DESIGNING KINETIC ARTS SCULPTURE IN PRODUCING RENEWABLE ENERGY FOR LEARNING PURPOSES.

By

MR. Waiyawat SAITUM

A Thesis Submitted in Partial Fulfillment of the Requirements

for Doctor of Philosophy DESIGN ARTS (INTERNATIONAL PROGRAM)

Graduate School, Silpakorn University

Academic Year 2018

การออกแบบงานจลนศิลป์ด้วยพลังงานทดแทนสำหรับพื้นที่การเรียนรู้ในมหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี : แผงพลังงานไฟฟ้าโซลาร์เซลล์

โดย
นายวัยวัฒน์ สายทุ้ม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปรัชญาดุษฎีบัณฑิต
สาขาวิชาศิลปะการออกแบบ แบบ 1.1 ปรัชญาดุษฎีบัณฑิต(หลักสูตรนานาชาติ)
บัณฑิตวิทยาลัย มหาวิทยาลัยศิลปากร
ปีการศึกษา 2561

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By	Waiyawat SAITUM
Field of Study	DESIGN ARTS (INTERNATIONAL PROGRAM)
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Keyword : Renewable Energy, Photovoltaic, Kinetic Art

MR. WAIYAWAT SAITUM : DESIGNING KINETIC ARTS SCULPTURE IN PRODUCING RENEWABLE ENERGY FOR LEARNING PURPOSES. THESIS ADVISOR : ASSISTANT PROFESSOR VEERAWAT SIRIVESMAS, Ph.D.

The objectives of this study were (1) To study the Kinetic Arts Design with Renewable energy by experimenting with the sculpture art form, (2) To research and examine the competency of photovoltaic cell generating electricity power which could be enough for moving the sculptural form itself, (3) To present the aesthetic of new designed which is both beautiful and capable to fulfill the human needs through Kinetic art and 4. To produce a manual guideline documentary of the Kinetic Arts Design with Renewable energy for next generation designers and also any researchers interested in this topic.

Learning Garden (LG) is sculpture installation site where located at the center of King Mongkut's University of Technology Thonburi. Participants involved in the installation area can be divided into two major groups. (a) University residents such as; lecturers, staffs and students. (b) Non-university residents such as; general public that come to use university's facilities.

Research findings were as follows : (1) The creation of the sculpture involving an aesthetic and science blending together, these two disciplines together creating a sculpture made a unique piece of art. (2) Sculpture could generate electricity by its own, the energy application could be used for developed into kinetic arts, or the art works consisted of movable parts or movement driven by the electric power. (3) From the design with an integration of function and aesthetic. When an energy source generates movements, we call this an illusion-move Kinetic Art.

ACKNOWLEDGEMENTS

The dissertation was completed with the help and support from many people and organizations. I wish to thank my advisors, Assistant Professor Veerawat Sirivesmas, Ph.D. and Professor Eakachat Joneurairatana for their time, patience, and guidance. I extend my gratitude to all dissertation committee members of the Doctor of Philosophy International Program in Design Arts, Silpakorn University. Gratefully, I extend my thanks to Mr. Prapon Ruengvuthchanaphuech, Advisor to the President of King Mongkut's University of Technology Thonburi and the experts from his team for their time to cooperate with this research. This research wouldn't have been success without my family and friends, the Ph.D. friends class 7.1 and 7.2, who were involved in pushing and encouraging me to do the dissertation to success. Finally, I wish to thank my parents for their support and budget also.

Waiyawat SAITUM

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Chapter 1
INTRODUCTION AND BACKGROUND OF THE STUDY

1 Introduction

Sculpture used to be considered as an art of mass, or the art that primarily deals with solid form. As the history progressed, sculptors started to shift their focus towards spatial sculpture, which finally become one of the branch in the art of sculpture nowadays. Kinetic art is a type of spatial sculpture. It was described by Phillip Barcio (2016) as “any purposeful aesthetic creation that, in order to be considered complete, depends on the designed, extraneous physical movement of one or more of its parts to a degree that is within the perceptible range of human senses.”

Kinetic arts found in the various cultures were mostly simple creations rather than a serious work of art. Wind chime is one of the ancient example of kinetic art, as it has been found for at least 5,000 years all over the South East Asia. And although there might still be some disagreement whether the wind turbine should be called art, there is still the possibility that it could be. These objects mediated between human, nature, beliefs, cultures, and inspiration, which are all related to the definition of the aesthetic phenomenon. However, the idea of incorporating technology in the Kinetic art is recently developed, especially the technology of renewable energy.

As the demand of energy for human usage is increasingly impacting the social and economic development, while the heavy use of fossil fuels have led to the exponential growth in carbon dioxide emission, renewable energy becomes more important than ever. Solar energy is one type of the renewable energy which can be collected every day for free, although there might be some start-up cost in building the facility to collect the energy. (Crowther, 1983) described the cycle of solar energy that *“The energy that plants absorb is potentially convertible into food energy and material for combustion (logs, etc.) or fossil fuel (long-term decay). The energy absorbed by*

the oceans causes water evaporation and motivates the complete water (hydrologic) conversion cycle." (Crowther, 1983)

The sunlight ray is emitted in the form of wave. The solar cell, or photovoltaic (PV) cells, was thus invented to transform the wave energy into electricity. Pearsall and Hill wrote that "PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the PV effect". Solar cell was first discovered by the scientists at Bell Telephone, who found that silicon could generate electricity when exposed to sun. Due to its direct conversion of sunlight into electricity which does not require any moving part nor generate any emission, the solar cells became widely used and could be found from in the small consumer products such as watches or calculators to the space satellites and large power stations feeding electricity into the grid. (Pearsall, 2003) Chenming Hu also defined photovoltaic effect as the phenomenon of producing voltages and currents from the solar cells, which are "the devices in which sunlight releases electric charges so they can move freely in a semiconductor and ultimately flow through an electric load, such as a light bulb or a motor". (Hu, 1983)

Kinetic Art is usually defined as the genre of art which consist of movement or require some degree of motion for effective presentation. They are mostly three-dimensional sculptures and mobiles, although there are wide ranges of styles and technique used. The movement can be actual or virtual, involve just some part of the art work or the whole art work, and could be powered by natural energy, human, or machine. Thus, the Kinetic art could bring a new relationship between art and technology.

As mentioned above, there is the possibility that the Kinetic art sculpture could be combined with Photovoltaic cell, and create both beauty and the energy support for further usage. This could blur the line between art and science together, and could express the stylishness of the renewable energy as an art object. The further

development for daily life application would confirm that the sculpture could offer note only beauty but also the energy which would be beneficial for everyday usage.

With all these reasons, this purpose of the research is to study the Kinetic Arts Design with Renewable energy for Learning Garden in KMUTT : Photovoltaic. The research methodology is practice base, by attempting to create kinetic art by using various kinds of materials available locally. The final stage will be constructed into an actual work. The researcher expects that the results of this study could be a guideline for any designers to understand the Kinetic art, how to create Kinetic art form that could be inspiring, and how to incorporate value of the craft and the expression of the artist's imagination. Finally, this study will be the most useful for the next generation designers and any researchers who need to develop their knowledge in Kinetic arts and renewable energy.

2. Objectives

1. To investigate the potential or possibility of the kinetic arts sculpture elements in producing renewable energy.

2. To experiment the significance and fundamental elements of kinetic arts sculpture elements in producing renewable energy.

3. To produce and appropriate kinetic arts sculpture in producing renewable energy functions which can be benefits for educational purposes.

3. Research Questions

1. Can sculpture involving an aesthetic of art combine to the renewable energy by science objects such as photovoltaic cell?

2. Sculpture that can generate electricity by its own, The power which had been produced can use energy for sculpture itself and turned them into into kinetic arts.

4. Scope of the study

1. This study focuses on two topics

1.1) Sculpture design of Kinetic Arts

1.2) Renewable energy products and tools, especially photovoltaic cell.

2. The experts consists of two groups:

2.1) The experts in art and design.

2.2) The experts in photovoltaic cell.

3. The population and samples to study are population who interesting in art and photovoltaic system.

5. Significant of the Study

1. To discover a suitable planar surface and angle of sculpture for receiving of sunlight for Photovoltaics cells related development.

2. The sculptural appearance design aim to find the most suitable design direction for mechanics and techniques creation of the actual sculpture.

3. This Kinetic Art expect to be an inspiration source for other body of knowledges creation continuously, not only restricted only for art, but also other type of sciences.

6. Definitions of Terms

a) Renewable Energy = Generally defined as energy that comes from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.

b) Photovoltaic = Solar cells, also called photovoltaic (PV) cells, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage)

c) Sculpture = The art of making two- or three-dimensional representative or abstract forms, especially by carving stone or wood or by casting metal or plaster.

d) Kinetic Art = Kineticism, is an international movement that refers to art of both real and apparent motion.

e) Photovoltaic cell = Photovoltaic cell in a standard size of 156 square millimeters, which is approximately 6 inches long and 6 inches wide which can generate electricity.

f) Learning = Satisfaction of the viewing aesthetic can lead to the source of inspiration that produced art creation, as well as, encourage the continuously learning by themselves.

7. Abbreviations

a) KMUTT = King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

b) LG = Learning Garden (LG) located in King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

c) PV = Photovoltaic : Photovoltaic system has been applied as the power source for many instruments.

Chapter 2
LITERATURE REVIEW AND RELATED STUDIES

In this chapter, the researcher reviewed the discussion of the sculpture and Kinetic Art design, environmental design and renewable energy approaches from the related literature. The insight of the researcher is that the natural renewable energy is an important concern for the design of Kinetic Art, and therefore it is necessary to explore the design concept from various perspectives of the sculptors before further application. The theoretical bases from this chapter would be synthesis into a conceptual framework for the dissertation. The content of this chapter will be organized as following.

1. Sculpture
    - 1.1 Definition
    - 1.2 Evolution of Sculpture
    - 1.3 Sculpture in society
2. Kinetic Arts
    - 2.1 Definition
    - 2.2 Evolution of kinetic arts
    - 2.3 The significance of kinetics art in society
3. Photovoltaic
    - 3.1 Define what is photovoltaic
    - 3.2 Application for daily use
    - 3.3 Renewable energy application in art practices
4. The relationship of Kinetic arts sculpture with the photovoltaic in producing renewable energy
    - 4.1 From arts perspective / dimension
    - 4.2 From economy and education purposes
5. Summary

1. Sculpture

1.1 Definition

(Ryan, 2002) wrote that *"The investigation of material, volume, and construction made it possible for us in 1918, in an artistic form, to begin to combine materials like iron and glass, the materials of modern Classicism, comparable in their severity with the marble of antiquity. In this way an opportunity emerges of uniting purely artistic forms with utilitarian intentions..."* - Vladimir Tatlin (1920)

1.2 Evolution of Sculpture

The oldest sculptures seemed to exist for spiritual function, such as representing gods, supplying magical help, or making someone immortal as the gods themselves.

Prehistoric Sculpture

The aesthetic function of prehistoric sculpture was secondary. The most important function of these sculptures, figurines, and masks were spiritual, as nature was frightening and survival was hard. The sculpture provided spiritual support by personification the abstract quality of nature into the concrete spirits, which can be prayed or fought with. In other words, the ritual with sculpture gave the hope for good life with healthy heirs and abundant supplies of food, or sometimes the hope to be cured from diseases.

Sculpture in the Ancient World

Although the civilizations were established later, people still continued their beliefs in sculpture and their spiritual power as in the following examples.

a. Egypt

The belief in life after death was a prominent force in the Egyptian sculpture and art. Powerful rulers or Pharoahs and the nobles would ensure that their bodies would be preserved in the Pyramids or tombs, together with abundant supplies of goods, until they would need it again. The size of sculpture and tomb would convey the importance of the individual. The shapes were

simple and conventional. The eye would always look straight forward, the face would be in the profile, the upper body would be frontal, and the legs would be profile. And the character of the individual might be symbolized and glorified in the form of combination of human form, or intelligence, with animal forms which represent the individual's strength and power. And they would be carved in alabaster stone to ensure eternal existence.

b. Mesopotamia

As their lives were highly involved with the flood and soil, the Mesopotamian were the experts of using clay, both baked and unbaked, as well as the wood and shells since the Sumerian period. Later, the colored tile and bronze or gold was introduced by the Babylonian and the Persian. And they used these materials to depict their hierarchical society, gods, priests, people, and sometimes animal or abstract patterns.

c. Aegean Civilization

The enigmatic Minoan civilization on the island of Crete left some dynamic and colorful sculptures made of ivory and terra-cotta. They depicted the snake goddesses, athletes, and the scene of bullfighting as well as harvesting.

d. Greek Sculpture

The influential Greek civilization, which emerged around 600 B.C., was based on the belief that "man is the measure of all things" and thus the sculpture of human figure became the manifestation of this idea. The Greek sculptors were trying to refine their skills of representing the abstract quality of each god or goddess through the form of human. These statues were not only the personification of nature but also the confirmation of human dignity, as even the gods were just like human. Temples or shrines were construct to enclose the space for worshiping these gods and thus became the home of each god. The

influences from Greek civilization lasted long even the Greek was defeated by the Romans, who continued their Hellenistic style by imported the example of Greek sculptures and copied them or creating the new roman work in the Greek style.

e. Etruscan and Roman Sculpture

The Romans and Etruscans imported and translated the Greek sculpture and art into their own art. The Etruscans used bronze to create figures of people and gods, which were mostly left in the cemeteries untouched by the Romans, who also copied the Greek sculpture in marble. They also developed the portraits of people, not just gods. And later the Roman sculpture became more and more simple and abstract.

f. Early Christian Sculpture

The early Christians followed the style of Rome, although depicting Christianity subjects was a taboo according to the Ten Commandments. Therefore they had to represent the holy idea through the use of symbolic forms which would not be considered as the idols, or the false gods. Later when Christianity was accepted among the Germanic tribes who invaded the western Roman Empire from the north and central Europe, the complex patterns and shapes were introduced. As it was forbidden by the commandments, few examples of sculpture existed during the middle ages except for the portable altars, reliquaries, books, figurines, and objects for rituals made from precious and fragile metal or ivory. They were portable in order to be easily hidden in the case when safety and discretion was needed or to be carried during the pilgrimage trip.

g. Romanesque Sculpture

After AD 1000, the Christian art developed with the construction of churches and cathedrals, merging the skills of all crafts together. Working

together to achieve the spiritual purpose of building the home of the God, the architects, sculptors, carpenters, and craftsmen were able to achieve the impressive result which all part of the churches were carefully construct to convey the faith in Christianity. The bronze doors of Cathedral would depict the scene from Bible through the placing and arrangement of dynamic figures.

h. Gothic Sculpture

The Gothic sculpture developed from the stiff and unnatural posed towards the more realistic and dynamic look as the creator gained more freedom and skills. However, the expressive statues with the natural-draping garment came to an end because of the series of wars and plague. The sculpture became once again small and portable.

i. Renaissance Sculpture

As Rome was rather untouched by the war and crises from the north, it became the center of art and culture at the time. The 13th century slowly saw the coming of Renaissance with the Italian artists' attempts to revive the classical art. The subject was still Christianity, but the forms were liberated and human figure was celebrated. Once again the freestanding nude sculptures were created to depict biblical hero such as David. With the works of Donatello and Michelangelo, sculptures reached its peak during 15th century in depicting Christianity stories through the static, , ideal, graceful, and life-like human figure. Later, the work of Michelangelo became more and more elegant, decorative, elaborate, as found during the mannerism period.

j. Baroque Sculpture

After the sculpture was finally allowed to use the human figure as the form of expression when Vatican heavily commissioned the works from great artists during Renaissance period, the sculptors in 17th century could explore the same problem with much greater freedom. And they incorporated greater

strength and energy in the dramatic baroque sculptures. For example, Giovanni Lorenzo Bernini (1598 – 1680) expanded the largeness and strength of Michelangelo's David by depicting the moment when David was aiming the slingshot towards the enemy off scene. The scene became more energetic and dramatic, while the space around the sculpture expanded to include the audience as the witness of the action.

k. Rococo Sculpture

The 18th century sculpture followed the basic qualities of the art in 18th century. They became lighter in subjects and technique, and included more decorative element. The movement in the works such as Jean Baptiste Pigalle (1714-85) and Étienne Maurice Falconet (1716-91) became more graceful and delicate. Meanwhile, the same technical dexterity still manifest itself in the figures which are no longer strong and intense but rather sweet and tiny.

l. Neoclassic and Romantic Sculpture

The Neoclassicists hinted to the classical style as the true style and they rejected the levity of Rococo and the drama of Baroque. The works of Antonio Canova (1757-1822) became popular among the monarch and elite of Europe, as he specialized in depicting important person in the monument resembling Roman nobles. His works could be displayed alongside the ancient classical sculpture harmoniously as he imitated their features. However, the neoclassical tradition became rebelled against in 19th century as the imitation of classical sculptors was deemed as not saying or expressing enough idea or feeling.

m. 20th-Century Sculpture

The rapid changes in 20th century brought the new ideas, styles, technology, and materials in sculpture. The subjects were no longer limited to the physical reality but ascended to another level of dreams, myths, ideas,

feelings, and psychological conditions including sub-consciousness and melancholy. Artists were inspired by the art from the far-east, primitive African, and Oceania. Sculptures could now be created in any form or space, from almost all kinds of materials including plastic, chromium, welded steel, boxes, broken parts, or even pieces of old furniture. The emergence of Pablo Picasso and Cubism liberated the forms from the solid mass of nature towards the arrangement of geometric forms. And later the Dadaist incorporated the element of chance and play in their works and paved way for the conceptual arts as well as the idea that artist no longer have to do anything by oneself and thus could create work from the "ready-made" or "found objects". Many of the dada artists later became the surrealists who explored another level of truth in the sub-conscious or dreams. And they matched the objects or household items which do not seems to belong together in their works. Meanwhile, the futurists attempted to capture the rapid movement of the machine age and further explored with the abstract quality of the forms. The moving sculptures or mobiles were also created at this time by Alexander Calder (1898-1976). The structures became lighter with the use of wire and metal strips, as in the work of Richard Lippold (1915-2002). And the works of David Smith (1906-65) used the geometric steel to generate the feeling of balance and order.

