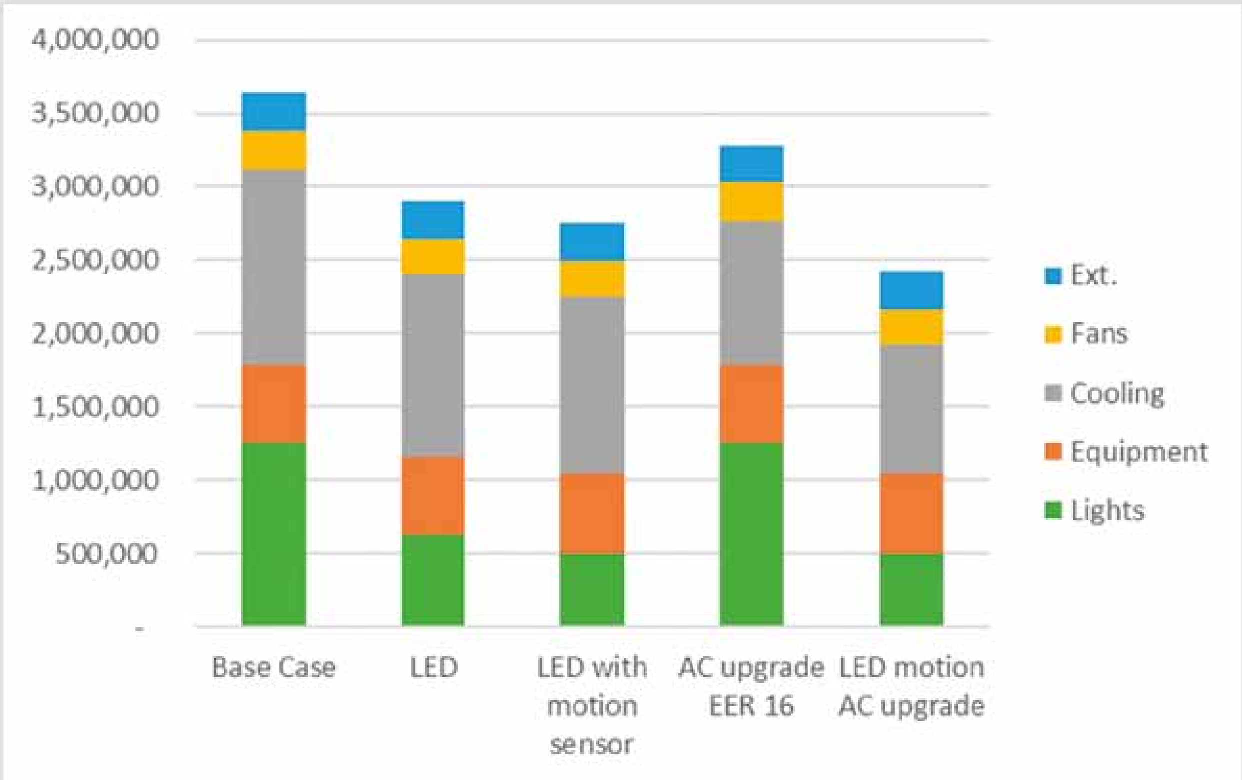

Figure 4 The Simulation Results of each alternative
Source: Sreshthaputra and Sirithummapiti (2016)

the building. Most of the glass surface has a high shadowing ratio. Given the high costs, installation of high-efficiency glass to further reduce radiation may not be cost-effective.

2) Lighting system

The lighting system has a strong influence on building use, and accounts for 34% of total power use at the Mahamakut Building. The building survey found that fluorescent lighting predominated, with only occasional use of LED bulbs. The first option for renovation will be to replace fluorescent bulbs with LED bulbs. Another option is to use motion sensors to minimize unnecessary consumption in unoccupied rooms. It is estimated that motion sensor scan saves up to 20% of the energy used for lighting. However, motion sensors are more expensive than replacing the bulbs and require additional wiring, so are considered less cost effective. In this regard, the first option was selected.

Daylight sensors offer a third energy-saving opportunity. When a room has enough natural light, the system will switch off the light. This system is suitable only for rooms that can rely on natural light for a certain period during the day. According to the survey of Mahamakut Building shell, the eaves are 2 meters long throughout the perimeter, and window glass is used to reduce glare. Therefore, as relatively little natural light enters the building, the daylight sensor would be less effective.

3) Air conditioning

Most areas at the Faculty of Science have local air conditioning systems. Users reflected that this is more flexible when room changes are required e.g. due to changes in class schedules or change in space usage. Although centralized air conditioning system is technically more energy-efficient than local systems, all users confirmed that the former is not suitable for the Faculty of Science. The renovation plan is expected to focus on local air conditioning systems using more energy-efficient models.

4) Electrical devices

Excluding laboratory devices, typical electrical equipment accounts for only 15% of the building's energy consumption. (The scope of this study does not cover the devices used in laboratories). Laboratory devices are very specific and required for instruction, so it is therefore difficult to change the specification of such equipment. Upgrading of electrical devices might therefore only be feasible for office equipment. Given their relatively minor level of consumption, this might not generate significant savings.

Considering the above alternatives, ***the energy savings resulting from installation of motion sensor, replacing fluorescent bulbs with LED bulbs, and using air conditioners with a higher coefficient of performance (COP = 16)***, is shown in Figure 4.

According to the calibration results for Mahamakut Building energy consumption, using LED bulbs throughout the entire building can save up to 20.3% of total energy consumption, motion sensors by an additional 4%, and higher COP air conditioner 33.5%. Most importantly, the change to LED lighting will achieve the breakeven point in only 6.24 months.

Conclusion

Government buildings such as teaching and laboratory buildings at the Faculty of Science, Chulalongkorn University, face numerous limitations to becoming green buildings, including bureaucratic processes, procurement and budget restrictions and insufficient manpower to maintain environmentally friendly buildings in compliance with new global standards. However, the management team at the Faculty understand the importance of increasing our understanding of these challenges and opportunities in order to inform the decision-making process towards developing green buildings. This study offers an example for other government agencies to build upon.

Acknowledgement

This article is part of a research project entitled ***"Energy Conservation Research: Approaches to Develop Green Buildings at the Faculty of Science, Chulalongkorn University"*** funded by the Faculty of Science, Chulalongkorn University.

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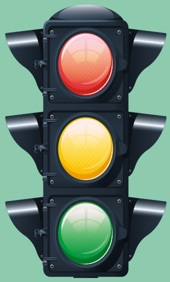
Article



The Study and Development of Transportation Network and Public Space for Sustainable Development in Chulalongkorn University

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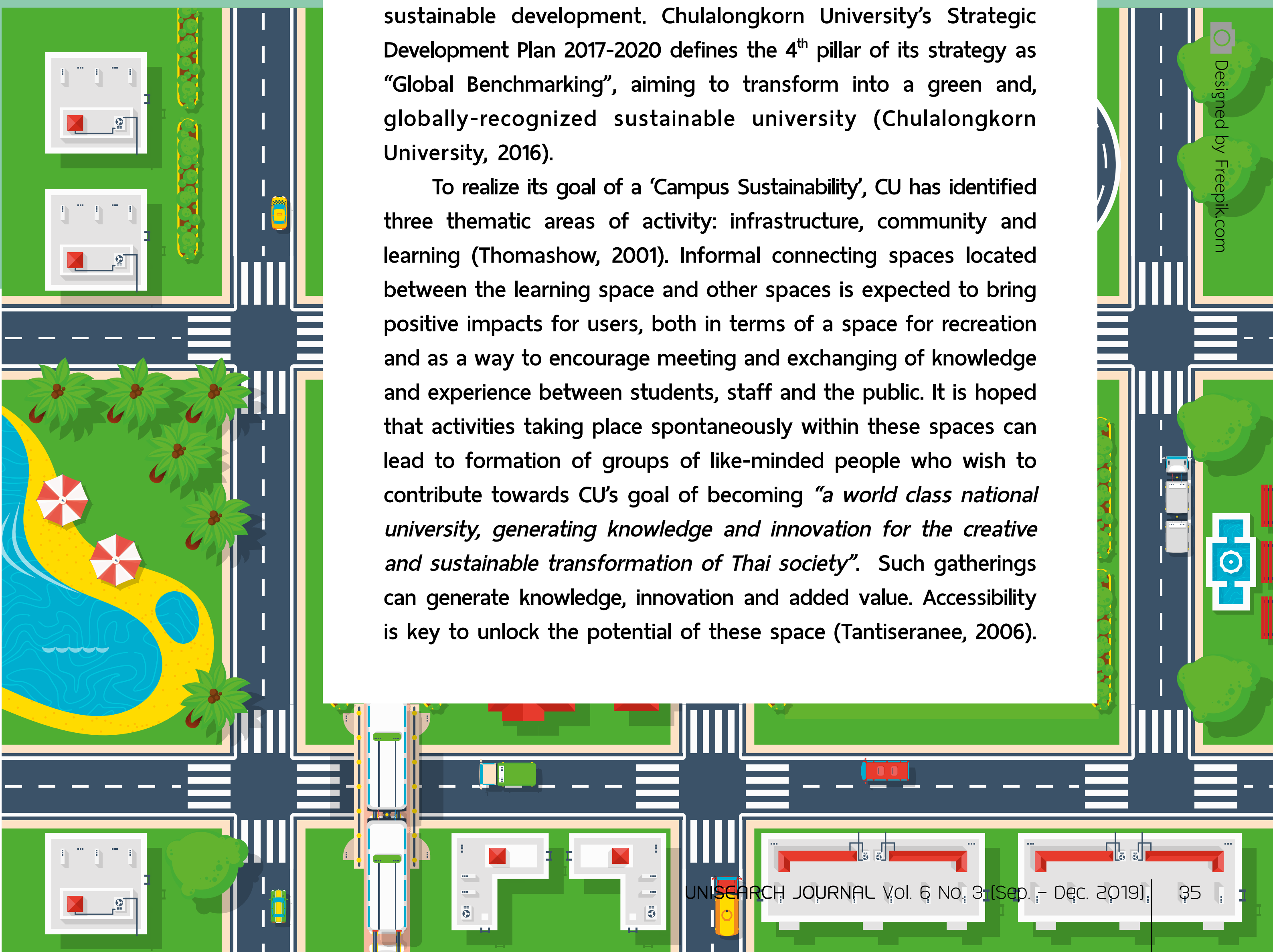
Introduction