More styles were developed during the 1960's and 1970's, when the artists posed the question of what art is and explored the boundaries between the everyday world and the artistic experience. Barnett Newman (1905-70) and Tony Smith (1912-80) used the massive scale of outdoor sculpture and sometimes computer-controlled movement to shock the viewers.

Figure 1. The Brillo boxes and soup cans of Andy Warhol (1928-87). From "Brillo Soap Pads Box", by Ballard, Brenda D., 1972, https://www.warhol.org/lessons/brillo-is-it-art/. Copyright 1998 by The Andy Warhol Foundation for the Visual Arts, Inc.

1.3 Sculpture in society

Sculpture has always been one of the major pillars in the art, whether it was the classical ideal or the modern exploration type. The power of sculpture was used by human for many functions; spiritual, documentary, and even decorative. The material of sculpture follows the cultural factors as well as the function. Hence, the study of sculpture could reveal something about the cultures which the sculpture was found.

Moai

Moai statues were found on Easter Island. They might be the world's oldest megaliths or massive stones. They were hand-carved by the island natives between 1400 – 1650 A.D. from the volcano Rano Raraku, in order to honour the rulers or important person. Around 1,000 statues were found mostly at the volcano itself and distributed around the island.

Figure 2. Moai, on Easter Island.

From "The island enigmas", by Philippa Taylor, 2014, https://www.cascada.travel/en/News/All-About-Moai. Copyright 1991 by Cascada Expediciones.

The Great Sphinx of Giza

The giant statue of the Sphinx, or a creature with human head and lion's body, was widely believed to represent Pharoah Khafre of the 4th dynasty who reigned during 2558 BCE to 2532 BC. This view was still in debated, and some scholar proposed that the Sphinx could be as old as 7000 BC. It was one the largest limestone sculptures in the world and the oldest known sculpture in Egypt.

Figure 3. The great sphinx, Giza, Egypt.

From "The Great Sphinx of Giza.", by Pual Darin, 2015, https://www.theepochtimes.com/fossil-suggests-egyptian-pyramids-and-sphinx-once-submerged-under-sea-water_1274558.html. Copyright 2000 by The Epoch Times.

Christ the Redeemer

Christ the Redeember was finished in 1931 and since then became the landmark of Rio de Janeiro, where the sculpture located 700 metres above the city on top of Corcovado. With the height of 39 metres, and the width of the arms of 30 metres, this reinforced concrete and sandstone sculpture is the largest of its kind and became one of the New Seven Wonders of the World in 2007.

Figure 4. Christ the Redeemer, Rio de Janeiro, Brazil.
From "Christ the Redeemer Statue, Rio de Janeiro, Brazil.", by John Misachi, 2018, https://www.worldatlas.com/articles/the-christ-the-redeemer-statue-rio-de-janeiro-brazil.html. Copyright 2019 by worldatlas.com.

The Monument of an Anonymous Passer-by

Jerzy Kalina used the medium of sculpture to honor people who were silenced by the martial law in Poland for its 24th anniversary in December 2005. The sculpture with 14 people rising from the ground was installed in the downtown Wroclaw, in contrary to the traditional monument which would rise from the high base and usually depict single elite. Here, it talked about the role of underground organizations such as Fighting Solidarity and Orange Alternative in helping voiceless ordinary people to be seen and to continue their normal life

Figure 5. The Monument of an Anonymous Passer-by, Wrocław, Poland. From "The Monument Of An Anonymous Passerby, Wroclaw, Poland.", by Helena Hon, 2017, https://www.livingmsia.com/astounding-swimming-pools-no-4-the-library-pool-kohsamui-thailand/ Copyright 2019 by livingmsia.com.

Nelson Mandela

Marco Cianfanelli collaborated with Jeremy Rose to produce the unconventional monument of Nelson Mandela which blended the line between portraits, architecture, and sculpture. It was constructed of 50 steel poles with various heights which would form Mandela's face when being viewed from the particular angle. The site of installation was of historical importance, as Mandela himself was captured in 1962 when his 'Long Walk to Freedom' started.

Figure 6. Nelson Mandela. KZN, South Africa.

From "The Nelson Mandela capture site near Howick.", by Clive Ndou, 2019, https://www.news24.com/SouthAfrica/News/spat-over-madiba-site-20190111-2

The Shoes on the Danube Bank

Sculptor Gyula Pauer and film director Can Togay collaborated in the creation of this memorial monument for the Jews who were asked to take off their shoes, then were shot and thrown into the river by the Arrow Cross militiamen during World War II. The shoes were installed on the Danube Promenade in Budapest to represent the lives lost in the massacre.

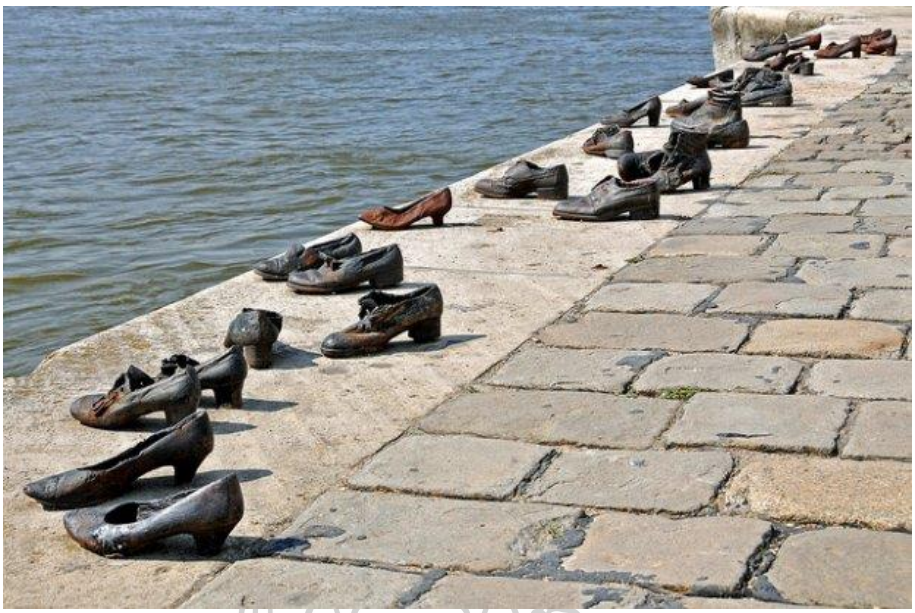

Figure 7. The Shoes on the Danube Bank, Budapest.
From "The Shoes on the Danube Bank: a moving memorial to war horrors in Budapest.", by Magda Origjanska, 2018, https://www.thevintagenews.com/2018/01/08/shoes-on-the-danube-bank/ Copyright 2018 by thevintagenews.com.

Non-Violence

Swedish sculptor Carl Fredrik Reuterswärd created the bronze sculpture "Non Violence", also known as "The Knotted Gun", in 1980 after John Lennon was murdered. It depicted a large Colt Python 0.357 Magnum revolver with the twisted end, suggesting of the impossibility to fire. It later became the symbol of non-violence project and the gift from the Government of Luxembourg to the United Nations in 1988.

Figure 8. Non-Violence (The Knotted Gun).

From "The Knotted Gun.", by Judi Lembke, 2017,

https://theculturetrip.com/europe/sweden/articles/the-best-of-public-art-in-malmo/

2. Kinetic Arts

Kinetic Art is usually defined as the genre of art which consist of movement or require some degree of motion for effective presentation. They are mostly three-dimensional sculptures and mobiles, although there are wide ranges of styles and technique used. The movement can be actual or virtual, involve just some part of the art work or the whole art work, and could be powered by natural energy, human, or machine.

As the Kinetic Art might be considered as a branch of sculpture, selecting material for Kinetic Art would depend on the similar factors of selecting material for sculpture, such as the site for installation and the artist's intention.

2.1 Definition

(Theophanidis, 2012) Wrote that *"The reality of our century is technology: the invention, construction and maintenance of machines. To be a user of machines is to be the spirit of this country. Machines have replaced the transcendental spiritualism of past eras."* - László Moholy-Nagy (1922)

As Aristotle stated that any change in the material cause, efficiency cause, and formal cause would affect the final cause, it is worth exploring the current state of material, technique, and perception of Kinetic Art and consider their impacts towards the representation of artists' intention. The researcher will do so in this section, starting with material.

Figure 9. "Leaf", by Peter Kourtz'.
From "Muskoka forest leaves.", by Brenda D. Ballard, 1972,
http://www.dorsetcanada.com/attractions/ Copyright 2019 by dorsetcanada.com

Peter Kourtz's "Leaf" is another example of kinetic art which create optical pattern. Kourtz said that *"They are all variations on the same theme. Many of them have long leaves or wings that catch the wind. The differences come through the way you arrange things. For instance, the purple coneflower's leaves are longer and thinner than others. The two rows of leaves move in different directions at the same speed. The secret is to be able to make wings that are similar in size and shape. When they are all similar, they behave. That's why the upper and lower parts of the coneflower behave in the same way."* - Kourtz, 2017. Thus, it could be said that optical pattern

would require some symmetrical balance and the careful planning so that the element would diffused together and creating the illusion when it move.

In shorts, the perception of visual illusion is a result from the movement that generate question and attract the eye. When the audience question the origin of movement, they would be strongly motivated to watch in order to try to find the answer on how it move and might attempt to create something by themselves, which might be just a small action that could further lead to something larger for those who actually committed to find the answer. Therefore, the hypnotic quality of the kinetic work of arts should be said to ignite the creative flame as well.

2.2 Evolution of kinetic arts

(Poché, 2018) *wrote that "Kinetic art was created by artists who pushed the boundaries of traditional, static art forms to introduce visual experiences that would engage the audience and profoundly change the course of modern art."* – Theo Jansen

Prior to the 1950s, Kinetic Art was not considered as an art form nor a major artistic movement, although it has been around for decades. The pioneers of Kinetic Art includes Naum Gabo and Laszlo Maholy-Nagy, who incorporate electric machinery with their sculptures. In the 1950s, Kinetic Art became shortly fashionable and faded out after a decade due to the emergence of digital era, when the artists shifted their focus towards experimental works with computers, video, films, and lasers. At its peak, Kinetic Art was an international trend in 1955, led by Soto, Takis, Agam, and Schoffer. (Organization, 2013)

Figure 10. Bicycle Wheel, By Marcel Duchamp, 1913.
From "Marcel Duchamp's Bicycle Wheel (1913).", by Kinetic Art Organization, 2019, http://intlkineticartevent.org/?page_id=107,%20access Copyright 2019 by International Kinetic Art Exhibit & Symposium

Marcel Duchamp's Bicycle Wheel (1913), in figure 10, was considered as the first modern Kinetic Art work, as the wheel affixed to the stool could be spun. It was also groundbreaking as an important work of the "readymade" genre, which defy the belief that art is something that is completely made by the artist. Duchamp said that he enjoyed looking at the wheel *"just as I enjoyed looking at the flames dancing in a fireplace. It was like having a fireplace in my studio, the movement of the wheel reminded me of the movement of flames."* (Duchamp, interviewed by Arturo Schwartz, 1969) Thus, the movement is an essential component in the work as it open up another possibility to interpret the work differently when it moves.

Figure 11. Kinetic Construction (Standing Wave), By Naum Gabo, 1920.
From "Kinetic Construction (Standing Wave)", by Hilary Floe, 2016,
https://www.tate.org.uk/art/artworks/gabo-kinetic-construction-standing-wave-t00827
Copyright 2018 Nina & Graham Williams / Tate

Naum Gabo's Kinetic Construction (Standing Wave), in figure 11, is another interesting example of early Kinetic Art. The work was made of steel rod affixed to a wooden base, connected to an electric motor which would oscillate the rod until it "dance" and resulted in the illusion of the fixed waveform. Without the oscillation, the sculpture would be just a static rod. But Gabo is successful in creating the new form by introducing mechanical movement into the regular material, corresponded to the "Realistic Manifesto" (1920) which he wrote together with his brother Antoine Pevsner. The manifesto was the first document that mention "kinetics" as an aspect of artistic form "*of our perception of real time". (Organization, 2013)*

Figure 12. Arc of Petals, by Alexander Calder, 1941.

From "Arc of Petals", by Lucy Flint, 2018, https://www.guggenheim.org/artwork/745

Alexander Calder's Arc of Petals, constructed from a delicate iron wire attached with various petal-like shapes created from painted aluminum, is an example of Kinetic Art in the forms of "mobiles". The gradation of size from largest pieces at the top to smallest pieces at the bottom contradict the general expectation of heavy and light. And the movement can be triggered by just the presence of the viewer who generate a passing air current and breathe life into the mobile, which dance and change its shape randomly in the unexpected way. Calder's work was different from the other artists' works at that time as he refused to use any mechanical contraptions in his work but resorted to the natural energy instead. In a way, his work is the predecessor of the light art, which also seek to interact with the natural world.

Techniques involved in Kinetic art concerned mainly on the movement which is generally perceived as divided in two types ; electrical-powered movement, natural-powered movement. The technique also impact the choice of material. For example, Alexander Calder, one of the pioneers in Kinetic art, used to work with motorized or

hand-cranked mechanisms at first and later shifted his focus to the movement generated by passing air currents. His material selection thus response to the technical requirement of each work. Early works were made of glass or pottery, while the later works were made of hand-shaped aluminum for its much lighter weight.

Nevertheless, some technique is hard to be defined as “motorized” or “natural-powered”, and can become the concept of the work itself, such as the technique found in the work of Daniel Wurtzel and David C. Roy., discussed in this section.

Figure 13. Flag Waver, by Daniel Wurtzel, 2016.

From “Flag Waver”, by Daniel Wurtzel, 2019, http://www.danielwurtzel.com/index.cfm

Copyright 2019 danielwurtzel.com

Daniel Wurtzel’s “Flag Waver” (in figure 13) consisted of a flag waver machine, which is a small axle connected to a spherical joint and the control system that allow the axle to be waived in multi directions. A large piece of lightweight fabric is then attached to the axle, which is installed in the room set up with some airflow system. So when the axle wave, the fabric would “dance” like a “ribbon dancers of rhythmic gymnastics”. - Wurtzel, 2016. Thus, it could be said that the technique in this sculpture is a combination of a mechanical movement of the flag waver machine, and the natural

movement of the fabric in the wind, resulting in the interesting dance of the two techniques together.

Figure 14. "Duality", by David C. Roy, 2017.
From "Duality", by David C. Roy, 2017, http://www.woodthatworks.com/kinetic-sculptures/duality Copyright 2017 woodthatworks.com

David C. Roy studied Physics, Engineering, and Chemistry during college to fulfill his curiosity, and the combination of disciplines later gave birth to his intuitive understanding of motion and mechanics. "Duality" - Roy, 2017 in figure 14 is an example of his kinetic wooden sculpture which is solely powered by the energy released from a spring. Therefore this mechanical movement required no motor nor battery, and could also be said as "natural" movement. The only requirement is that there must be someone who wind the springs, then let the sculpture move and constantly generate new mesmerizing patterns when each layers of wood overlap each other.

In conclusion, the technique of Kinetic art and material choice would depend heavily on each other. In other words, the artists would consider the form of the work of art that would be created, then imagine the movement that would require particular mechanism such as joint, twisting, swinging, or changing of directions. Then the technique will be the solution to move the work according to the desired concept. The material choice could also be changed constantly in order to find the most suitable material which could express the concept and move according to the artist's

imagination. The wind-powered sculpture requires lightweight material or the form which could pick up the wind enough to initiate the movement. But anyway, the lightweight material would be the primary choice. And lastly the technique of the mechanism would respond to the artists intention and designate the movement as desired.

"Visual illusions can provide evidence of object knowledge and working rules for vision, but only when the phenomena are explained and classified."

- Knowledge in perception and illusion - ,Richard L. Gregory (1997)

A unique aspect of the Kinetic art is the dynamic perception which might generate hypnotic effect and visual illusion in some case. As the sculpture move, it would constantly bring up the new image, that if carefully designed, could be phenomenal. This section would discuss the perception and visual illusion specially found in the work of David C. Roy, the hypnotic pendulum display, and Peter Kourtz.

Figure 15. "Déjà Vu", by Devid C. Roy, 2018.

From "Déjà Vu", by David C. Roy, 2018, http://www.woodthatworks.com/kinetic-sculptures/deja-vu Copyright 2018 woodthatworks.com

Roy intended to generate the feeling of Déjà Vu, which he defined as *"what you refer "This reminds me of something" or "I think I've seen something like this before"*. The hypnotic optical illusion was achieved by combining 15 wheels with different patterns which rotated slowly on the opposite direction. The speed would be shifted sometimes so that the patterns would seems to "pulse" in the different rhythm. This kind of effect can also be found in Roy's other works, as he has been experimenting with various patterns for many years.

2.3 The significance of kinetics art in society

2.3.1 Kinetic Art and Wind

Works of art which involve the wind are more likely to be created by artists who have some degree of knowledge in engineering or physical balance. This section explore the works of George Rickey and George Sherwood.

Figure 16. George Rickey, Crucifera III, 1964. Medium stainless steel. Size h: 63.5 x w: 172.72 x d: 60.96 cm.

From "George Rickey", by Marc Zaref, 2018, http://www.artnet.com/usernet/awc/awc_workdetail.asp?aid=425933959&gid=425933959&cid=244827&wid=426192644u Copyright 2018 Artnet Worldwide Corporation

Crucifera III, the sculpture in figure 16 is a result of a careful balance on the axle fixed on a base, with the shape that expand horizontally rather than

vertically. The weight was balanced by the metal pendulum designed as cube in order to blend harmoniously with the thin stainless steel squares, which could spin just by a gentle touch of the wind. The cubes and squares were hanged together on the unstable axle, which gave the gentle and slow movement that resembles the willowy tree in a wind with the sparkling reflection from the glossy material.

George Rickey stated that *"Since the design of the movement is paramount, shape, for me, should have no significance."* , therefore it seems like he gave higher priority to the movement rather than the pleasing appearance, as the beautiful appearance must be the result from a beautiful movement. He further said that "*Technology is not art but every art has its technology... I do not develop technology for its own sake or to cause wonder, only in response to my felt need."* Thus, he did not attempt to find the technology to be used with his work, but it is a technology of its own when new things were found every time he created a new work. However, discovery is merely the first step of art, as he said that *"In art discovery is not enough. Pioneering in a new idiom, with new material, even with a new aesthetic (or a non-aesthetic) does not make it art, it makes it pioneering."* - G.W. Rickey, 1963

Figure 17. Memory of Water, by George Sherwood, 2014.

From "George Sherwood | Memory of Water, 2014", by Courtesy Shelburne Museum, 2016, https://thetakemagazine.com/sculpture-in-motion/ Copyright 2016 The Take Magazine

This sculpture in figure 17 is a part of an exhibition “Waves and Particles”, which displayed six kinetic sculptures by an American artist, George Sherwood. It was created by stainless steel, shaped in forms of hollow tubes assembled into an incomplete sphere. Inside the sphere, there are three mirrors installed and rotated by a hidden motor. So when the mirrors rotate, the reflection of light also move along the sphere’s surface. Sherwood’s intention was to display the connection in nature, as he said that *“Each sculpture is a three-dimensional painting of shifting light, drawing all the colors of the environment, pulling down the sky, drawing up the earth and gathering everything in between,”*. - Sherwood, quoted by Tory Paxson, 2015

Figure 18. “Flock of Birds”, by George Sherwood.

From “Flock of Birds 2015”, by George Sherwood Sculpture Studio, 2017, https://www.georgesherwood.com/outdoor-sculpture Copyright 2017 GeorgeSherwoodSculpture

"Flock of Birds", in figure 18, is another mesmerizing Kinetic Sculpture by Sherwood. It was inspired by the artist's interest in the dynamic relationships of objects in motion. He intended to *"explores the qualities of light and playful choreography of an organized grouping of rapid, small movements within a larger, slower movement."* - Sherwood, 2000. Each "bird" was constructed by folded stainless steel sheet, hung in a steel frame, which was a part of a larger square frame placed on top of a column that could be rotated by the wind. The result resembles a flock of birds, which each individual bird fidget or move independently but still head towards same direction with the whole flock.

2.3.2 Kinetic Art and Water

Kinetic Art with water requires some knowledge about the characteristics of water and the imagination in utilizing those characteristics for the unique artistic effect desired. Discussed here in this sections are the examples of Kinetic Art with water by Susumu Shingu, Phil Price, David Černý, and Pol Bury.

Figure 19. "Water Tree", by Susumu Shingu, 1992.

From "Water Tree, Astral Statue

(Aono Dam Park, Sanda, Hyogo, Japan)", by Susumu Shingu, 2019, https://susumushingu.com/en/work.shtml Copyright 2019 Susumu Shingu

This sculpture “Water Tree”, by Susumu Shingu (1992) was built at Aono Dam Park, Sanda, Hyogo, in Japan. The water jets out from the tubes into the air, falling in parabolic lines. As the tubes rotate in reaction to the jets of water, the water draws complex curvilinear orbits in the air. However, the actual motion of curved lines is much more complex because it is three-dimensional and there is always the influence of wind and changes in water pressure. The mechanism simply utilize the water nozzles and allow them to flick around in various directions and thus maximizing the usage of water pressure power. Here it shows that collective body of water becomes energy when it moves. Water could also refracts, reflect, and diffuses light. As water could be found in the air, it circulates through the atmosphere and serves as the foundation of life.

Figure 20. “Dodo”, by Phil Price, 2009.

From “2009 Flinders, Victoria, Australia Height - 5m”, by Phil Price, 2004, https://philpricesculpture.com/project/dodo/ Copyright 2004-2019 Phil Price

Phil Price is specialized in design and construction of kinetic sculpture with carbon fiber composite, in order to withstand all extremity of climate and temperature, that it could be installed anywhere. In this breathtaking work, “Dodo”, that resembles a gigantic mysterious creature emerging from the water, The structure consisted of just three pieces; one ‘column’ and two ‘blades’. The design of the blades is quite similar to the wind turbine, but they were installed in the manner that they could move independently of each other. The column’s elegant shape also resembles the neck of a bird, and it could also rotate with the wind. The final result is ever-changing and highly alive. Here, the most obvious characteristic of water is providing reflection to the ever-changing shape.

Figure 21. Metalmorphosis Mirror Fountain by David Černý.
From “Metalmorphosis Mirror Fountain by David Černý”, by Phil Price, 2011,
https://www.thisiscolossal.com/2011/10/metalmorphosis-mirror-fountain-by-david-cerny/
Copyright 2019 Colossal

David Černý’s “Metalmorphosis”, in figure 21, is a kinetic fountain sculpture constructed from stainless steel in the shape of giant head which could be divided in 6 groups of layers. Each layer group could rotate

independently, resulting in the unexpected turning of the “head”. The sculpture reflects the landscape around it and transforms the reflection as it turns and spills out water from the “mouth”. The characteristic of water in this kinetic sculpture is dynamic and responsive to the wind and sunlight in the environment.

Figure 22. Fontaine (1978) by Pol Bury (1922-2005).

From “Fontaine, 1978”, by Don de l'artiste, 2015, https://www.fondation-maeght.com/en/collection/selected-pieces/40/pol-bury Copyright 2015 by Fondation Maeght

“Fontaine”, a kinetic sculpture by Pol Bury in figure 22, is a complex structure of simple metallic tubes which intertwined, connected, and disconnected to allow the water to fall through the series of small holes at the bottom of the tubes. The water and gravity together tilt the tubes back and forth continuously, as Pol Bury said that “They are holding each other by the thread, defying gravitation, leaving an impression of lightness”. The result is the

dreamlike, mystic, and unexplainable quality of the work, which corresponded to the artist's interest in the surrealism.

2.3.3 Kinetic Art and Technology

In this group of Kinetic Art, technology plays important role not only with the kinetic feature, but also the unique essences of the works as intended by the artists. This section will discuss the work of Ralfonso Gschwend, Anthony Howe, Daniel Wurtzel, Matthew Mohr.

Figure 23. Union #3", by Ralfonso Gschwend.

From "Six sculptures", by Ralfonso Gschwend, 2013, https://www.ralfonso.com/latest-news?start=15. Copyright 1991 by Ralfonso

Many factors are considered and interacted in the work of Ralfonso Gschwend, including wind, electricity, light, interaction, movement, and especially time. Gschwend stated that *"You're kind of exploring the fourth dimension – the three dimensions of a sculpture, plus the fourth, which is time and change over time*". And in order to accomplished the desired result,

"mechanics and a bit of engineering" is required so that *"the elements don't hit each other as wind speeds increase*". (Gschwend, 2015) In this work, "Union #3" in figure 23, Gschwend installed the programmable LED at the spherical buds located at each end of the six columns, which serve as the axle for five symmetrical stainless steel blades, designed to rotate separately by the wind while never touched. At the distance, the blades seem to dance like a group of ribbons, but from underneath the image changed as if one walks underneath the water and look up to the ripple surface while seeing one's own reflection simultaneously. At night, the LED lights change colors rhythmically and united all the elements to represent the fourth dimension in the meditative, soothing way.

Figure 24. "Cauldron", by Anthony Howe, 2016.
From "The Rio 2016 Olympic cauldron is surrounded by a huge kinetic sculpture. Photograph is by Filipe Costa", by James Brillon, 2013, https://www.dezeen.com/2016/08/08/rio-2016-cauldron-massive-kinetic-sculpture-anthony-howe/. Copyright 2013 by Dezeen

Anthony Howe designed the Kinetic sculpture "Cauldron", in figure 24, for the opening of Summer Olympics in Rio de Janeiro, Brazil. The sculpture was made from stainless steel, Howe's favorite material for its permanence, shaped

in hundreds of reflective spheres and plates attached on the ring of rotating bars which were motor-powered, in a way *"that I thought was the most like a sun".* - Howe, 2017 As soon as the small cauldron is lit manually, the small but meaningful Olympic fire would be raised up in front of Howe's cauldron which start to rotate, as if the Olympic spark ignite the cauldron and give birth to a new, mesmerizing sun right in front of the audiences. The formal quality of the sculpture and the motored-power movement together serves the intention, which Howe stated that *"I just hope everyone enjoys it and experiences a moment of grace and silence inside themselves…,and wonderment at the joy of being alive and at the Games".* - Howe, 2017

For outdoor installation, the researcher found that most sculptors would work with durable materials. For example, Phil Price's "Protoplasm" (figure 25) consisted of carbon fibre GRP and epoxy glass. Anthony Howe generally works with stainless steel (figure 26). And Patrick Shearn works with mylar, a form of polyester resin used to make heat-resistant plastic films and sheets, which could be used to create a lightweight net as used in "Liquid Shard" (figure 27)

Figure 25. "Protoplasm", by Phil Price, 2001.

From "Protoplasm, Wellington, New Zealand, 2001, 7m", by Phil Price, 2004, https://philpricesculpture.com/project/protoplasm/. Copyright 2004-2019 Phil Price

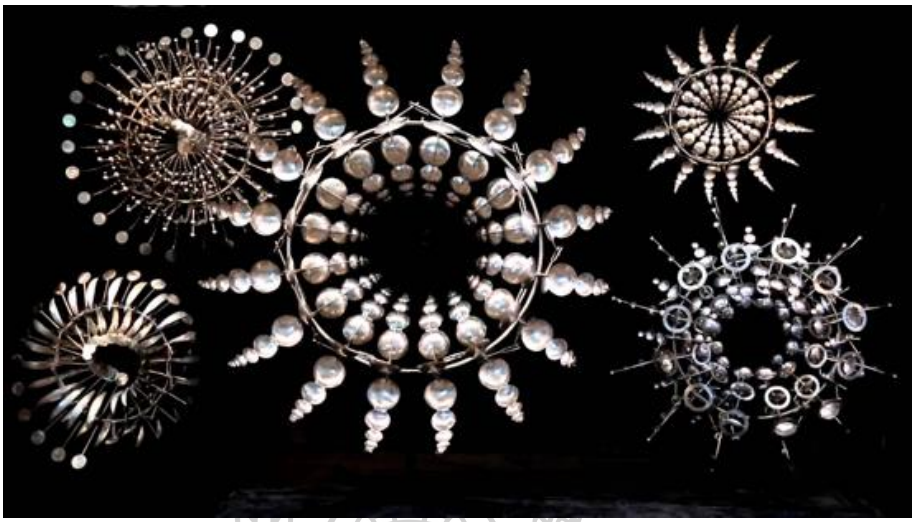

Figure 26. Anthony Howe's works.

From "Anthony Howe", by Anthony Howe, 2019, https://www.howeart.net/new-page-1. Copyright 2019 Howeart

Figure 27. "Liquid Shard", by Patrick Shearn, 2016.

From "patrick shearn's liquid shard glistens above LA's pershing square", by Phil Sanchez, 2019, https://www.designboom.com/art/patrick-shearn-liquid-shard-pershing-square-08-14-2016/. Copyright 2019 Designboom

For indoor installation, the choices of material are wider as the sculptor have fewer concerns about durability and could use both highly or slightly durable material. Therefore, the material selections depend more on the artist's

intention and the desired effects. The examples of material found in this section are Tyvek, paper, lightweight fabric,

Figure 28. "Diffusion Choir", collaboration between Sosolimited, Plebian Design, and Hypersonic, 2016.

From "Diffusion Choir is a kinetic sculpture that hang from the atrium of BioMed Realty", by Liz Stinson, 2016, https://www.wired.com/2016/10/watch-mesmerizing-sculpture-morph-like-flock-birds/. Copyright 2018 Condé Nast

"Duffusion Choir", an indoor origami-like installation in figure 28, was constructed out of 400 pieces of Tyvek, a high-density polyethylene, which can be folded according to the design. Each "bird" can open and close independently in the same manner with an umbrella, while moving together as a part of the "flock", similar to George Sherwood's flock of bird. The difference is that this sculpture is controlled mechanically with software, while Sherwood's work was solely wind-power outdoor installation. Tyvek is a suitable material in this case, as it is durable enough to withstand the UV light that would penetrate the atrium space where the sculpture is installed, yet light and flexible enough to be moved constantly.

Figure 29. Magic Carpet, Daniel Wurtzel, 2009.

From "Magic Carpet", by Daniel Wurtzel, 2019, http://www.danielwurtzel.com/.