Chulalongkorn University (CU) has a vision to become a national university that strives at the global level as a creator of innovation and knowledge to steer the Thai society towards sustainable development. Chulalongkorn University's Strategic Development Plan 2017-2020 defines the 4th pillar of its strategy as "Global Benchmarking", aiming to transform into a green and, globally-recognized sustainable university (Chulalongkorn University, 2016).

To realize its goal of a 'Campus Sustainability', CU has identified three thematic areas of activity: infrastructure, community and learning (Thomashow, 2001). Informal connecting spaces located between the learning space and other spaces is expected to bring positive impacts for users, both in terms of a space for recreation and as a way to encourage meeting and exchanging of knowledge and experience between students, staff and the public. It is hoped that activities taking place spontaneously within these spaces can lead to formation of groups of like-minded people who wish to contribute towards CU's goal of becoming *"a world class national university, generating knowledge and innovation for the creative and sustainable transformation of Thai society"*. Such gatherings can generate knowledge, innovation and added value. Accessibility is key to unlock the potential of these space (Tantiseranee, 2006).



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A transportation network and public space within CU's campus that is accessible to the public is being used for diverse purposes. Characterizing the use of the space and visitor behaviour is therefore important to maximize benefits to all users. This study investigates the various ways in which visitors access and use the space, including by foot, bicycle and vehicles. As these public spaces are linked together by the transportation network, they are considered as a public space network.

The research team designed public spaces within the CU campus and identified three types of space (Figure 1): 1) a public space for transportation, such as streets and footpaths connecting all spaces togethers; 2) a public space within the campus; and 3) a public *"transition space"* located outside the campus itself. Any space located between the learning spaces and commercial spaces surrounding the campus may serve as a transition space.

Methodology

The research was carried out through seven different activities as described below:

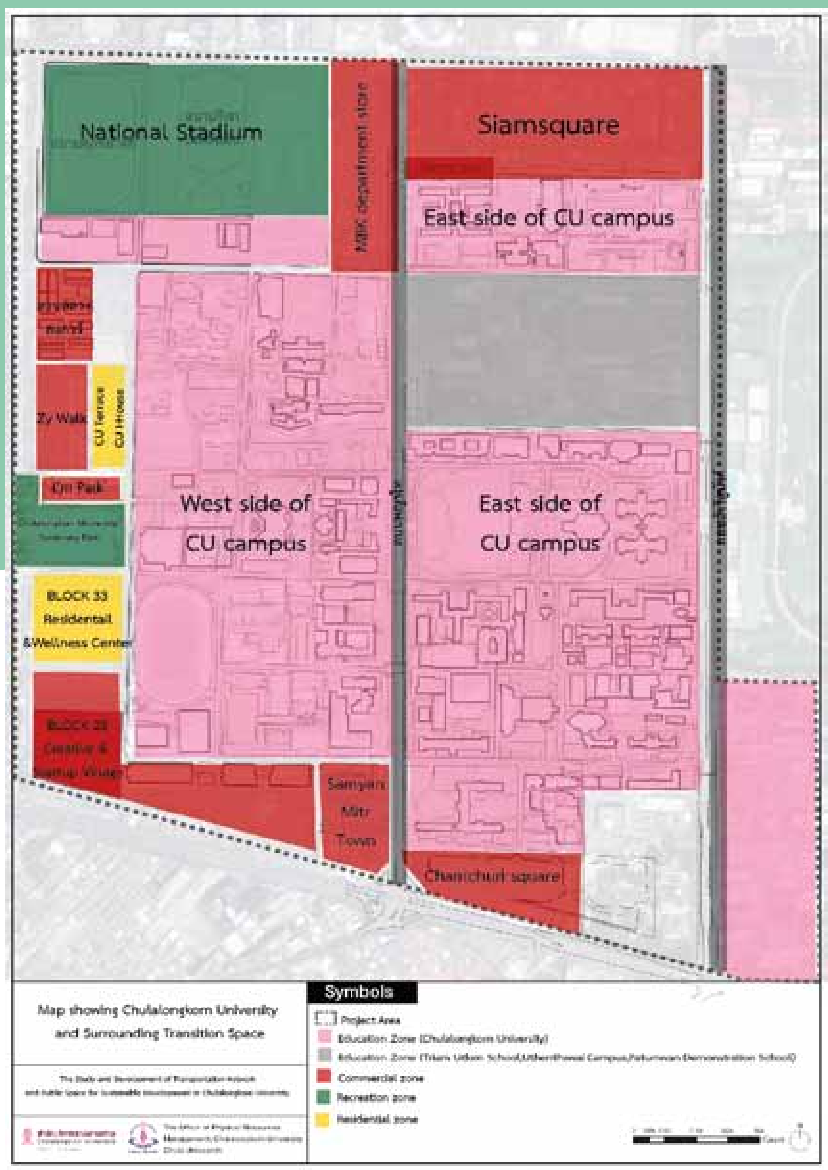


Figure 1 Learning Spaces and Surrounding Transition Space
Source: Pujinda et al. (2019)

Activity 1 Literature review regarding a good public space design and a transportation network to promote accessibility to public spaces

A literature review was conducted regarding sustainable development, the development of innovative spaces, good design for public spaces and designs to promote accessibility to public spaces. The review included both national and global sources as well as criteria and indices used to develop public spaces that align with CU's vision.

Activity 2 Physical survey and data collection regarding users' travel behaviour and use of public spaces within the CU campus

The survey was conducted using direct observation and a guided questionnaire. The data collected included the following:

1) Physical data: 1.1) size and width of campus roads; 1.2) location and size of public spaces; 1.3) other infrastructure including footpaths, cycle lanes, cycle parking spaces, motorcycle parking spaces, bus stops for CU shuttle buses and parking spaces for CU TOYOTA Ha:Mo – small electric cars (Figure 2).