Daniel Wurtzel works required lightweight fabric in order to make visible the airflow system he carefully laid out. In this work, Wurtzel stated that he used *"a large sheet of shimmery red fabric"*, which could be seen *"flies untethered in the center of a room, twisting and turning, rising and falling, coiling and unfurling, as it gracefully moves in and out of the vortex at the center of the air system"*. - Wurtzel, 2009

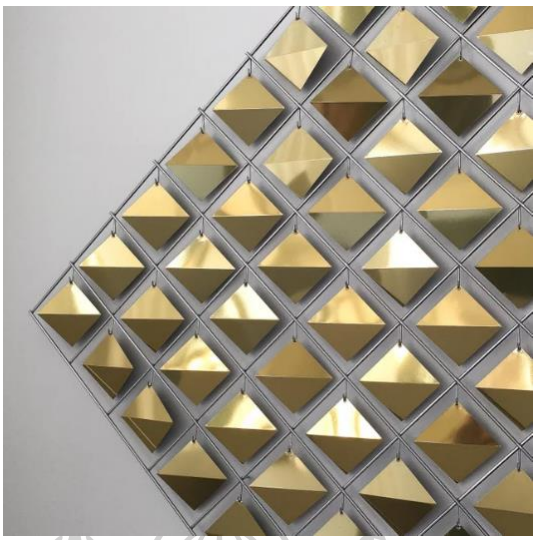

Figure 30. "Brass Diamond", by Curtis Jere, 1984.
From "Curtis Jere brass diamond shaped wall sculpture", by Curtis Jere, 1980, https://www.decaso.com/product/1098911/curtis-jere-brass-diamond-kinetic-wall-sculpture. Copyright 2019 Decaso Inc

Curtis Jere's "Brass Diamond" was made from folded brass elements hanging within a steel frame. As it was intended to be part of the architecture, the material selection resembles the architectural materials with the concern of durability and the luxurious visual effect.

In short, material selection for Kinetic art is no different from material selection for any other type of sculpture or architectural element, that it would depend most on the installation site. For example, although the work might be installed indoor, but if the sunlight could penetrate the room, it might require the material that could respond to the light and yield the expected effects. In the case of outdoor installation, the environment and the climate condition must be concerned, as it would definitely impact the choice of material. However, the choice must also respond to the artist's intention as well. If an artist meant to create the work that require no durability and focus on the decaying of substance, the sculpture could even be created from paper installed to be easily decayed, for example. Thus, it could be said that material selection for Kinetic

Art should follow the concept of the work first, then the concept would lead the priority to other factor by itself.

In summary, during the past decades, the world have witnessed more applications of renewable energy with a level of success, as the rate of usage is continuously increasing. As it could fully respond to the functions in daily life, the usage of renewable energy is now starting to respond to the aesthetic need. The street lamp could be the decorative sculpture for the street while simultaneously absorb the solar energy for further use. Initially, the Kinetic art works were powered by human or electricity. Later, the natural sources of energy such as wind or water are increasingly involved. The work of art might be beneficial for daily life as well as aesthetically pleasing. As the technology is developing, the work would continue to evolve. Many artists utilize technology to enhance the unique essences in their work, such as digital camera and LED monitors which could project the people's face on the work and gave it a publicity. Some works are even commissioned by famous sponsors, which also add the interest to the work. In other words, the works of art are more participatory in the life of people within our society.

In Thailand, most kinetic objects were created not as a sculpture for aesthetic purpose, but rather for a kinetic design for functional use and decoration. Discussed in this section are the examples of the kinetic objects generally found in Thailand, such as the Aeroklas Energy Tree, decorative wind turbine, wind turbine for pumping water, and more.

Figure 31. The Aeroklas Energy Tree. From "The Aeroklas Energy Tree", by Aeroklas, 2012, http://phithan-toyota.com/forums/index.php?topic=28920.0. Copyright 2019 phithan-toyota.com

The Aeroklas Energy Tree was designed to generate electricity from wind power, which flow through the tulip-shape turbine attached with photovoltaic cell. Therefore, the "tree" could generate electricity from both wind power and solar power.

Figure 32. Decorative Windmill.

From "Windmill with Thai local cloth", by TripAdvisor, 2016, https://www.tripadvisor.com/LocationPhotoDirectLink-g2237503-d3860696-i264072226-Jim_Thompson_Farm-Pak_Thong_Chai_Nakhon_Ratchasima_Province.html Copyright 2019 TripAdvisor LLC

Decorative Windmill, this type of wind turbine in figure 32 is mostly used for decorative purpose and could be found in the residential building, garden, or commercial space. The not-so-large turbines are made of various material, such as wood, plastic or even cloth, and generally available for sale at the gardener's shop on the roadside.

Figure 33. Wind Turbine for pumping water.

From "Wind Turbine for pumping water", by Usa Economic Development Co.,Ltd., 2018, Copyright 2018 Usa Economic Development Co.,Ltd.

https://www.ausawindmill.com/product/19357/%E0%B8%81%E0%B8%B1%E0%B8%87%E0%B8%AB%E0%B8%B1%E0%B8%99%E0%B8%A5%E0%B8%A1%E0%B8%AA%E0%B8%B9%E0%B8%9A%E0%B8%99%E0%B9%89%E0%B8%B3)

The wind turbine for pumping water in figure 33 has been researched and developed for over 40 years, so that the turbine could work efficiently and effectively for the agricultural use according to each location's climate and characteristic. The wind would power the pump without using any electricity nor fuel, and could pump water from every water resource including the artesian well of 30 meters depth. A single wind turbine could function for both pumping and irrigation task. It could pick up the wind from all direction, and works well even at the slow wind speed (3 kilometers per hour). The turbine would adjust itself according to the wind speed and automatically stop when the wind speed is too fast or during the storm. The turbine would start working again when the wind speed is back to the safe level, and could endure some degree of natural disaster such as lightening or flood. The wind turbine is also an attractive feature that could become the landmark in each area and beautify the landscape.

Figure 34. Thai Windpump in salt farm.

From "Windpump in salt farm", by Suan Mon Mai, 2019,

http://www.monmai.com/%E0%B8%81%E0%B8%B1%E0%B8%87%E0%B8%AB%E0%B8%B1%E0%B8%99%E0%B8%99%E0%B8%B2%E0%B9%80%E0%B8%81%E0%B8%A5%E0%B8%B7%E0%B8%AD/ Copyright 2019 Suan Mon Mai

Thai Windpumps, the application of wind power to pump water from lower area to the higher area have been found for a long time in Thailand, such as the use of Thai windpumps in the salt farm. Thai windpumps, as seen in picture 34, which resemble the ancient Chinese windmills, serves the application in the rice farm, salt farm, and shrimp farm, in the same way with the European windmills' agricultural application. Thai windpumps are usually constructed of the suitable, cheap, and locally available material, such as canvas or Gedabu mat. And the structure, gutter, and blades are usually constructed from hardwood, which could withstand the salty water and have a longer lifespan. The design consists of 6 blade. When the wind is too strong, three blades can be folded away. Or if the windpump must be stopped, all 6 blades can be folded away.

This type of windmill could be counted as the original villager's wisdom heritage, which could use the wind power to pump water and thus require no electricity. Nevertheless, they are disappearing, and could be extinct in the near future if there is no conservation.

Figure 35. Promotional Inflatable Tube as known as "Air Dancer". From "Air Tiger Doll", by 7Balloon, 2019, http://www.xn----twfs3fc0bwf0juc4dua3fe.com/%E0%B8%95%E0%B8%B8%E0%B9%8A%E0%B8%81%E0%B8%95%E0%B8%B2%E0%B9%82%E0%B8%9A%E0%B8%81%E0%B8%A1%E0%B8%B7%E0%B8%AD%E0%B9%81%E0%B8%A5%E0%B8%B0%E0%B8%95%E0%B8%B8%E0%B9%8A%E0%B8%81%E0%B8%95%E0%B8%B2%E0%B9%82%E0%B8%9A%E0%B8%81.htm Copyright 2019 7Balloon

Promotional Inflatable Tube, as known as "Air Dancer", prior to switching on the fan, the air dancer's hand would be folded down and the wind could not flow through. Then, when the fan underneath is switched on, the air dancer would be fully inflated and the arm would stretched sideway. But when the wind would flow towards the elbow of the air dancer, where there is a hole, the arm would flop up and down as the wind flow out and push on the opposite site. Therefore, it would seems like the arm is waving, while the head and another arm

would stay still, as there is no hole so this part would always be inflated. The whole body could also move together with the arm which move.

Figure 36. Promotional Inflatable Tube as known as "Sky Tube". From "Skytubes", by Winkel, 2018, https://www.springkussenverhuurflakkee.nl/product/skytubes/ Copyright 2018 Springkussenverhuur Flakkee

Promotional Inflatable Tube, as known as "Sky Tube", the principle behind the sky tube's movement is similar to the air dancer. The only difference is the shape, which is a long tube with a hole on the top. When the fan underneath is switched on, the wind would flow up and inflate the tube, but when the wind flow out of the tube, it would be flat again, but the direction can't be controlled. This cycle of inflate a deflate would continue and generate a lively image and attract the eyes, as the tube would inflate and fold randomly.

3. Photovoltaic

3.1 Define what is photovoltaic

Among the other type of renewable energy, Photovoltaic system might receive the most attention, as there is an obvious advantage of simple design which could be constructed as stand-alone system and require very little maintenance. Photovoltaic system has been applied as the power source for many instruments, ranging from calculators, watches, water pumping, remote

buildings, communications, satellites and space vehicles, and even megawatt-scale power plants. (Messenger, 2016). The systems prove to be versatile and has so much potential application. Hence, this section will discuss the innovative application of Photovoltaic system, both in the function for daily life and in art.

3.2 Application for daily use

Apart from the apparent application of generating electricity, the photovoltaic system is being applied in the increasingly innovative way. The examples discussed in this section consisted of the street facility, solar highway, and floating solar platform, as they represent the most recent trends of attempting to increase the presence of photovoltaic system everywhere and maximize the harvest of solar energy.

Figure 37. "Curve" by Spotlight Solar 2016.
From "The solar tree", by Spotlight Solar, 2019,
https://spotlightsolar.com/whatsnew/2016/12/7/reading-riting-and-renewable Copyright 2010 - 2019 Spotlight Solar Inc.

"Curve", in figure 37, is an commercial street facility designed to combined multi functions such as lighting spot at night, seating under the 120 square feet of shade of photovoltaic panel, table with power outlets, and brand message communicator. This structure is just one of the products by Spotlight Solar, whose intention of its creator was to "*make architectural solar structures*

designed to be visible and signal environmental stewardship", which would help people remember the corporate who provide this facility in their place in the meaningful way. In launching "Curve" commercially, Spotlight Solar encouraging the adoption of system among the major corporates and directly bring the presence of photovoltaic system closer to people's life.

Figure 38. Jinan Stretch, China, designed by Zhang Hongchao et al. (2017). From "The two lanes of solar panels.", by Qilai Shen, 2019, https://www.bloomberg.com/news/features/2018-04-11/the-solar-highway-that-can-recharge-electric-cars-on-the-move Copyright 2019 Bloomberg

The Chinese government is attempting to increase the presence of Photovoltaic system in China as well. The Jinan stretch, in figure 38, is one of the pioneer project to find the way to utilize the space of expressway available throughout the vast country to harvest the solar energy. In this 1 km section of expressway located in Jinan, the capital of the northeastern Shandong province, photovoltaic panels is installed between the transparent concrete top and the insulation bottom, for the approximate area of 5,875 square metres (63,200 sq ft). It is expected that this section of expressway could generate 1 million kWH of electricity each year, which will power the street lights and the built-in snow-

melting system on the road, as well as supply power for electric vehicles' charging station.

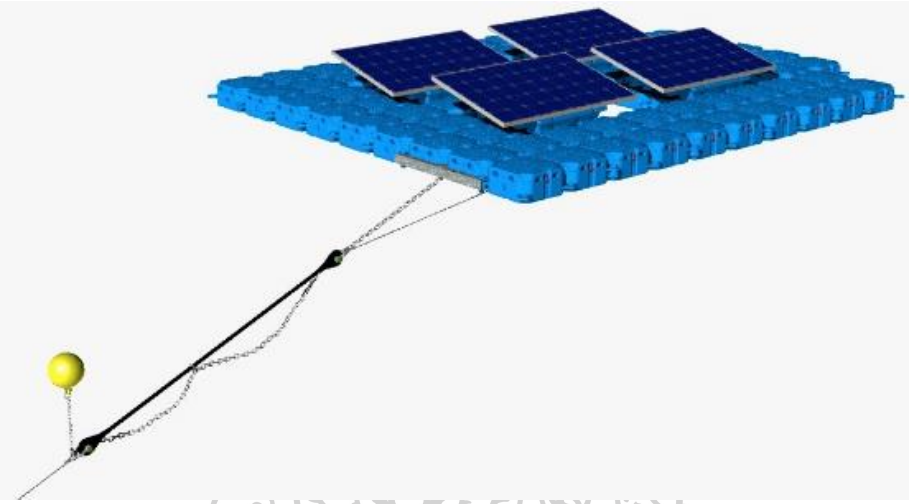

Figure 39. AqvaFloat system 2018.

From "The system is based on an established pontoon system used for larger infrastructure.", by John Parnell, 2018, https://www.pv-tech.org/news/uk-start-up-eyes-global-floating-solar-market Copyright 2019 Solar Media

The scarcity of land is the major obstruction for the adoption of photovoltaic system in many countries, where the suitable land to install the photovoltaic system is hard to find. AqvaFloat is one of the startup company from United Kingdom who attempt to solve this problem by designing a photovoltaic system which could be floated on the water in figure 39. Between each row of photovoltaic panel, there would be 50 cm wide walkways for human access to the panel, in case any maintenance is required. They nick-named this system "floatovoltaics", and planning to expand towards the project in USA, Caribbean, and Asia region, where the land price is high, so *"that's where utilizing water bodies begins to make sense"* - Simon Piggot, Founder and MD, AqvaFloat, quoted by John Parnell, 2018. If this project become popular, it might be normal to see more floating solar farms emerge in the public waterways, and photovoltaic system might be able to replace the current energy source at the higher proportion.

3.3 Renewable energy application in art practices

The application of renewable energy in art is emerging, although in very few places, during the last two decades. For example, “SOH19 States of Nature”, the work of Alex Vermeulen (2006) in figure 40, incorporate the photovoltaic panels as the part of installation, and use the power to lift a levitating Buddha sculpture using the sun's energy.

Figure 40. “SOH19 States of Nature”, by Alex Vermeulen, 2006. From “SOH19.”, by Ana Lisa, 2012, https://inhabitat.com/alex-vermeulens-floating-solar-panels-installation-in-eindhoven-is-designed-to-lift-a-levitating-buddha/ Copyright 2019 Inhabitat

The photovoltaic panels were installed on the black eggs and generate the solar power that is converted into a magnetic field. When the magnetic field is present, a Buddha figure within a transparent cylinder would levitate and move up and down in the middle of the pond. The floating eggs attached with the photovoltaic panels could be drifted and turned by the wind and water. Thus, the project is a poetic combination of the art, technology, and the forces of nature which manifest in the public space.

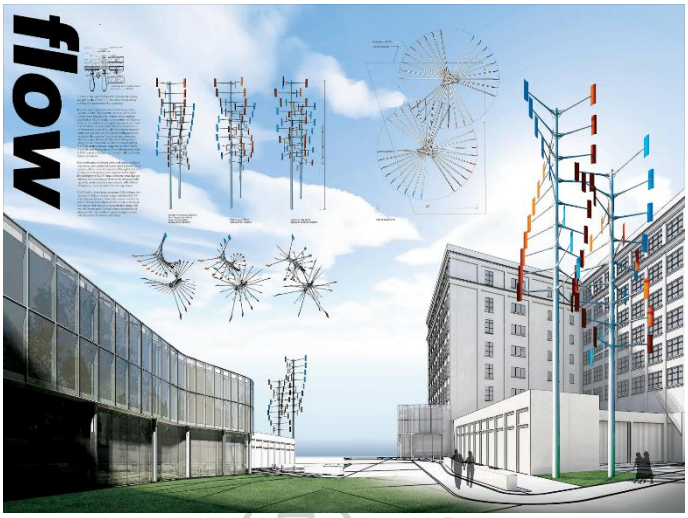

Figure 41. "FLOW", by Avoid Obvious Architects studio, 2015. From "Gillette – Razor Turbine.", by Avoid Obvious Architects, 2018, https://aoarchitect.us/2015/08/flow-razor-turbine/ Copyright 2008-2018 Avoid Obvious Architects

Apart from the solar energy, the wind power is also gaining momentum in the art and design field. One example is "FLOW", in figure 41, which is a design of two vertical-axis wind turbine that won the 3rd place in the Gillete Landmark Design Competition in 2015. Each of the two turbines consisted of nine mini sets of blades, which the design team intended for it to "retains the proportion of Gillette's Razor, as if the blade is constantly shaving the sky". As the blades turn, the double spiral patterns emerge and would be constantly powered by the wind throughout the year.