2) Data on user behaviour: the study monitored 2.1) use of the transportation network including travelling rate, type of travel, type of users and time of day; 2.2) use of public spaces for activities, documenting types

(a) Parking space for small electric cars (CU TOYOTA Ha:Mo)

(b) CU electric shuttle bus

(c) parking space in CU campus

Figure 2 Transport infrastructure within CU
Source: Haetanurak taken in October 2019

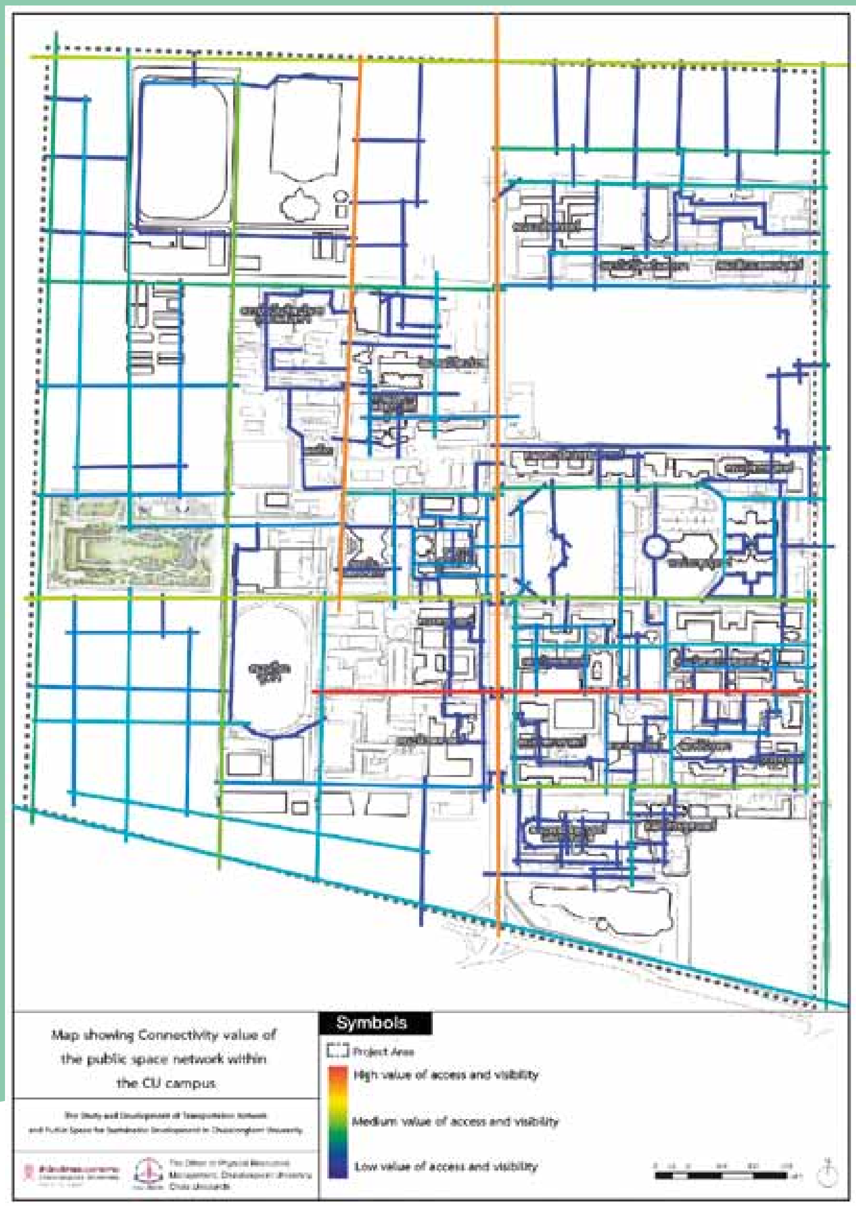


Figure 3 Connectivity value of the public space network within the CU campus
Source: Pujinda et al. (2019)

of activity, locations, types of user, time of day and duration.

3) The amount of travel to calculate carbon footprint within the CU campus

Activity 3 Accessibility and visibility analysis

Collected data were imported and developed into a network map showing public spaces as travel routes including footpaths or walking routes, cycles, motorcycles and routes for the CU shuttle bus. The map was analysed for its accessibility and visibility using the space syntax programme.

Activity 4 Correlation analysis between accessibility potential of the area and user behaviours in public spaces within the CU campus

Data on visitor activity were analysed in terms of their spatial patterns, resulting in a map showing movement patterns among public spaces and transition spaces within the learning space. It also showed types of

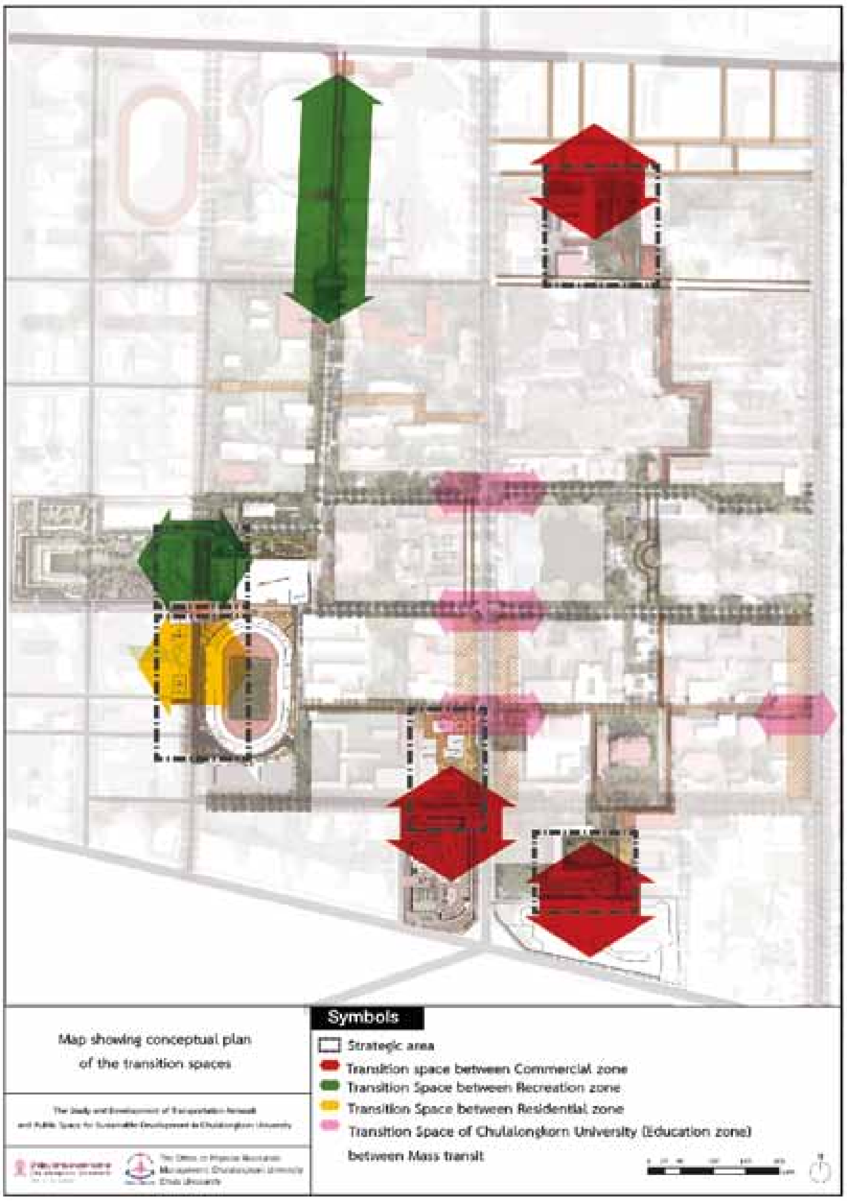


Figure 4 Map showing conceptual development of the transition spaces
Source: Pujinda et al. (2019)

activities conducted by various groups of visitors as well as the respective time periods. The data were analysed together with the accessibility potential to identify correlations between the accessibility potential and visitor behaviours within the CU campus.

Activity 5 Carbon footprint calculation within CU campus

A carbon emission footprint was calculated using data from different types of journey made within the CU campus. The data were collected from the whole area including vehicles within the campus, vehicles passing through the streets and those using the parking spaces. The data revealed that the overall carbon footprint within the learning space was 1,699.94 tonCO_2eq/year. The east side of the campus released 42.62% while the western side released 57.38%. The data also indicated that 92.45% of emissions arose from vehicles on the streets and 7.55% from vehicles using the parking spaces.