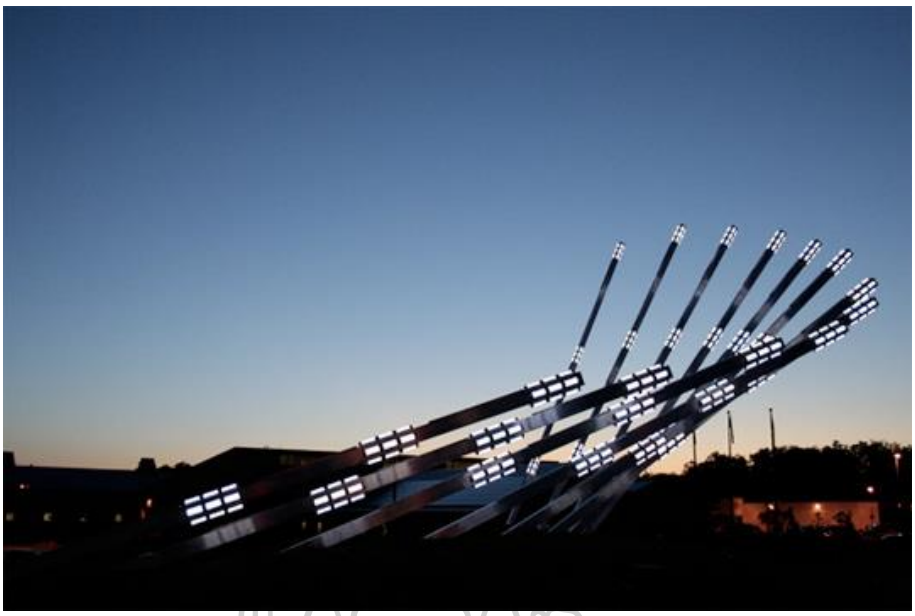

Figure 42. "Solar Collector" by Gorbet Design, 2008.
From "Solar Collector's 12 shafts rise from a grassy hilltop at the Waterloo Regional Operations Centre.", by Gorbet Design, 2008, https://aoarchitect.us/2015/08/flow-razor-turbine/ Copyright 2008 Gorbet Design Inc.

In Canada, there is an interactive installation called "Solar Collector", in figure 42, by Gorbet Design, which collect the solar energy during the day and use the energy to display a light show at night, which can be interacted via website. The sculpture itself is installed in the way that is related to the angles of the sun throughout the year, including the winter solstice and summer solstice.

In conclusion, the renewable energy such as solar energy, wind energy, and water energy are all involving the daily life enormously and increasingly, as the source of energy is available by the natural phenomena. Whether we will use it or not, it would not result in the additional cost, and will always be available. We only need to build the opportunity to grasp "what is in the air" and make use of it. Therefore, the idea of maximizing the renewable energy usage in every possible way should be the appropriate act for the human race.

4. The relationship of Kinetic arts sculpture with the photovoltaic in producing renewable energy

The experiment in this topic would mainly concern about the form of sculpture, in order to find the appropriate guideline for the application of mechanical technique with Kinetic art. The form must be beautiful and suitable for the installation of Photovoltaic cell, that it could be beneficial functionally and aesthetically.

According to the literature review, the possible site for kinetic art could be both indoor or outdoor. Some works require small space, while the other require wider space, depending on the major factor of how the movement is powered. For example, if the movement is electrically motorized, the sculpture might be limited to the indoor site only, as it must avoid moisture and rain which could disrupt the wire. But if the movement is naturally powered, the sculpture would need to be installed outdoor, or indoor where the wind could flow, etc.

Thus, each artist must understand one's own specialization, so that it would be easier to dictate the site where the Kinetic art would be installed. On the other hand, the site would dictate the working process of the artist, as the context of the site must be studied first. The pros and cons of the site should be utilize in the design as much as possible. Therefore, the understanding of site would result in the design which could blend harmoniously and specifically to the site.

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4.1 From arts perspective / dimension

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Figure 43. "Energetic Energies", by Akihasa Hirata, 2013.
From "Energetic Energies – Akihisa Hirata's 30-meter energy landscape.", by Johny, 2008, http://www.spoon-tamago.com/2013/04/03/milano-salone-2013-energetic-energies-by-akihisa-hirata/ Copyright 2018 SPOON & TAMAGO UP

"Energetic Energies" is an installation by Akihasa Hirata, for Panasonic's participation in the Milan Exhibition, 2013. It comprised of individual solar cells arranged in random patterns in the manner of the leafs on a tree, as a tree has been evolving to catch sunlight for its survival. The result is the organic structure of photovoltaic cells which could be installed anywhere in an entire town in order to create a "sustainable smart town". This installation demonstrates an idea that the city does not have to be the opposition of the nature and could be the source

of renewable energy itself. As Hirata stated that "*What if a city is a hill covered with solar panels like foliage, alive with twittering birds and gentle breezes? Here we present a new look at an energy park of the future with miniature panels*." - Akihasa Hirata, 2013.

As the kinetic art with solar energy involves technology and could be costly to build, the kinetic art in this group are mostly corporate-sponsored and some of them can be mass-replicated. Described below are the examples of the kinetic art which involve solar energy. Some of them consisted of actual movement, while some of them require light or sound to generate the illusion of movement.

Figure 44. "Solar Tree", by Ross Lovegrove.

From Ross Lovegrove Solar Trees.", by Inhabitat Staff, 2007, https://inhabitat.com/ross-lovegrove-solar-trees-take-to-the-streets-of-vienna/ross-lovegrove-solar-tree-solar-powered-urban-lighting-sustainable-art-project-mak-museum-in-vienna-the-solar-tree-ross-lovegrove-solar-lighting-solar-powered-street-lamp/ Copyright 2019 Inhabitat

This urban sculpture which resembles a tree with curve stems instead of regular branches and circular collections of photovoltaic cells instead of leafs,

was created by Ross Lovegrove and manufactured by Artemide, a manufacturer of design products in Italy. This work was called *“the successful marriage of the most advanced technology and the aesthetic requirements of the urban environment by way of renewable energy”* by the Artemide, as the sculpture does not only act as a landmark but also light the plaza of Milan with solar energy. Lovegrove’s solar tree consisted of steel pipes, which support a light bubble connected to 38 solar cells of 38 watt and a hidden 12v battery system. The 1W LED lights are installed at the tip of each stem. The batteries would be charged during daytime, and the LEDs would be switched on automatically at dusk. Lovegrove stated that, *"Solar Tree represents the DNA of our time and it also shows it is possible to create beautiful things using the most advanced technology."*

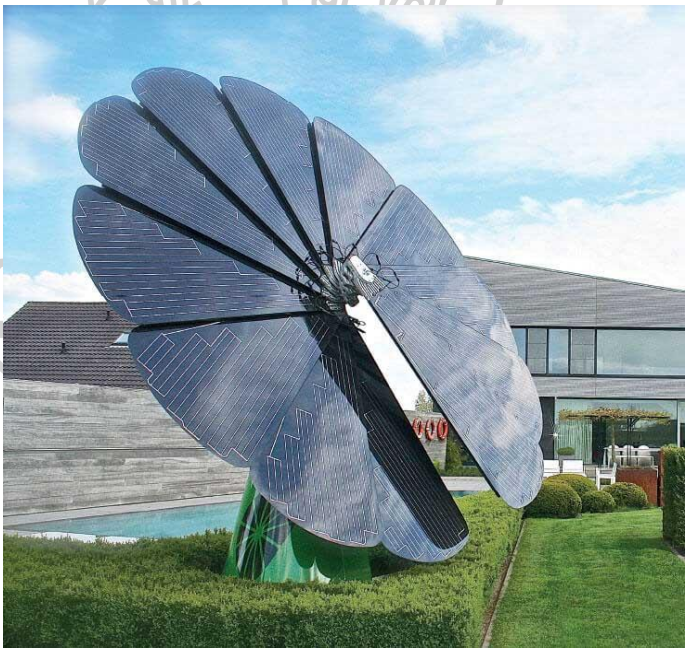


Figure 45. “Smart Flower”, by Alex Swatek et al, 2010.

From “Smartflower” by Digital technology, products & trends, 2019, https://www.specifile.co.za/news/digital-technology-products-and-trends/solar-panel-follows-sun-generates-40-percent-more-energy/ Copyright 2019 New Media, a division of Media24

Swatek et al noticed the problem that “Generally, green tech is not renowned for its correlation with design”, as the solar panels are usually static and not very pleasing to look at and generally required days of installation on the roof. Therefore, they designed “Smart Flower”, a solar power system which could be easily transported and adjustable in the form that resembles a flower. The “petals” would automatically unfold in the morning and positioned by a built-in GPS-based dual axis tracker to follow the path of the sun and maintain the optimal angle all day. The petals could be folded back at night or in the windy day to protect the system.

Figure 46. Sonic Bloom, by Dan Corson, 2013.

From “SONIC BLOOM, 2013, Pacific Science Center, Seattle Center, Seattle WA.” by Dan Corson, 2013, http://dancorson.com/sonic-bloom Copyright 1989-2019 Dan Corson

“Sonic Bloom” was commissioned by the Pacific Science Center and Seattle City Light’s Green Up Program. The sculptor, Dan Corson designed a

group of five gigantic flowers of 40' height and 20' width, each installed with 46 photovoltaic cells so they could absorb the solar energy which would power the patterned LED lighting and illuminate the sculpture at night. Moreover, each flower has multiple sensors which could be triggered by people's movement. When any motion sensor is activated, each flower would set off distinctive set of notes and would "sing" in an interactive chorus. The public could "play" with this work by engaging with it and conducting music together. Thus, the kinetic aspect of this sculpture does not only rely on the visual dimension but also the sonic landscape triggered by people.

4.2 From economy and education purposes

Figure 47. LG Puricare Commercial featuring Daniel Wurtzel's Kinetic work. From "LG PuriCare™ air purifier" by LG Electronics, 2018, https://www.lg.com/ae/press-release/world-renowned-air-sculpture-artist-daniel-wurtzel-collaborates-with-lg-puricare-air-purifier Copyright 2009-2019 LG Electronics

Daniel Wurtzel generally works with lightweight fabrics, lighting, and airflow in order to create Kinetic Art, by *"imposing an order on the chaotic air flow systems".* He would first design the invisible airflow in the room by carefully placing the airflow generators and create a system of airflow where he could place a piece of fabric to dance freely in it. In this work, he collaborated with LG

by using their air purifiers which could rotate and blow the strong air flow to work with a large piece of fabric, which was *"the largest piece of fabric that I have ever worked with before*" - Wurtzel, 2017. Although this work was commissioned for commercial usage, it is undeniable that without the newly available technology, this Kinetic work might not be possible at all. The result of lighting and free-flow movement of the fabric resembles an elusive creature growing and floating in the space.

Figure 48. "As we are", by Matthew Mohr, 2017.
From "As we are", by Steve Dent, 2017, https://www.engadget.com/2017/12/18/as-we-are-public-selfie-art-the-big-picture/ Copyright 2009-2019 LG Electronics

At first glance, this 14-foot interactive sculpture in figure 48 might look like David Černý's "Metalmorphosis" without water jet. However, it was not designed to reflect the environment through the glossy surface but rather the monitors wrapped around the pieces. The most important feature of this Kinetic Art work is the interaction with its audiences, by projecting the faces of the city's residents and visitors on the bands of LED screens. The faces were kept in a

database, which could be added indefinitely when anyone walks inside the small studio located behind the “head” and let the computer photographs their faces. This interactive feature was sensational for the audiences, when they saw the sculpture’s face changed into different people including their own face.

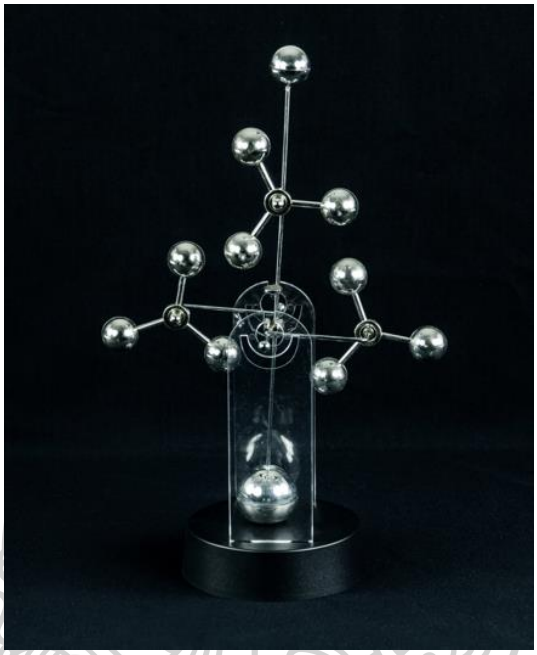


Figure 49.“Asterism”, a pendulum display.
From “Asterism”, by Scientificsonline, 2019,
https://www.scientificsonline.com/product/asterism. Copyright 2019 Scientifics Direct, Inc.

The pendulum display is a popular desktop decoration for many and could be easily purchased nowadays, as it constantly moved by the electromagnet force and gives the feeling of everlasting movement. The movement from the major axle and the sub axles swinging back and forth could give the hypnotic effect and the illusion of perpetual movement, even if the pendulum would eventually slow down and stop when the battery runs out.

5. Summary

According to the literature review, the researcher could synthesis the following issues, which would be the framework for further design.

The trends found from literature review

1. Renewable Energy : Photovoltaic system

From the literature, it is evident that the renewable energy becomes increasingly relevant in life, especially the Photovoltaic system, which is the renewable energy with so much potential applications in daily life. There is the global attempt to replace the existing electricity production which is exhausting the world's natural resource with Photovoltaic system.

2. Designing Public Facilities with Photovoltaic System

There is also the expanding trend of designing public facilities with Photovoltaic system. In some countries, the street lamps are designed to be powered by solar energy while function as a decorative feature. The facilities would respond to the basic need of each society and simultaneously be the beautiful object for encountering. The structure incorporated with photovoltaic system could generate power for daily-life usage and could also be viewed as a sculpture installed on the street as well.

3. Kinetic Art

The charms of Kinetic art is that it always provoke the viewer to question on how it could move. Some motorized movement required electricity, while some could be moved by the wind available in the garden where the sculpture is installed, such as the wind turbine, or fabrics which could float above the airflow, or even the fountain which could be moved by the water power. The technique of movement generation varied according to the unique characteristic of each artist. Thus, each work of Kinetic art has its own unusual and different beauty.

4. Incorporating the Renewable Energy in Art and Design

The work of art or design which incorporate the photovoltaic cell were mostly functional design, that focused on the utility rather than the aesthetic dimension. The power generated would be used in daily life, with very few application with the work of

art itself. In some case, the photovoltaic cell was incorporated as the compositional element in the installation. Moreover, it was found that most Kinetic art are wind-powered, with some works which focus on utilizing the balance in the work to create the fulcrum which was shifted to one side, resulting in the easier movement with small amount of driven force applied.

Chapter 3
RESEARCH METHODOLOGY

This chapter is about the qualitative experiment in developing the kinetic art, divided into two sections include 1) the experiment with photovoltaic cell in order to find the suitable surface planar and the direction for sunlight exposure, which will be used in the development related to the photovoltaic cell that will be incorporated with the sculpture, and 2) the experiment with the sculptural form design, in order to find the appropriate design direction for the actual application of the mechanical technique is sculptural creation. Both section have procedures of experiment to pay attention in every steps.

PHASE I : Experiment of the sculptural form design.

The experiment was divided in 4 sub-phases as follow.

1. The adjustment of the photovoltaic cell.
2. The adjustment of the planar surface from geometric form.
3. The structural modeling from geometric form.
4. The construction from module.

1. The adjustment of the photovoltaic cell.

Photovoltaic cell comes in a standard size of 156 square millimeters, which is approximately 6 inches long and 6 inches wide. And in order to experiment in the adjustment of the photovoltaic cell shape for various application with the sculpture surface, the researcher cut the photovoltaic cell by cutter and glass-cutter, and found no significant difference. By far, the most prevalent bulk material for solar cells is crystalline silicon (c-Si), also known as "solar grade silicon". Therefore, when it is cut, the cell would crack into small fragment. Afterwards, the surface was coated with resin solution in order to protect it from collision, water, or moisture.

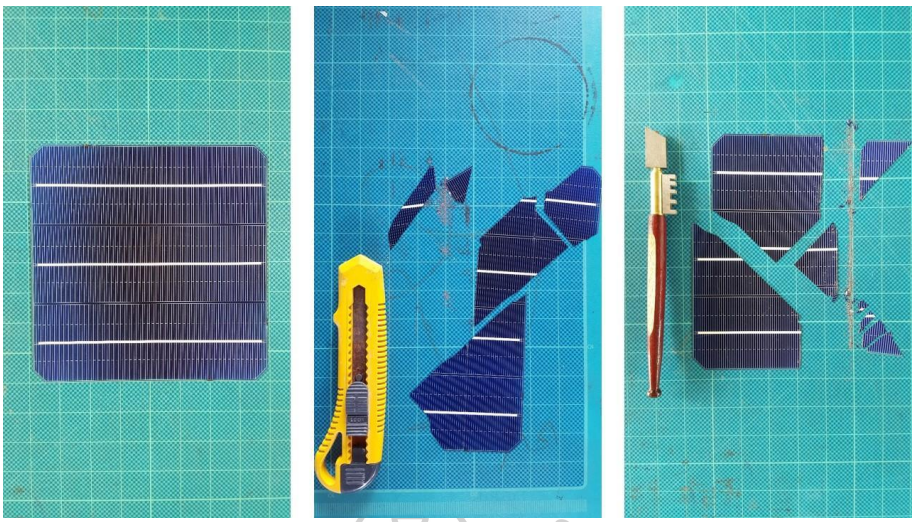


Figure 50. Experiment in cutting the photovoltaic cell with different tools. By Researcher.

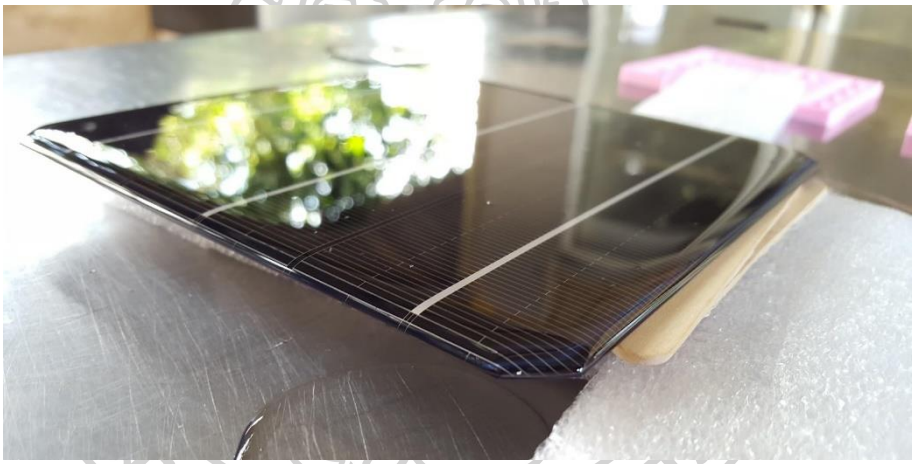


Figure 51. Coating the photovoltaic cell with resin to prevent damage. By Researcher.

In order to get the neater cut, the researcher tried firing the laser beam and cut the cell in sections of geometric form. Afterwards, the cell is coated by thermal plastic in order to protect it against moisture and cracking. However, since the thermal plastic is flexible, when it is bended too far, the photovoltaic cell would crack inside and the electricity would not be transmitted.

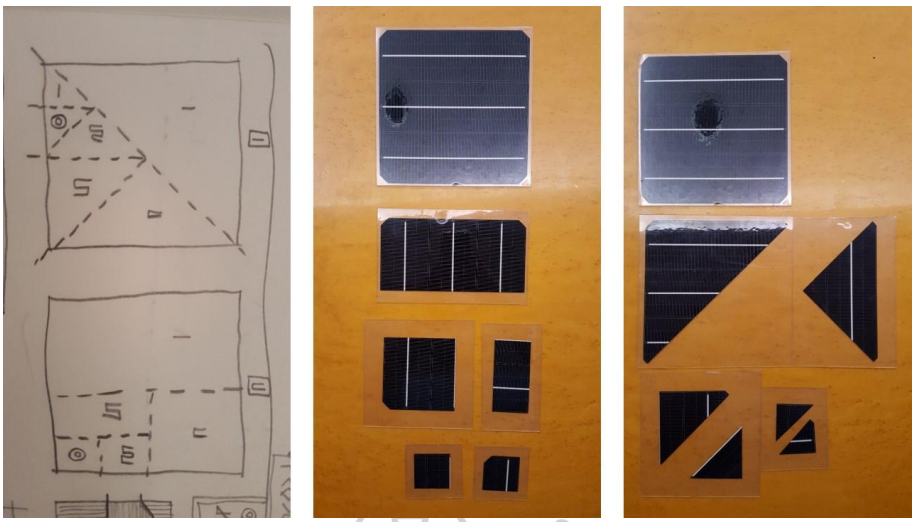


Figure 52. Sketches of photovoltaic cell cutting into rectangles and triangles. By Researcher.

Results

Cutting the photovoltaic cell into smaller pieces would led to the reduction in the electricity voltage and would later impact the energy calculation. The process is complicated and risky for the damage. After assembling the cell into the photovoltaic panel, it would be harder to identify the damaged cell. Moreover, the resin coating or thermalplastic coating is not as durable as expected. The procedure could lead to the minor problems throughout the use, and could shorten the functional lifespan.

Concept for further revision.

The sculpture should incorporate the standard-size photovoltaic cell manufactured from the qualified factories, which could be bought generally, and focus on the adjustment of the sculptural form in order to reach the harmonious and beautiful blending.

2. The adjustment of the planar surface from geometric form.

The planar surface would be created from the basic geometric forms; i.e. sphere, cylinder, cone, cube, pyramid, and prism. In selecting the forms for this experiment, the researcher set up some criteria. 1) The form should consist of various planar surface, as they would be designed to expose to sunlight from multi-direction. 2)

The form should be easily adjusted in various ways, and could become new forms. 3) The form should be harmonious and could be enjoyed from many directions. 4) The form should be adjustable into modules of simple repetitive shapes assembled together. Afterwards, the researcher selected the various forms according to the criteria, and finally selected the sphere, as it consists of most various directions of the planar surface and could be viewed symmetrically from all direction. Finally, the researcher explored the possibilities of assembling other geometric structures such as triangle, rectangle, pentagon, together into a sphere.

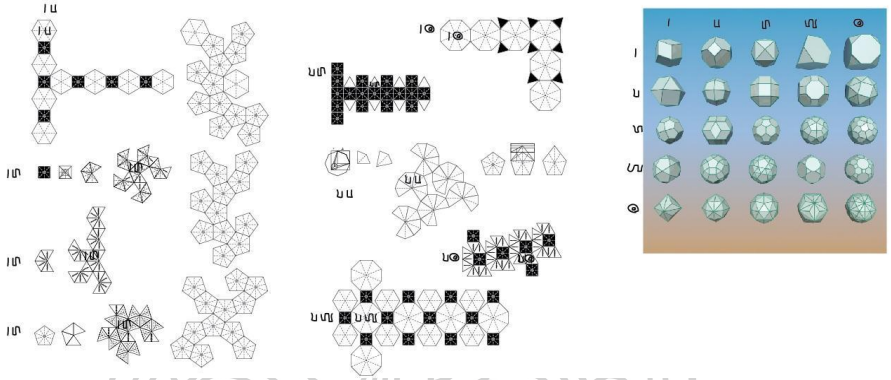


Figure 53. The sketches of various shapes which would be assembled into a sphere. By Researcher.

When assembled, the spheres would have the various appearances as the figure 54.

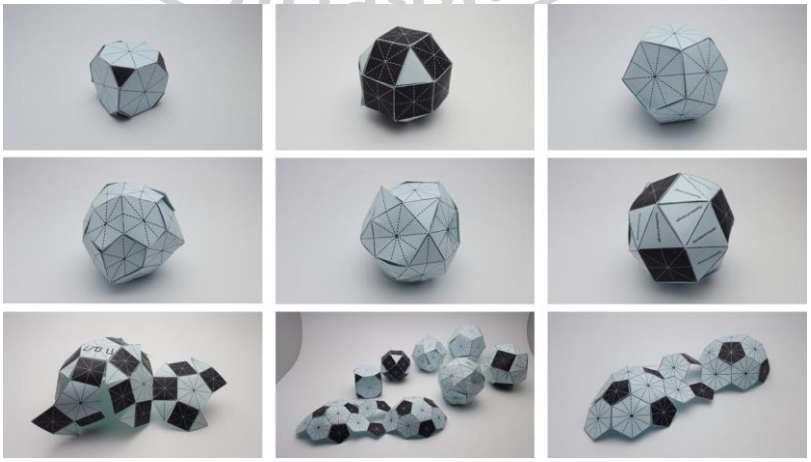


Figure 54. The spheres resulted from assembling the various shapes together. By Researcher.

Figure 55. The most suitable shapes to assemble a sphere are the pentagon and hexagon. By Researcher.

The researcher found that pentagon and hexagon are the most suitable shapes to create a sphere. Afterwards, the researcher design various patterns to decorate the selected shape and create several appearances, which would be later cut into the acrylic panel.

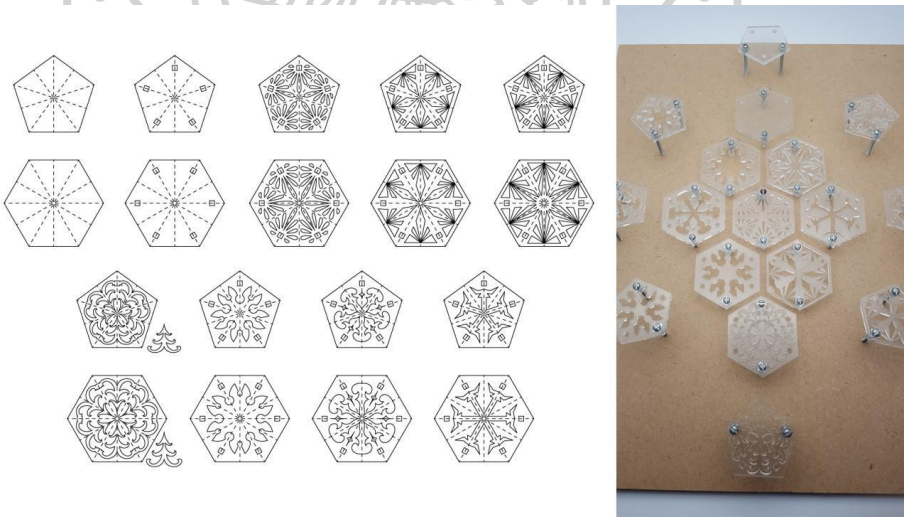


Figure 56. The designed patterns which were cut into the acrylic panel. By Researcher.

The acrylic panels were assembled into the sphere as desired. And in order to add the movement in the work, the researcher added the gear to enable the mechanical movement in some pieces. By moving just one point, the whole work could be movable.

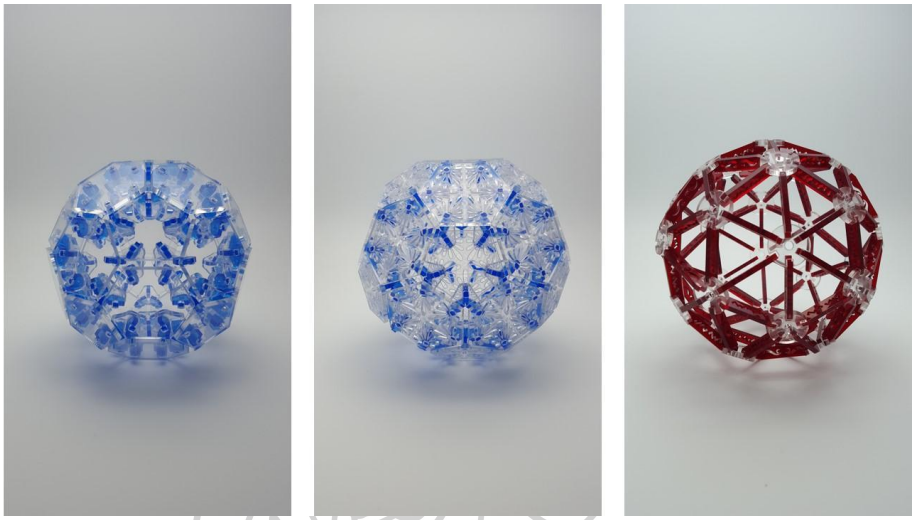


Figure 57. The assembled spheres. By Researcher.

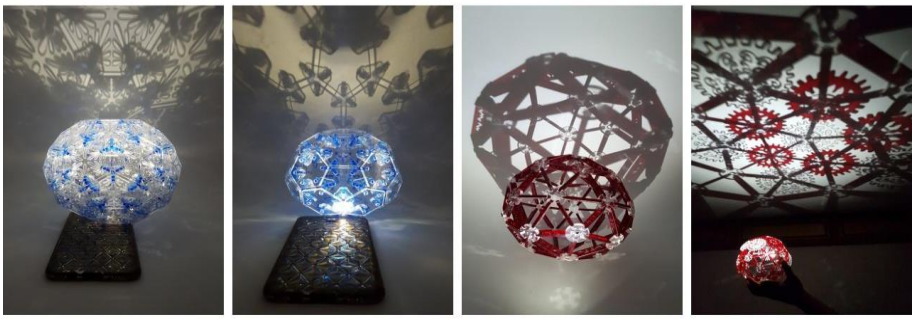


Figure 58. Experiment with lighting and mechanical movement. By Researcher.

This step of experiment led to the design of different forms, such as the oval could be divided into the structural outline and internal structure.

Figure 59. Oval structure. By Researcher.

Experimental works

Acrylic was incorporated in the work in various way. In some piece, the acrylic panel was used as the module to assemble into a sphere as described above. The acrylic was also applied in the creation of other forms, resembling the prototype jigsaw which can be assembled into various shapes according to the imagination. Some pieces were constructed entirely of new forms, with the addition of joints and balls, or weighted by the clear glass ball which gave the harmonious and balanced look with the clear acrylic. These works can be easily moved by the wind.

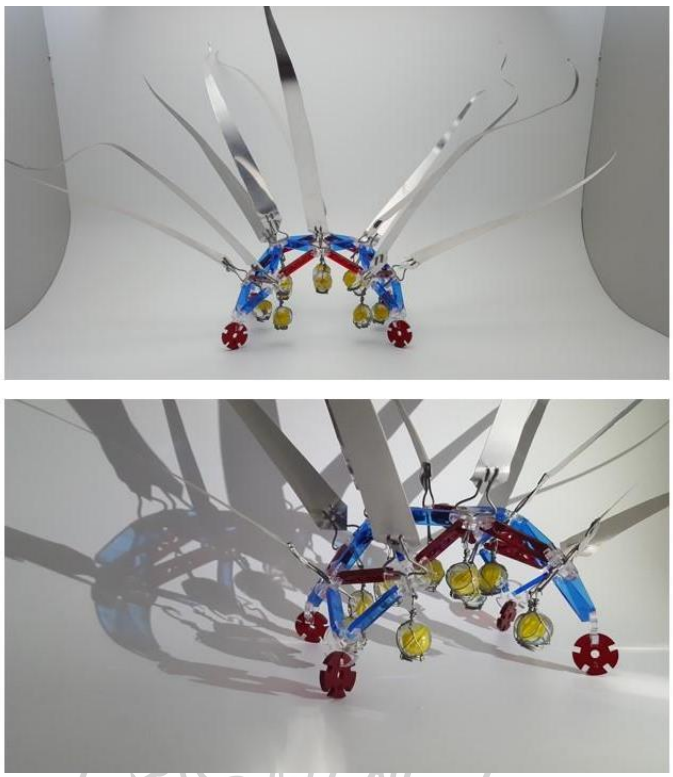


Figure 60. Experiment in acrylic work and the application of the existing structure of sphere. By Researcher.