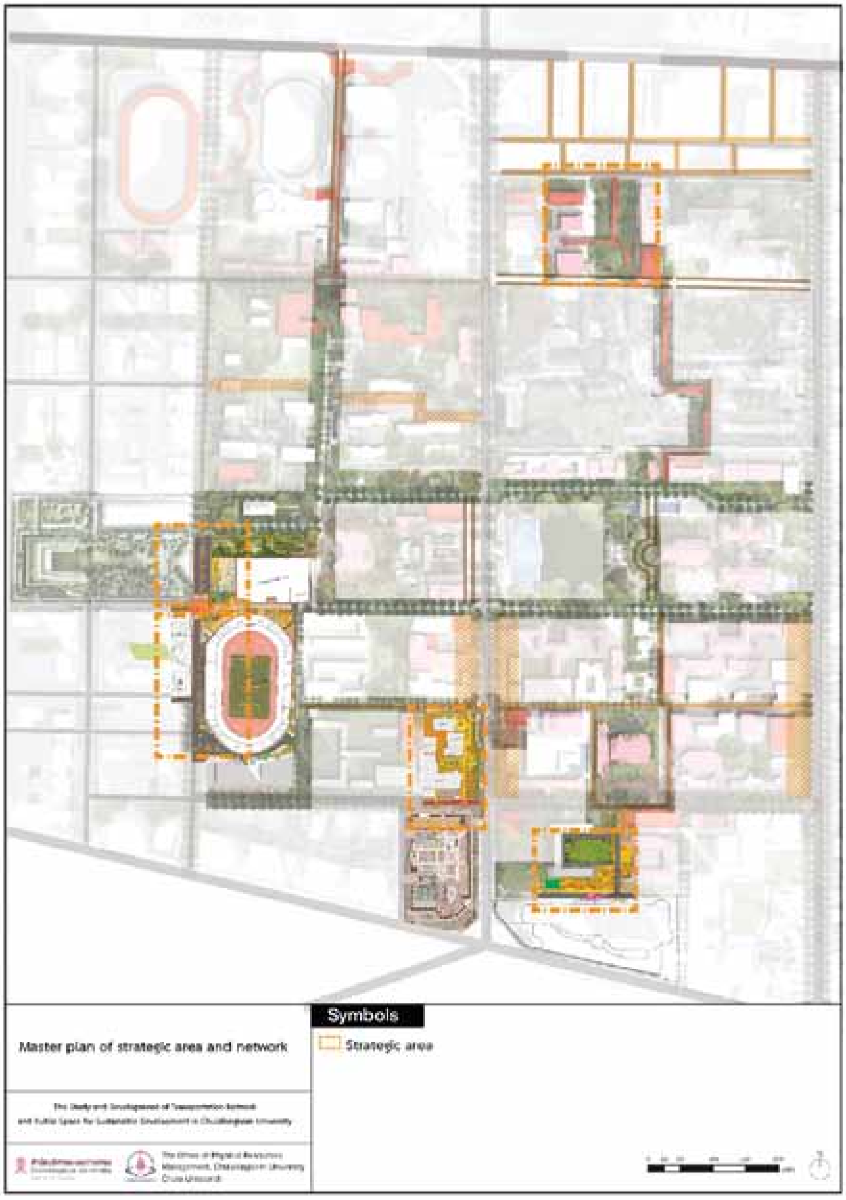


Figure 5 Master plan showing development of the transportation network, public spaces and transition spaces
Source: Pujinda et al. (2019)

The ratio of greenhouse gas removal was tested in three different zones: Eastern Zone 1; Eastern Zone 2 and Western Zone. The results are as follows: 1) areas in the Eastern Zone 1 that contributed the most to GHG removal were the CU Auditorium (14.18%), Faculty of Engineering (9.29%) and the Faculty of Finance and Accountancy (6.77%); 2) the area in the Eastern Zone 2 that contributed most to GHG removal was the Faculty of Pharmaceutical Sciences (3.65%); and 3) in the Western Zone the areas that contributed most were Sasa International House (11.63%), Office of Academic Resources (6.23%) and the CU Sports Complex (5.93%).

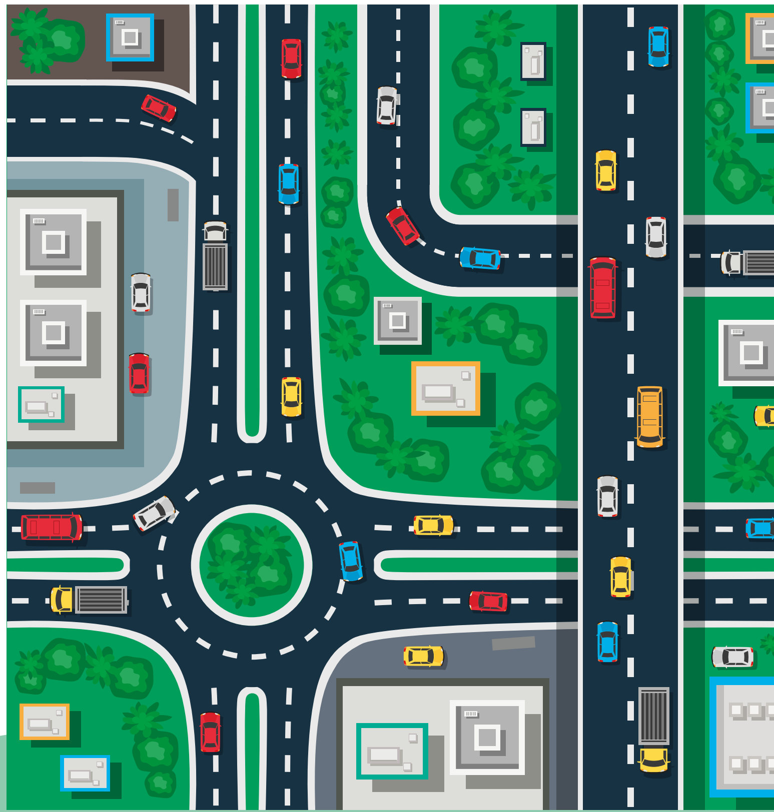
Activity 6 Selection of spaces and recommendations for a model design for public spaces

A roadmap model was created by selecting three different types of public spaces within the CU campus

(Figure 3-5): 1) a network of public spaces for transportation; 2) public spaces within CU campus; and 3) transition space. The criteria for choosing the spaces were 1) a space with high accessibility potential and visibility but low traffic and usage; and 2) spaces with low accessibility potential and visibility but with high traffic and usage. The latter is a space with potential to be used as a model space in developing a master plan, detailed place, perspective and design guideline.

Activity 7 Preparation of the final report and Executive Summary

The results and development of the master plan, detailed design and perspective were combined and reported in the form of a Final Report and Executive Summary.



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Conclusion

From the findings of this study, the research team considers that the Study and Development of Transportation Network and Public Space for Sustainable Development in Chulalongkorn University offers a useful guideline to promote use of non-motorized vehicles to reduce the University's carbon footprint, both within and outside the campus area. Moreover, it could serve as a model for development of public spaces to contribute to the University's vision and as a model for the development of public spaces in other parts of the city.

Acknowledgements

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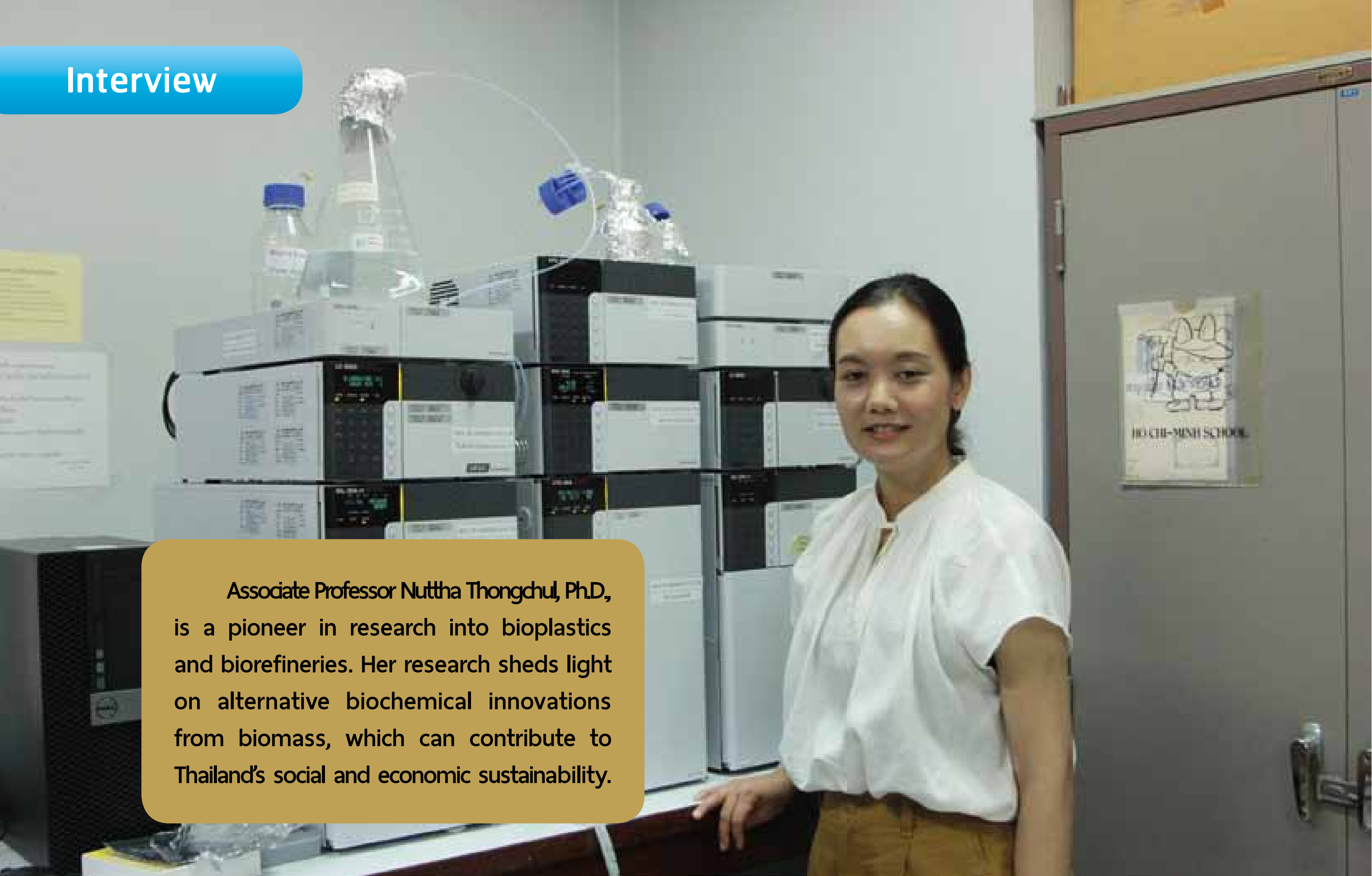
Interview