Figure 61. Experiment in acrylic work with new shapes. By Researcher.

Conclusion of the Kinetic Results

The overall movement was not very effective. The movement was stiff and unsmooth as the researcher focused on the process rather than the technique and did not incorporate much mechanism into the work. The process was also experimental, with the anticipation of the result from the particular process. The expected results were achieved, but it would be complicated when creating the actual work. Some pieces were too complex, with 20 hinges connected together. So if one joint is moved, all other joints would also be moved. So it would require a lot of kinetic power. Moreover, the movement depend mostly on the kinetic energy and the man power in order to initiate the movement. The researcher had not incorporate other type of energy such as clean energy from sunlight, wind, and water in this stage of experiment yet.

Concept for further revision

Modeling from the geometric shape would require the precise calculation. If there is any error in the calculation, the form would be distorted or could not be assembled completely. On the other hand, if the shape could be modeled completely, it would allow mass reproduction. For example, if the laser cutter could be used with the acrylic panel, it could shortened the time of work significantly, while the structure would be firmer. However, the drawback is that there would be the limitation of the appearance, which would be hard to create the free form. Therefore, designing with geometric form should incorporate the capacity to adjust the shape within the work, as if providing the alternative doors. Then the design direction would not be forced to follow just one path and could generate more possibilities.

3. The structural modeling from geometric form.

For this experiment, the structure would be modelled from the geometric from by drawing a diagonal line vertically and horizontally, in order to pinpoint the center of the work, then drawing another diagonal line at 45 degrees, then creating two radius lines of two circles. The smaller circle would be the internal edge, and the larger circle the external edge. Afterwards, eight diamond shapes could be created by drawing the line

to connect each intersection point. Then the external intersections were connected together. This structure would be the starting point in modelling. Afterwards, the axis line can be added, and the radius of both circles can be lengthened or shortened, which would change the appearance of the diamond shape according to figure 63. Moreover, if the third circle is added externally, the diamond shape would be larger and longer, that it could catch the wind better according to figure 64. The edge or the surface of the diamond shape can be decorated, then cut and folded in alternate for all 8 sides. This design resembles the turbine blade, which is movable by the wind. So when the central axle was added, it could move when pick up the wind according to figure 65.

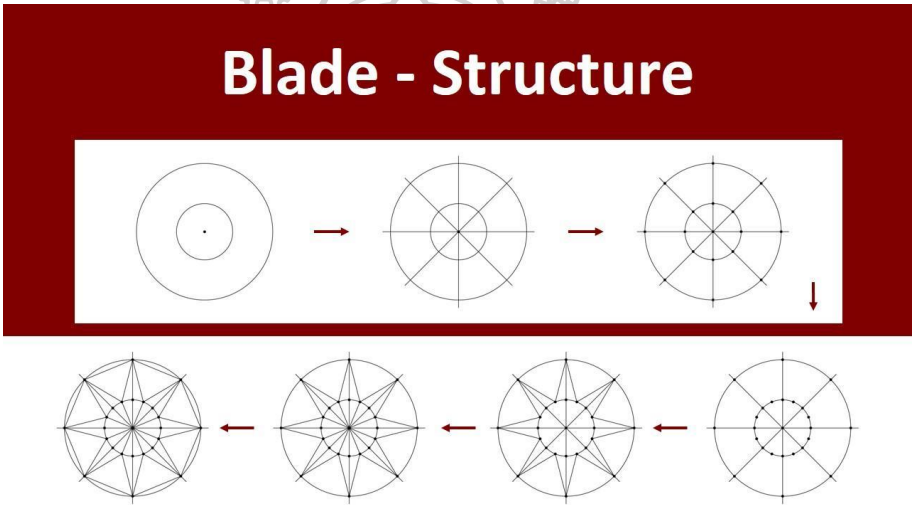


Figure 62. Structural modeling from straight lines and circles. By Researcher.

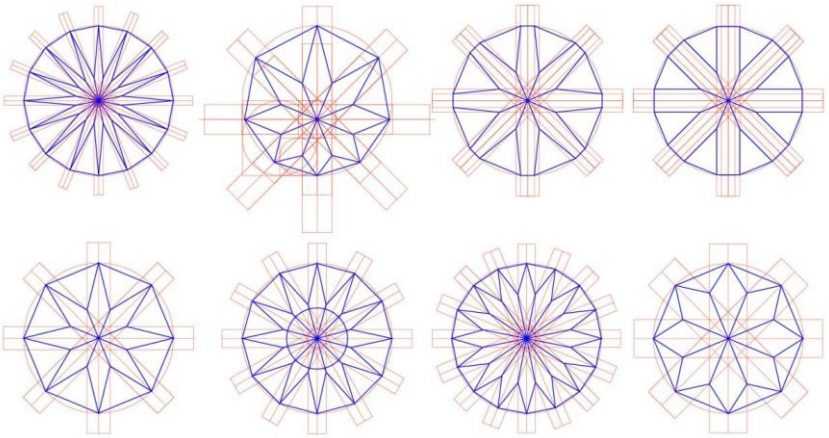


Figure 63. Structures which can be adjusted according to the design. By Researcher.

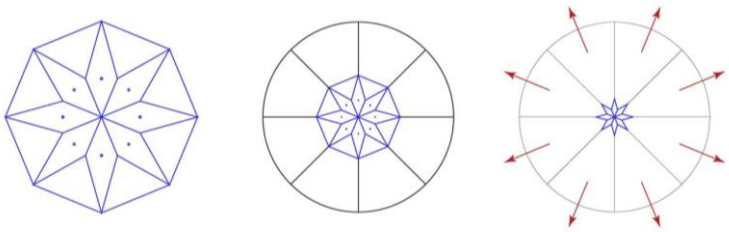


Figure 64. Structure with additional 3rd circle, which could expand the edge indefinitely. By Researcher.

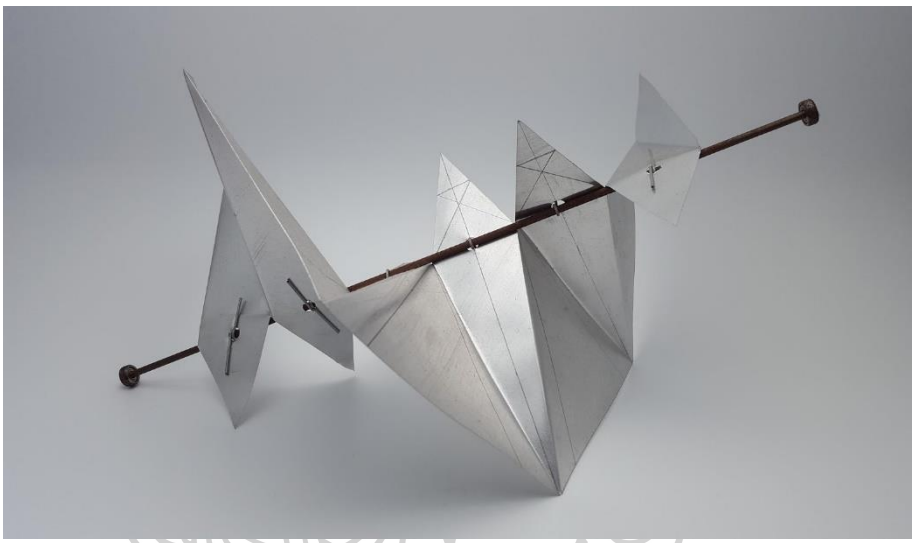


Figure 65. Assembling with the central axel, with pellets at the end. This piece could move as a turbine. By Researcher.

Figure 66. The decorative edge of the blade, which can be bend into curve. By Researcher.

With different type of blades, the capacity to pick up the wind is affected according to these factors. A) The angle of the diamond shape edge directly affected the surface which would pick up the wind. B) The radius of the circle mainly affected the length of the blade, and indirectly affected the angle of the diamond shape. Therefore, the researcher built more models to experiment the capacity to pick up the wind of 12 different types of blades.

Figure 67. Models for experimenting with the capacity to pick up the wind. By Researcher.

Most blades could pick up the wind well from the horizontal axis, but not very effective from the vertical axis. As when put up vertically, both left and right side could pick up the wind similarly and therefore prevent it from rotating. The solution is to adjust the axle line diagonally. After folding, the shape would be slightly tilted and allow it to pick up the wind better from the vertical axis, as there would only be one side which could pick up the wind, as in figure 68.

Figure 68. Tilted blade allow one side to pick up the wind better than the other side, so it could rotate easily. By Researcher.

The problem found in this experiment is the lack of balance in the horizontal axis, as the angle of folding was restricted to eight directions, the folding of the blade was not completed in one round or too long that it lost the balance. Therefore, it could not pick up the wind due to the larger weight underneath, which would require more wind power than usual in order to start turning away from the fulcrum. What must be solved is the calculation of the complete round in order to create balance. When the structure is balanced, the movement will be easier. Hence the mathematical formula is required for balance. The formula could be used to adjust the frequency of the number of diamond shape as well as the length and breadth of the shape, which would help speed up the work.

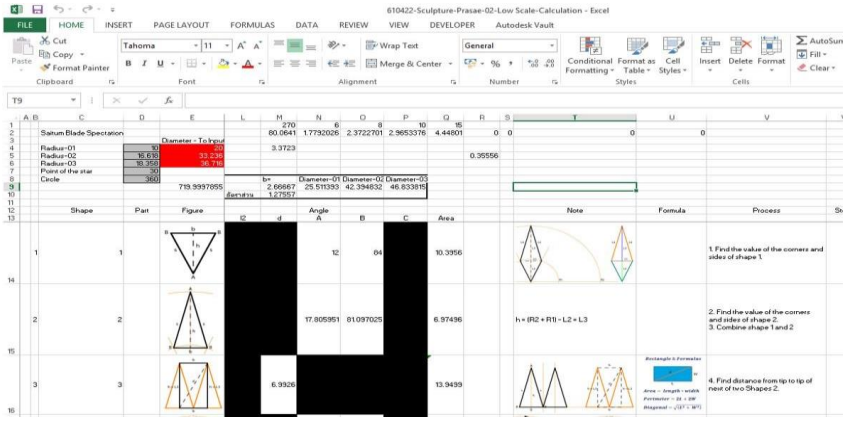


Figure 69. Calculation formula used to adjust the shape and allow the researcher to build the appropriate shape with balance. By Researcher.

Experimental works

The various shape transformation differentiated the characteristic of each work. The material adjustment also brought greater variety by using glossy material such as aluminium, bronze, and copper which would be even more attractive when the sculptures pick up the wind and the blades of different size reflect the sunlight. The researcher also bended the end of the blade to curve slightly in order to allow rotation with balance as in figure 71.

Figure 70. The adjustment of circle size and the angle of the line resulted in different works. By Researcher.

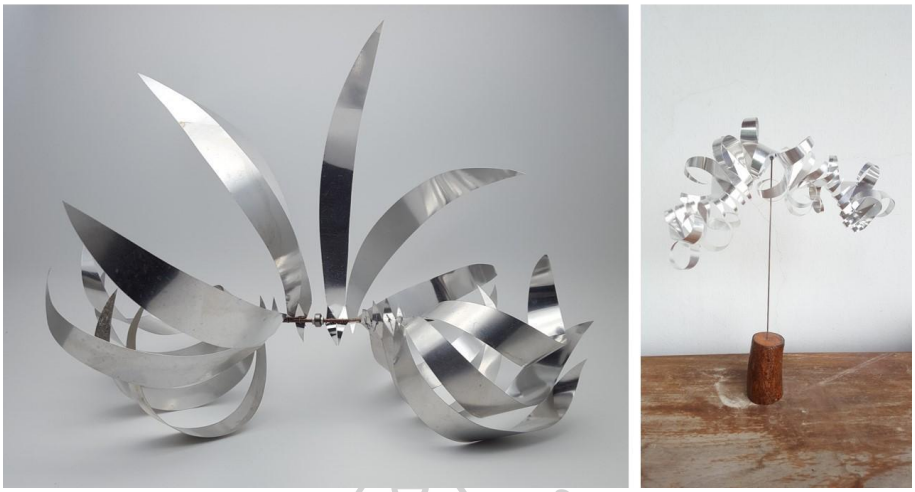


Figure 71. The blades were bend to create balance in itself and installed on the single axle. By Researcher.

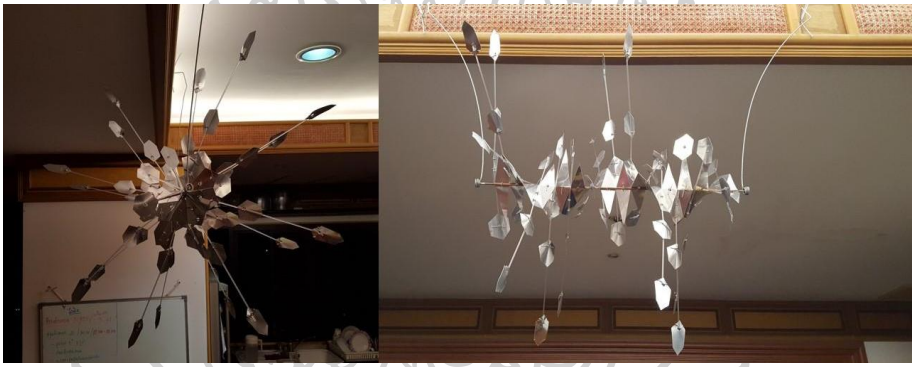


Figure 72. Adding the sideway axle and the wind picker in order to increase efficiency in rotation. By Researcher.

Then the researcher built the mobiles from wire and bamboo, weighted by the wire bended into geometric forms for balance, and decorated with blades made from paper and aluminum. The photovoltaic cell was installed on the top and connected to a small motor, so when the cell is exposed to the sun, each axle would turn according to figure 73. When the axles rotate, the photovoltaic cell would also rotate and turn its back towards the sun. So when the mobile stop rotating from solar power, the branches could rotate by the wind power and therefore alternate the movement between solar-energy movement and wind-energy movement.

Figure 73. Hanging the mobile with photovoltaic cell exposed to sunlight so that the motor could work. By Researcher.

The researcher did more experiment by adding two more circles. The forth circle was inside and the fifth circle was outside. When the central axis and edge were removed, the resulted shape would be linear and after folded could stand alone while being flexible from the folded edge. Aluminum and plastic were used. The resulted structure could be hanged on the bended wire and swing with the wind naturally as figure 74.

Figure 74. The shape was adjusted into linear in order to create a firm structure which is also flexible from the folding of material. By Researcher.

Afterwards, the blades with the adjusted edge were cut, decorated, and assembled in the flexible plastic axle. The wooden pendant was added at the top to add the weight, and the unstable base was made from cylindrical plastic axle. The motor and photovoltaic cell was also added, so when the motor work, the axle would rotate around. The bamboo at the base would tilted alternately in rhythm as the cylinder base would rotate according to the centrifugal force.

Figure 75. Using the adjusted blade to decorate the work, assembled with motor and photovoltaic cell in order to allow movement. By Researcher.

As the structure was flexible because of folding, the researcher bended it and connect both end to an axle. One end of the axle was connected to a ball, and other end of the axle was connected to the motor, which was also wired underneath the wooden panel at the base towards the photovoltaic cell. When the cell is exposed to sunlight, the motor would rotate, resulting in the rotation of the work from aluminum blade which reflect the light and create moving reflection.

Figure 76. The blades were hanged into mobile, attached with photovoltaic cell exposed to sunlight in order to allow the motor to work. By Researcher.

Conclusion of the Kinetic Results

In this experiment, the researcher started to incorporated various forms of clean energy, which are readily available such as wind or solar energy, to enhance the movement. The wind energy and solar energy were explored separately. Solar energy would require the photovoltaic cell in order to transform the light wave into electricity power transmitted towards the motor through the connecting wire. The experiment clearly demonstrated the capacity of each energy type, as the wind energy would affect the kinetic sculpture only when the sculpture surface was adjusted to pick up the wind. Additional instrument could also enhance the movement significantly. As for the solar energy, the mathematical calculation of the voltage would be required in the assembly of photovoltaic cell, in order to generate enough voltage to drive the movement of the electrical component.