Associate Professor Nuttha Thongchul, Ph.D., is a pioneer in research into bioplastics and biorefineries. Her research sheds light on alternative biochemical innovations from biomass, which can contribute to Thailand's social and economic sustainability.

Alternative Biochemical Innovation for Sustainability of Thailand

Associate Professor Nuttha Thongchul, Ph.D.

Status quo of alternative biochemical innovations in Thailand and changing global trends

"...Awareness of alternative energy and biochemicals in Thailand is low compared to other developed countries despite supportive government policies..."

Most of the energy and chemicals that we use today is petroleum-based. With Thailand dependent on imports of oil and gas, overdependence on petroleum presents a significant economic risk for the country. It is therefore not surprising to see the emergence of efforts to seek alternatives to petroleum. Biochemical production is one such alternative. While alternative energy includes bio-energy, wind and solar energy, alternative chemicals can be the biochemicals derived from biorefinery platform as substitutes for petroleum-based chemicals. In embracing renewable resources, both approaches deliver benefits to the national economy, business, the environment and quality of life. However, despite growing interest around the world, these approaches have yet to gain significant traction in Thailand, compared to the European Union (EU), America, Australia, as well as other Asian countries including Japan, China, Korea and Malaysia, which have all invested heavily in renewable energy and biorefinery development.

Viewing this phenomenon from a policy perspective, these countries have mandated government agencies to promote alternative biochemicals through research and practical application. The facilities in both pilot and demonstration levels are employed in verifying the biorefinery platforms developed in the lab scales with the well-established funding mechanisms that support R&D to commercialization. Nevertheless, policies that drive the R&D in biorefinery technology and promote the biochemical industry vary considerably by country. Such policies of course need to be tailored to the specific context. For example, sugar and starch was once utilized as the feedstock for bioethanol fermentation in the United States because of their availability locally. In the past few decades, agricultural wastes such as lignocelluloses were introduced as the second generation feedstock to replace the edible sugar and starch in bioethanol production in order for food and feed security. The United States Department of Energy (DOE) sponsored researchers in government agencies, educational institutes and biotech R&D companies in the form of research funding and soft loans to promote biorefinery technologies to expedite the technology transfer from the labs towards the pilot to commercialization levels. Eventually, some of these projects were approved for industrial application.

While European countries and the US are launching policies to reduce the use of plastic and promote cloth bags, Japan has taken a different approach. Instead of focusing on reducing the use of plastics, Japan promotes recycling or reusing plastics or items that will soon be discarded. With effective management, the policy has achieved remarkable success. Interestingly, the Japanese government did not make any intervention against the market mechanism. Manufacturers were therefore not immediately affected by the policy and could continue to produce their products. With the circular economy principle used by Japan, a good number of products is recycled. This mechanism allows Japan to manage and control consumption of energy and materials effectively, contributing to leveraging the demand and supply.

Despite their groundbreaking potential and diverse applications across the industrial spectrum, awareness of alternative energy and biorefineries in Thailand is low compared to the developed countries despite supportive

government policies. For example, the ban on the use of plastic bags in department stores was first implemented this year while the same measure was enforced in USA and Europe since 2008. Moreover, Brazil started promoting biodiesel B100 while Thailand is still selling biodiesel B20. The introduction of new technology and alternative biochemicals to replace goods or products on shelves today need to be implemented concurrently. This could be done by using other support mechanisms such as environmental conservation movements, business feasibility, technology readiness, and manpower. Government agencies need to enact policies to promote use of alternative biochemicals from upstream to downstream in key industrial supply chains. Tax exemption measures offer an example of effective supportive mechanisms. Policy measure for multiple needs also to ensure full understanding among stakeholders, as well as a smooth transition to minimize the impact of a shift toward biorefineries.

Approaches to drive bio-energy innovation and biorefineries

"...The government has established a mechanism to foster growth in biorefinery platform and reached out to connect stakeholders across all sectors, locally and globally..."

Today, Thailand is developing the Eastern Economic Corridor (EEC) as a hub for the new *'S-curve industry'*. Complementing this strategically important infrastructure, the Eastern Economic Corridor of Innovation (EECi) has been established as a pilot-scale R&D infrastructure to promote the readiness in term of technology and manpower. Biopolis as one of the key EECi projects– is soon to be launched, with the aim of serving as a regional translational research hub.

Biorefinery platform can be divided into three major sub-platforms: 1) thermal processes; 2) chemical processes; and 3) bioprocesses. These three main processes could be combined as either the consolidated processes or they could work separately. Typically, products from biorefineries can be categorized into four main groups: 1) biofuels; 2) biochemicals; 3) bioplastics; and 4) biopharmaceuticals. The government has established a mechanism to foster growth in biorefinery infrastructure and reached out to connect stakeholders across all sectors, locally and globally. All stakeholders now have the opportunity to collaborate through the Biopolis Project, which aims to transfer technologies from Thailand's leading research institutes to researchers and industrial players across the country. The project is also supported by Thailand's Board of Investment (BOI). The government's role is to assess and steer the direction of development, in keeping with the country's readiness and potential and progress in other countries. Through its supporting policies and incentive mechanisms, this role is key to fostering investment by industry to realize the potential of innovative biorefinery technologies.

Technology and industrial development

"...Government agencies, universities and large research organizations, as well as industry, all understand the importance of supporting R&D in biorefinery technologies to make it work in practice at industrial scale..."

Interest in technology and biorefinery development has been increasing at universities, government agencies, and large research organizations at national level. These include the following:

- Chulalongkorn University
- Khonkaen University
- Naresuan University
- Chiangmai University

- Prince of Songkhla University
- Suranaree University
- King Mongkut's University of Technology Thonburi
- National Science and Technology Development Agency (NSTDA)
- National Center for Genetic Engineering and Biotechnology (BIOTEC)
- National Metal and Materials Technology (MTEC)
- Thailand Institute of Scientific and Technological Research (TISTR)

These institutions understand the critical importance of research for technological development and the need to translate research into industrial-scale processes. Reflecting this commitment, Science Parks have been established across the country as regional centers for R&D. Chulalongkorn University has established a pilot facility for biorefinery technology in Saraburi Province, as well as biorefinery cluster. The cluster originated through collaboration among specialists and five research units in the Faculty of Engineering, the Petroleum and Petrochemical College, the Faculty of Science, the Institute of Biotechnology and Genetic Engineering, and the Energy Research Institute. This collaboration aims to develop researchers and their research projects to support the biorefinery industry effectively.

In the meantime, the private sector also has its own vision to develop the biorefinery industry, establishing

innovation centers and corporate R&D on biorefinery technologies to satisfy real-world industry needs. It is evident that the Thai industrial sector does not intend to merely buy technology from overseas, but also intends to develop its own expertise and technology by investing in R&D. Industry is currently conducting a technical and economic analysis of the biorefinery sector, benchmarking against progress in other countries. Investment decisions will likely pivot heavily on the outcomes of this study.

Thailand's biorefinery industry and the Bio-Circular-Green Economy

"...Biorefinery infrastructure will form a foundation to support the Bio-Circular-Green Economy..."

Biorefinery infrastructure will form a foundation to support the Bio-Circular-Green Economy (BCG Economy). This is because the biorefinery industry catalyzes economic development by creating a new *'bio-economy'*, adding value to low-value agricultural products and wastes by converting biomass, for example, tapioca and sugar cane, to higher value intermediate products, biofuels, plastics or fine chemicals. A clear example of the potential contribution of biorefineries to the BCG Economy is the production of bioplastics such as polylactic acid (PLA) from biomass such as tapioca starch. At the end of the lifecycle, the bioplastic decomposes, producing carbon dioxide and water, and regenerating the circle. Another key characteristic of biorefinery

technology is its focus on carbon-neutral processes that do not produce residual carbon that cause pollution or greenhouse gas emissions. This example demonstrates the strong potential contribution of the biorefinery industry towards national economic development through the BGC model.

How will alternative chemicals impact the industrial sector?

"...The success of the biorefinery sector will be grounded in the mechanisms by which the government promotes, underpins and facilitates industry investment..."

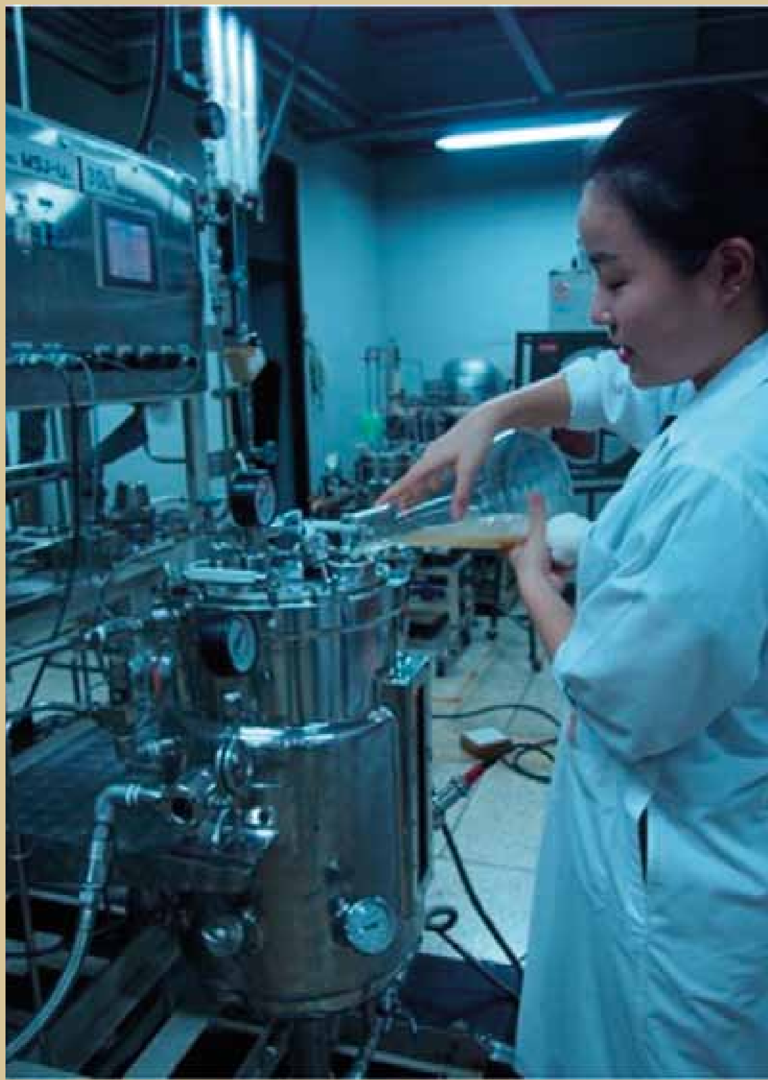
The outputs of biorefinery infrastructure as a pillar of the new *'S-curve'* industry can be divided into two groups: 1) alternative energy and 2) chemicals. Apart from biodiesel and bioethanol, alternative energy also includes bio-jet fuel, bio-hydrogen, among many other biomass-derived fuels. Among biochemical products, bioplastics have become the poster child, although the biochemical industry is highly diverse in its product potential, and projected to become one of the country's top five industries in the future. Technological development helps accelerate the development of the industry of this country. To improve the national industrial sector requires two driving mechanisms: governmental incentive mechanisms and industrial investment. Governmental mechanisms require policies to foster the industry and facilitate investment. Industrial investment is required to lay a foundation for a fundamentally new manufacturing platform. To enable both these prerequisites, a dialogue between government and industry is vital to ensure alignment and set a new path for Thailand's industrial development and global competitiveness.

In terms of technology, Thai researchers are now working closely with industry to focus on R&D to commercialization. However, the commercial risks are high due to the high investment requirements for biorefinery infrastructure as well as dependence on external factors, particularly crude oil prices. For example, technological development of bioplastics as well as demonstration scale production were delayed when global oil prices plummeted due to the discovery of shale gas in 2013. Nevertheless, researchers continued their work in anticipation of price recovery and an improved competitive position for renewables.

Benefits to society, country, and environment

"...Production processes in the biorefinery industry are green, reducing the environmental footprint of industry and stabilizing incomes for farmers, adding value and enabling Thailand as an integrated producer and improving the quality of life for Thai people...."

From an environmental and climate change standpoint, biorefinery-based processes significant reductions in emissions of greenhouse gases. Raw materials used in the biorefinery industry can be quickly recycled, and most biorefinery processes are accepted as green processes. Speaking from the economic and social point of view, it is clear that continuing dependence on petroleum will adversely affect Thailand's future economic prospects. Thailand's status as an agricultural country confers a natural comparative advantage and competitive positioning for a domestic biorefinery industry. With effective policy support, biorefinery investment will provide a much-needed boost for the agricultural sector, and stimulate domestic cash flows from production of raw material as feedstocks to domestic manufacturing. Production processes in the biorefinery industry are green, reducing the environmental footprint of industry and stabilizing incomes for farmers, adding value and enabling Thailand as an integrated producer and improving the quality of life for Thai people.

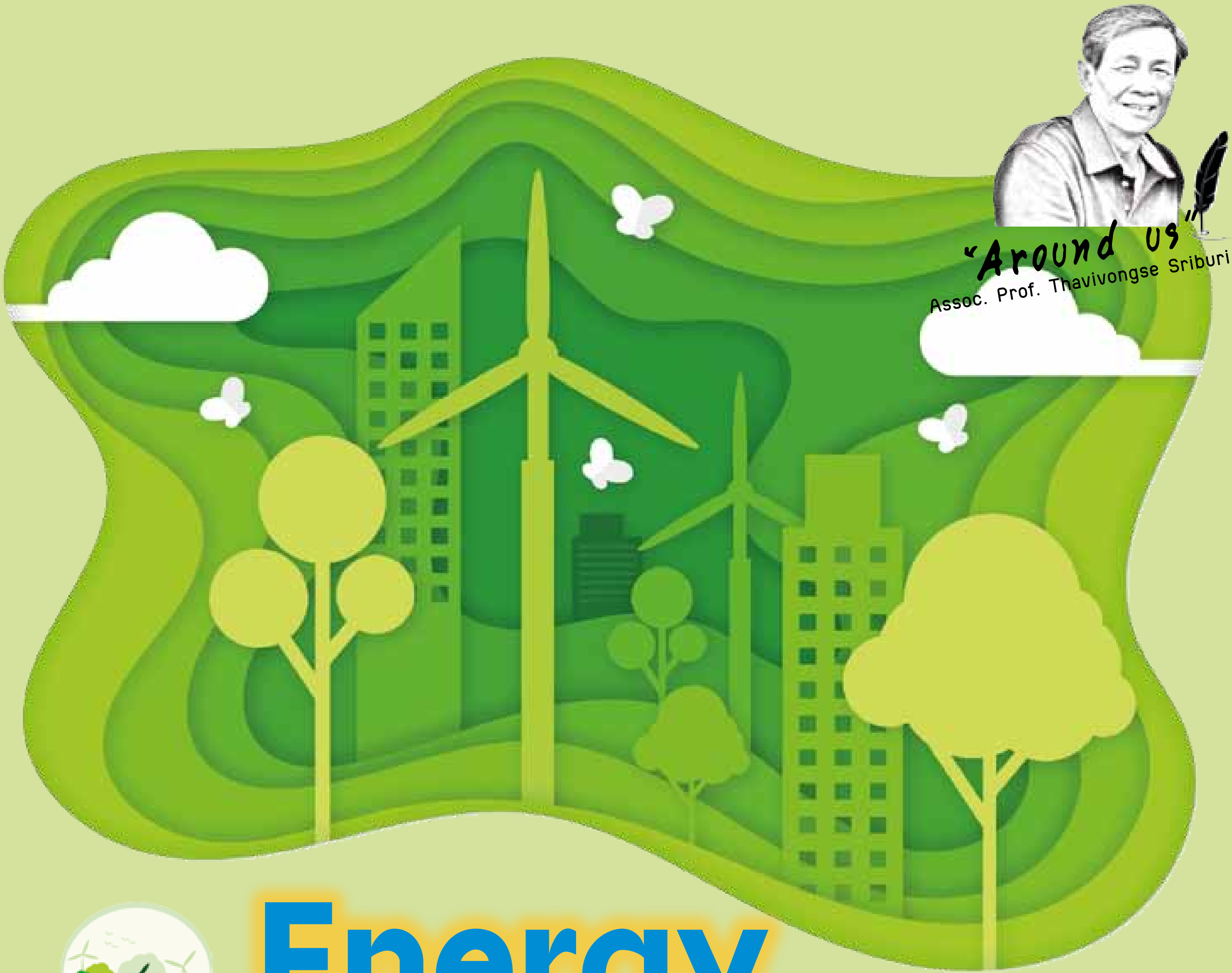


Collaboration in biorefinery industry development

"...By collaborating with industry, universities can overcome barriers to technology transfer and enable advances in R&D to be scaled up to real-world industrial processes..."

Today, we are witnessing flourishing new collaboration among universities, government and private organizations to develop the biorefinery industry. Chulalongkorn University in particular has been working together with government agencies as well as domestic and overseas industrial partners. For example, the university participated in developing the technology and prototype for a pilot biofuel production facility as a national-level project and test-bed for use by both researchers and industry partners. As another example, we may point to the development of biorefinery infrastructure and research on palm oil biorefinery infrastructure. Through experience in working with private sector partners, universities can also serve as a focal point to establish multi-stakeholder collaborations among private companies. However, in this role as mediator, universities must build trust through systems to ensure protection of commercial interests, e.g. through executing non-disclosure agreements (NDA), essential in term of research and development as well as marketing. The body of knowledge generated by such experience should also be channeled to support educational goals, e.g. as part of curriculum development at Thailand's higher education institutions.

Associate Professor Nuttha Thongchul, Ph.D. graduated with a Bachelor of Engineering (Chemical Engineering) from Chulalongkorn University, a Master of Engineering (Bioprocess Technology) from the Asian Institute of Technology, and a Ph.D. in Chemical Engineering from Ohio State University, USA. She is now Deputy Director of Research Affairs and Academic Services at Chulalongkorn University's Institute of Biotechnology and Genetic Engineering, specialized in fermentation and bioprocess optimization.



"Around Us"

Assoc. Prof. Thavivongse Sriburi, Ph.D.

Energy for Sustainability

With energy as a critical ingredient to the development of all countries, demand is continuously increasing across all sectors in every country around the world, including Thailand. As energy demand grows, prices increase accordingly, following price trends in fossil fuels. Thus, renewable energy sources have become strategically important as an alternative, in order to reduce our dependence on fossil fuels as our main source of energy. However, due to unfamiliarity, some sources of alternative energy have met with public opposition, and public relations and information campaigns have been limited in their effectiveness. Therefore, responsible government agencies need to redouble their efforts to disseminate knowledge and information to boost understanding among the general public in relation to renewable energy projects.

Energy experts agree that global energy demand is likely to double by the year 2050, compared to the year 2000. At the same time, the impacts of fossil fuel burning on climate change caused by greenhouse gases such as carbon dioxide (CO_2) emissions and other environmental problems are accelerating (Shell Thailand, n.d.). Dealing with the challenges of energy demand and a wide range of associated environmental problems will require a fundamental transformation in the global energy system, from procuring new energy sources and managing energy to maximize efficiency and efficiency. To meet the rapidly increasing energy demand will require full commitment and cooperation between public and private sectors both in planning and management of the energy system, in driving technological innovation and public awareness.

The race is on to find cost-effective alternative energy technologies with potential to substitute or even replace fossil-based energy systems, reduce costs and alleviate environmental impacts such as pollution and climate change. The main types of renewable energy currently under development include solar energy, wind energy, geothermal, bioenergy from biomass, hydropower, and power plants from waste. Hydropower has been used for millennia and is well understood by the general public, although in recent decades opposition to large dams has increased owing to social and environmental concerns as well as cost-effectiveness. However, bioenergy, biomass energy and waste energy is less familiar to the general public, and proposals to build such production plants have met with strong public opposition, particularly from adjacent local communities afraid of health and environmental impacts. Based on past experience and track record, there is little public confidence in the agencies and private sector implementation partners responsible for ensuring and enforcing safeguards and protecting the public interest for such new energy projects, particularly waste-to-energy. The perceived ineffectiveness of government agencies to regulate, monitor and enforce effectively has led to serious and long-term health and environmental impacts for local communities and delayed or prevented construction of new power plants.

Although the general public is familiar with waste and biomass as raw materials for energy production, the level of understanding of the production processes is still relatively low. It is therefore important to raise public awareness of the potential for utilization of locally-available biomass and wastes as feedstocks for community-based energy production. Such materials include agricultural waste, domestic waste, plastics or biomass waste that can be recycled. Currently, feasibility of production of bioenergy and biomass is being investigated as summarized in the following sections.

- **Bioenergy** refers to the use of locally available bio-based materials as feedstocks for energy production. Most must first be pre-digested before conversion into energy. Thus, plant materials are fermented to produce biogas (mainly methane) which is then used directly as an energy source. Thai farmers are already using animal waste to produce biogas (methane) through anaerobic fermentation, thus reducing their dependence on fossil-based energy. Some farmers also sell animal manure to biogas plants for commercial purposes. In addition, waste from agricultural processing plants such as pineapple peel from canning factories or wastewater from starch factories can also be fermented to produce biogas.
- **Biomass energy** refers to utilization of plant biomass by directly burning or pyrolysis to produce gas (known as syngas, comprising mainly methane and hydrogen) which can then be stored and utilized as fuel. Typically, feedstocks include wood waste, rice husks, sugarcane bagasse, grass cuttings and agricultural processing wastes, which are burned to produce heat, which is then used to generate electricity. Because Thailand has extensive agricultural activities across most areas of the country, agricultural waste materials such as rice husk, sawdust, bagasse and coconut pulp are abundant, with potential to produce the equivalent of not less than 6,500 million liters crude oil per year.

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Therefore, such materials have strong potential for commercial power generation. (Department of Industrial Promotion, n.d.). Sawmills, rolling mills and large sugar mills commonly produce biomass energy e.g. through co-generation, and may be permitted to supply any surplus electrical energy directly to the power utility via the electricity grid, thus reducing national dependence on fossil fuels.

Other types of biomass products can also be used directly as fuel, including alcohol from cassava, wood gas, fermentation gas from agricultural and community wastes (biogas). If it is commercially viable at scale, these also have potential as fuel feedstocks for electricity generation.

The inadequacy of Thailand's garbage and solid waste management system has exacerbated health and environmental impacts across the country, and the problem is accelerating with rapid economic development. Waste separation and effective recycling programmes will help reduce the total volume of waste, reduce budgets needed for waste management, conserve resources, save energy and help the environment.

Landfill has been the traditional and still the most preferred method for waste disposal in Thailand. However, new landfill locations are scarce because of public opposition. In many cases, poor design and construction has led to long-term damage, polluting surface- and groundwater and creating severe environmental harm as well as health hazards to local residents. Quality of life is also impacted by the foul smell from poorly managed garbage dumps.

With limited new capacity and increasing opposition to landfill, new waste management solutions are needed. While incineration also has its own problems (air pollution), waste disposal by incineration can no longer be avoided. Selection of the appropriate incineration technology will be important in order to minimize impact on living organisms and the environment; the repurposing of waste for economic purposes such as energy generation should be another important strategy for waste management as well as energy strategy.

A range of waste-to-energy technologies are currently available to use waste as a feedstock for electricity generation. Community domestic waste has high potential as an energy source. Such wastes typically comprise biomass including paper, food scraps and wood chips and can be used as fuel in power plants to generate steam to drive a turbine. Aside from its value as a low-cost feedstock, electricity from waste also helps reduce waste disposal problems. However, there are still many limitations, for example, local opposition to waste-to-power plants, high capital investment, and costs of managing waste before processing into energy. Such facilities must also have efficient scrubbing technologies to manage dust, smoke and toxic gases such as dioxins produced during incineration.

Advances in research and technologies are increasing the potential and cost-effectiveness of renewable energy solutions and can help address environmental and climate change problems simultaneously. Lack of trust among communities in responsible public agencies remains a major and continuing problem. This is understandable, based on the lack of understanding among local officials, and the generally minimal consequences for operators or officials of negligence or reckless disregard for environmental or health regulations by operators focusing only on profit. In order to introduce new technologies with potential for public health and environmental impacts, it will be important to provide sufficient local-level knowledge and capacity among responsible public agencies as well as ensure channels for meaningful stakeholder engagement from the outset. Such processes, undertaken with sincerity, honesty and transparency, will be essential to build trust, confidence and support for new local energy projects.

References

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Behavior Study During Meetings to Promote Physical Activity and Reduce Sedentary Behavior among the Working-age Population

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Although meetings are an important factor in working to exchange ideas among people both inside and outside organizations, to be effective they should not last beyond 30 minutes. This is because of the effects of prolonged physical inactivity, including body aches, neck and shoulder pain, and various illnesses. Prolonged sedentary behavior is known as a cause of non-communicable diseases (NCDs) such as heart disease, high blood pressure, cancer and diabetes, which is the number one cause of death in person and is expected to increase every year. Death before 60 from these causes is rising due to changing lifestyles and the advancement of technology. Sedentary Behavior is defined as sitting in various activities using 1.5 MET energy (units used to estimate the amount of oxygen that the body uses), not including sleep.

Recognizing the importance of this issue, the research team conducted a study *"Behavior study during meetings to promote physical activity and reduce sedentary behavior among the working-age population"* to collect data on the daily behavior of the working-age population by creating an environment that promotes physical activity including ongoing experiments. The study aimed to promote physical activity and reduce

sedentary behavior in the long term that can be disseminated and to provide guidelines for further implementation.

To implement this project, **Chula Unisearch** was supported by the Thai Health Promotion Foundation (ThaiHealth), which recognizes the importance of increasing physical activity among working age people. Increasing physical activity (PA) in the workplace should be straightforward, without requiring additional time from work. For example, organizations can start by creating a conference table stand for an energetic meeting (active meeting or active conference). Organizations should experiment with various types of meetings, such as international meetings, meetings between organizations, internal meetings, including face-to-face bilateral meetings, to summarize the time used and evaluate meeting efficiency.

The research team defined operational procedures for the study as follows;

• Step 1: study concepts and theories related to meeting room usage behavior, meeting room layouts that promote physical activity including international case studies related to meetings that promote physical activity by using a method to query data from various sources in both primary and secondary formats through interviews, experiments, observation or studies from related reports and research;

• Step 2: a study of guidelines for designing conference and meeting tables that promote physical activity in meetings at various levels, including searching for relevant case studies from abroad;

• Step 3: design and create a standing conference table for the conference and active design of the meeting room and to assess its acceptance and effectiveness in increasing meeting efficiency, promoting physical activity and reducing sedentary behavior in daily life;

• Step 4: create information media related to the trial activities of the standing conference table, teaching how to use the advantage of standing meetings and publicize to external parties and agencies interested to implement;

• Step 5: evaluating survey data from the trial standing conference table and standing meeting room in various meetings from pilot organizations. The survey findings will to be presented to ThaiHealth;

• Step 6: create and publish guidelines to promote physical activity and reduce sedentary behavior among the working-age population as a contribution to public health.

In this regard, the research team expects that the behavioral study will provide insights and understanding into theories and concepts related to meeting room usage behavior. In particular, the study will recommend meeting room layouts that promote physical activity and develop guidelines for designing a conference table stand and formatting a conference table that promotes physical activity. The study will contribute to health, well-being and efficiency in the workplace, and reduce illness and deaths from associated NCDs caused or exacerbated by long-term sedentary behavior.

Activities News

Opening Ceremony "Best of The Best^2"

On Monday 3 June 2019, Prof. Bundhit Eua-arporn, Ph.D., President of Chulalongkorn University, presided over the opening ceremony for the ***"Best of The Best^2" Course for Executives, Chulalongkorn University***. On this occasion, Prof. Emeritus Pirom Kamolratanakul, M.D., Chairman of Chulalongkorn University Council and Prof. Worasak Kanoknukulchai, Ph.D., Fellow and former President of the Asian Institute of Technology (AIT) attended a special lecture on the topic of ***"Leadership and Management under Crisis"***. The event aimed to help the 48 participants learn and prepare to lead the organization towards its goals and achieve the mission of the university.

Chula Unisearch was assigned by the Office of Human Resources Management, Chulalongkorn University to manage ***"Best of The Best^2"***, held from 3-27 June 2019 on Monday and Thursday of every week between 09.00-16.00 hrs., in meeting rooms 1 and 2, Maha Thirarachanusorn Building. The training course duration was a total of 30 hours.

Opening Ceremony for the 5th Bhumipalung Phandin

On 3 July 2019, Chulalongkorn University opened a training course: ***the 5th "Bhumipalung Phandin" Chulalongkorn University Executive Program (BPP)*** at Chulalongkorn University, Prof. Bundhit Eua-arporn, Ph.D., President of Chulalongkorn University, presided over the opening ceremony and delivered a special lecture on the topic ***"Chulalongkorn and Bhumipalung Phandin"*** In addition, ACM Prajin Juntong, Senator, Former Deputy Prime Minister and Chief of Bhumipalung Phandin Club, delivered a special lecture on ***"Bhumipalung Phandin and national development"***.

Under this initiative, Chulalongkorn University has assigned **Chula Unisearch** to develop a curriculum ***the 5th "Bhumipalung Phandin"***, and to establish a training course between 3 July and 3 December 2019 on Tuesday of every week between 13.00-18.00 hours at the Maha Chulalongkorn Building. The total training duration will be 100 hours.

RUN Digital Cluster Meeting #2 – Research University Network

From 25-26 July 2019, **Chula Unisearch** organized the ***RUN Digital Cluster Meeting #2 – Research University Network***, on the topic of ***"Digital for All: When AI meets 5G !!!!"***, at the Office of Academic Resources, Chulalongkorn University. This event was honored by the presence of Virach Sornlertlamvanich, Ph.D., President of RUN Digital Cluster and Prof. Kiat Ruxrungtham, M.D., Vice President for Research and Innovation, Chulalongkorn University, who presided over the opening ceremony of the meeting. The event aimed to present and transfer knowledge on the status and prospects for digital AI technology and IOT to students as well as providing an opportunity to exchange experiences in both science and the arts to support and drive adoption of innovation catalyzed by 5G digital innovations.

Water pouring ceremony Thai New Year's Day 2019

On 10 April 2019, **Chula Unisearch** celebrated the annual Songkran or Thai New Year festival at the Atrium Lounge. Celebrating ancient tradition, the ceremony involved anointing Buddha statues and the hands of Chula Unisearch executives with holy water. This is a cultural legacy and a beautiful tradition that has been carried on for generations in Thailand to show gratitude, beg forgiveness and seek prosperity and success. Assoc. Prof. Thavivongse Sriburi, Ph.D., Managing Director of Chula Unisearch gave a speech and blessed all executives and staff.

Leading universities visits and study Chula Unisearch

Assoc. Prof. Thavivongse Sriburi, Ph.D., Managing Director of Chula Unisearch, Chulalongkorn University and Supichai Tangjaitong, Ph.D., Deputy Managing Director of Chula Unisearch recently welcomed executives and staff from three leading universities: Silpakorn University (SU), Mahidol University (MU) and Prince of Songkla University (PSU) as part of their visit to study and observe the management services of academic and research guidelines of **Chula Unisearch**, in terms of system development to support academic services including introduction of technology, marketing strategy, project system and quality assurance programs to be used in support of service delivery, and that could be applied to benefit delivery of academic and research services at the three universities.

Practice fire prevention plan for the year 2019

On Friday 24 May 2019, **Chula Unisearch** executives and staff led by Assoc. Prof. Thavivongse Sriburi, Ph.D., Managing Director of Chula Unisearch, joined a fire prevention plan exercise for the year 2019 at the Chulalongkorn University Research Building. The exercise aimed to provide staff with knowledge and understanding in case of fire Including fire escape routes and procedures to ensure a safe escape without panic, and also to be able to carry out basic fire control measures efficiently and call for assistance in an emergency.

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