The movement from the clean energy became the rhythmic movement of the sculptural material and thus breathing live into the work, especially for the glossy material which the reflection would seems to dance like an animation.

Concept for further revision

The creation of work from the repetitive structure could led to the harmony and movement in the sentiment of the audiences. The gradation of size and proportion could also enhance the power of such movement. When both principles are combined, the pattern could be created. Designing by re-arrange the multiple sub-units, or the module creation from the harmonious blend of the sub-units, could continuously led to the new form of artworks based on repetition and gradation of size and shape.

4. The Construction from module

In order to connect the structure, the joint must be incorporated for the harmony. In this experiment, the researcher built two parts of component, which were the joint and the arm. The joint consists of three-way tenon of 120 degree, which could fit with the arm of long straw-like tube. In construction, the modules of tenon and arm could be added and adjusted to various tilting angle and direction.

Figure 77. Components consisted of joints and arms. By Researcher.

Experimental works

The joints and arms were assembled together with the central joint, using the wire tenon as the vertical axle. The arms spread in three directions, starting from the central joint outward. The different angle of the joints connected to the axle would dictate the direction of the arms which branch outward. A module consisted of an arm, starting from the first joint with the axle towards the end. The three modules must balance each other, so that the overall structure could stand on the main column (the

plastic column as seen in figure 78) which received the weight at the central. All modules are balanced by downward load-bearing principle, so that the whole weight would press on the metal axle on top of the column. At the end of each module, the researcher installed metal sheets for picking up the wind in the three sides, using different materials of aluminum, bronze, and copper. The sheets were folded to the shape which could pick up the wind in one side, and let out the wind on the other side. This shape adjustment would result in the entire work rotating in the desired direction when it pick up the wind.

Figure 78. Examples of structural design using joints and arms, with one balancing central axle. By Researcher.

Another work became more complexed, by starting in the same way with the two works mentioned above, with different structural quality. The modules were placed on top of each other. The first module was directly placed on the acrylic column. The second module was placed on top of the joint of the first module. The weight from the three modules would press on the joint of the first module and then on the column. Both modules include random aluminum sheet at their joint, adjusted to the suitable direction

to pick up the wind. So when the wind blow, both modules would rotate differently with separate rhythm.

Figure 79. More complex structural design with two balancing axle. The sculpture could stand with the weight of two arms branching away in separate directions. By Researcher.

Conclusion of the Kinetic Results

The movement of the repetitive elements in both near and far dimension create the overlapping of image in the audience's view. Moreover, the axle on the column is unstable from the attempt to balance and therefore tilted a little when the sculpture moves. The result is the variety from the overlapping of lines, which become the pattern that emerge and disappear while moving with the ever-changing wind. The effect is the image with non-constant rhythm of fast and slow, which is more enjoyable with the random images moving vertically, horizontally, and diagonally.

Concept for the revision in the actual construction

The repetition of the image in the work of art could well result in the imaginary movement. In addition, the gradation and interlocking of size and proportion also create the different feeling of shape and form, which would enhance the audience's feeling of movement as desired by the artist. Therefore, creating module is an interesting option in the design which attempt to breathe life into the work.

Conclusion

The creation of kinetic art involves movement, which could be defined in two ways. Firstly, the movement could be imaginary in the mind of the audience who look or feel the work. It means that when the audiences engage with the work, they would follow the movement of the shape and form of the sculpture. Secondly, the movement could be the actual structural movement, when the sculpture incorporates some mechanism which allows movement by various types of driven energy. Combining both the imaginary movement and mechanical movement then should be the matter of concern for the artist. When the work of art is designed sophisticatedly and carefully in detail, the harmonious result could be counted as a complete kinetic art.

Afterwards, the researcher created three sculptural design as described below, and consulted with the dissertation supervisors.

A. Design I

Concept : Representation of flourishing, aiming towards the sky.

Appearance : Using the stainless material, modeled from a single metal sheet. The folding would create strength, that the sculpture could be placed vertically on its own. The sculpture would be installed on the buoyancies fixed by the underwater anchors in the group of three pieces.

Movement : There would be the movement from three parts. 1) When the sculpture pick up the wind, it would rotate and appear like a bird spiraling towards the sky. 2) When the buoyancies which float on the water pick up the wave and weighted down below by the anchors, they would lose the balance and the sculpture would wobble. 3) The sculpture would incorporate the photovoltaic cell at the base which allow the solar energy to move the blade in the water and help the buoyancies to spin around without the wind.

Figure 80. Experimental Design I. By Researcher.

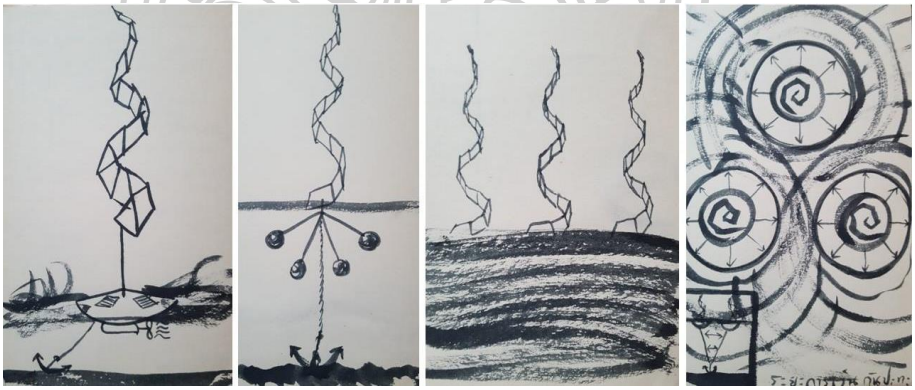


Figure 81. Sketches of Design I on paper. By Researcher.

B. **Design II**

Concept : Representing the progress and flourishing.

Appearance : The materials would include brass and copper, which would be modeled from two pieces of single metal sheet joined together. One piece would be brass, and another would be copper. The sculpture would be installed in a group of 5 pieces, with various sizes, on the column built on the concrete footing in the water.

Movement : The sculpture would include movement in two parts. 1) When the sculpture pick up the wind, it would spin and resemble the flourishing flower. 2) The sculpture would also incorporate the photovoltaic cell which allow the solar energy to drive the motor and spin the sculpture around without any wind required.

Figure 82. Experimental Design II. By Researcher.

Figure 83. Sketches of Design II on paper. By Researcher.

C. Design III

Concept : Representing the infinite budding of thoughts

Appearance : The material would be stainless joined by the joint and arms in three directions, resembling the atomic dispersion. The sculpture would be installed in one large piece on the concrete footing in the water.

Movement : The sculpture would include movement in two parts. 1) There would be the turbine blades attached on the whole sculpture. When it picks up the wind, the sculpture would spin around as if it would disperse around all direction. The sub-branches in each direction could also spin. 2) The sculpture would incorporate the photovoltaic cell connecting to the battery and light bulbs, in order to light during the night and create the dance of light and shadow around.

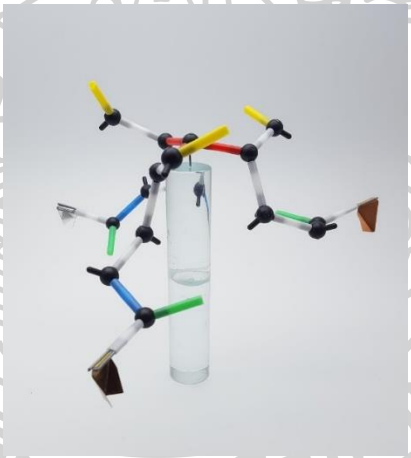


Figure 84. Experimental Design III. By Researcher.

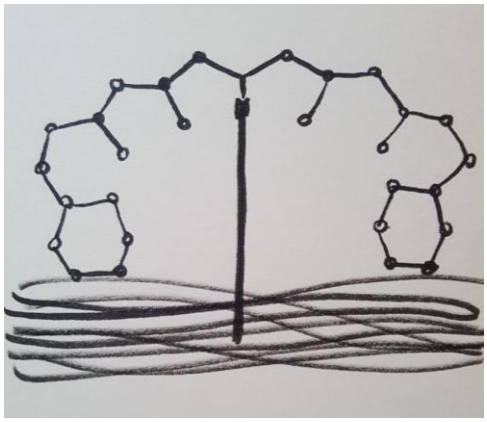


Figure 85. Sketches of Design III on paper. By Researcher.

Finally, the supervisor suggested that Design III should be further developed, by proposing the concept of budding in all direction randomly, reduce the banal repetition, and retain the balance by put in some weight. Afterwards, the researcher designed 3 variations of the design III, in order to select the most appropriate design for the actual construction as described below.

I. Design 3.1

The supervisor analyzed that the overall shape is still in the form of sphere, which does not correspond to the concept of the budding of thoughts or learning well enough. Therefore, the more organic form was suggested, that the arms should branch outward horizontally and broadly. The kinetic aspect is satisfying enough as it could create the gentle image and variety.

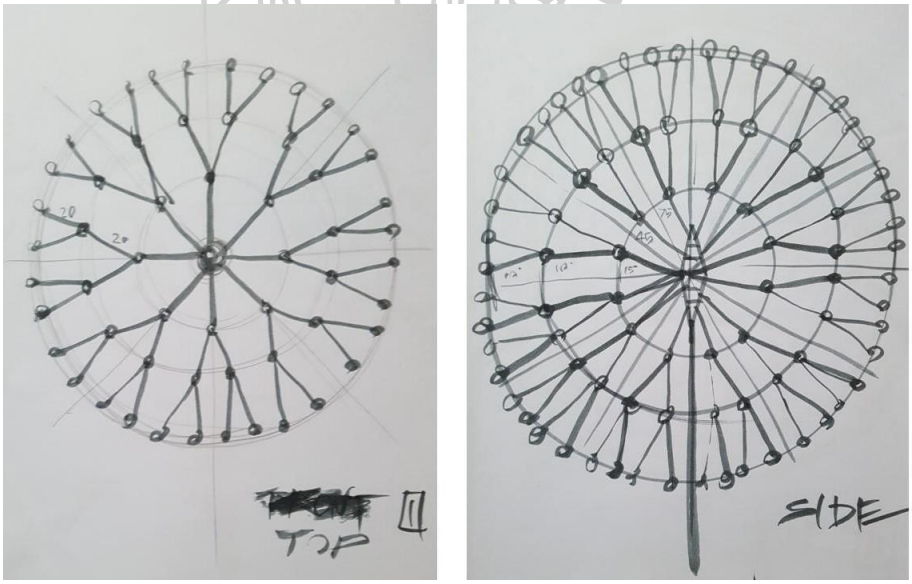


Figure 86. Sketches of experimental design 3.1. By Researcher.

II. Design 3.2

The supervisor analyzed that the overall form has the characteristic of branching out, which could correspond the concept of thought budding or learning well. The branches were dispersed broadly, and the kinetic aspect was satisfying enough.

However, there were just two spinder, which might not be enough and resulted in somewhat rigidity in the work, even if the forms are quite delicate.

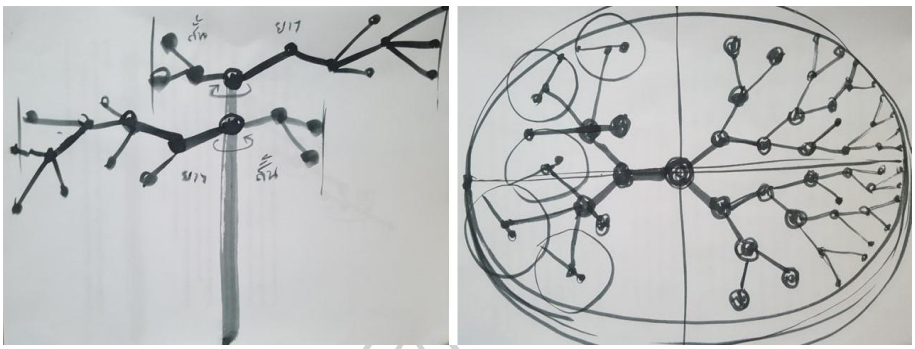


Figure 87. Sketches of experimental design 3.2. By Researcher.

III. Design 3.3

The supervisor analyzed that the overall form is diversified, with the gradation of branches from large to small, corresponding to the concept of learning little by little. The existing knowledge would enhance the new knowledge continuously. Thus, the concept of thoughts budding or learning could be corresponded well. The branches dispersed horizontally and broadly. The kinetic aspect is diversified. Each arm could be moved by the wind, while the major axis that control the overall structure could also be moved. Therefore the movement is flaunting well.

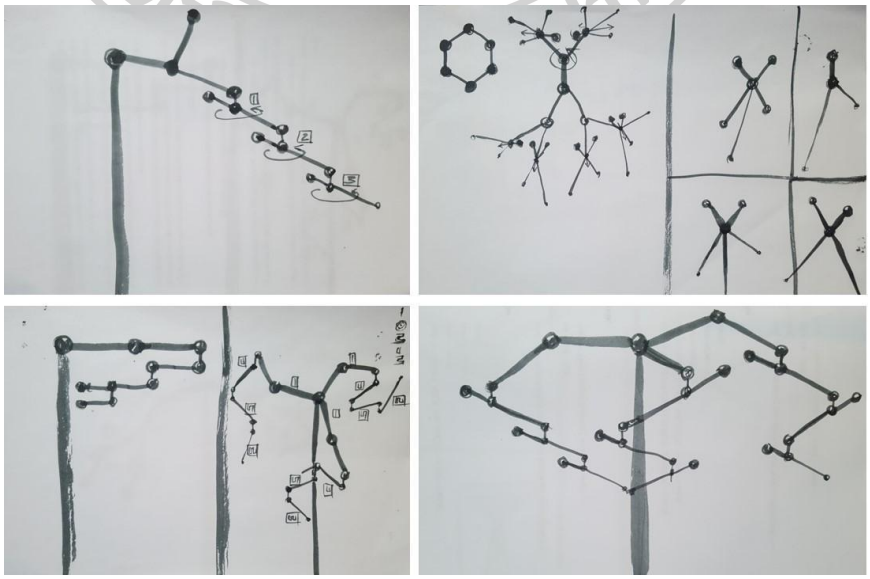


Figure 88. Sketches of the experimental design 3.3. By Researcher.

Finally, the design supervisor suggested using the design 3.3 to develop into the actual construction, as the movement in this design is the most continuous and balanced, as well as well-responding to the spatial design as required.

For the 1st stakeholder comment, Mr.Napop Yangsoong, the Architect / Acting, Head of Master Plan Division, Office of Building and Ground Management, stated that, “This sculpture is like an instrument which catch the thing that cannot be seen (the wind speed) and transform it into the clear tangible form. Each part could spin freely, with various speed of rotation according to the different length of the sub-axles. Therefore, the image would constantly change every time we look at it. Hence, what can be seen from this sculpture could ignite the idea in considering other issues. It represent the dynamic learning, which would constantly branching and moving conceptually, even when this Learning Garden is empty of activity or people. The suggestion is that the angle and direction of spinning could be developed in order to create more obvious change of the image. For example, the overall image might seems to be vertical sometimes, while seems to be horizontal at another time when the axles rotate another way. The obvious change of image would be more eye-catching, and might easily be more inspiring.”

PHASE II : Experiment with the Photovoltaic cell

1. METHODOLOGY

This research involved the combination of two subjects, which are the photovoltaic cell application and sculpture design. The researcher thus began with the literature review and the consideration of energy factor as well as the sketches of sculptural form, as the design of sculpture would dictate the form of work including the required electrical instrument, such as the size, amount, or voltage. Likewise, the calculation of the electrical circuit, the wiring, and the position to install the electric instruments on the sculpture would also affect the sculptural form. After the form and required electric instrument were designated, the researcher then combined them

together and exposed the sculpture to the sunlight, in order to observe the electricity production efficiency. The generated wattage would be measured into the digits, which would be calculated to see if it would be enough to run the electric instrument on the sculpture. Afterwards, the researcher would provide the creative works as the evidence of applying the experiment results for the artistic merit and conclude the result of the study.

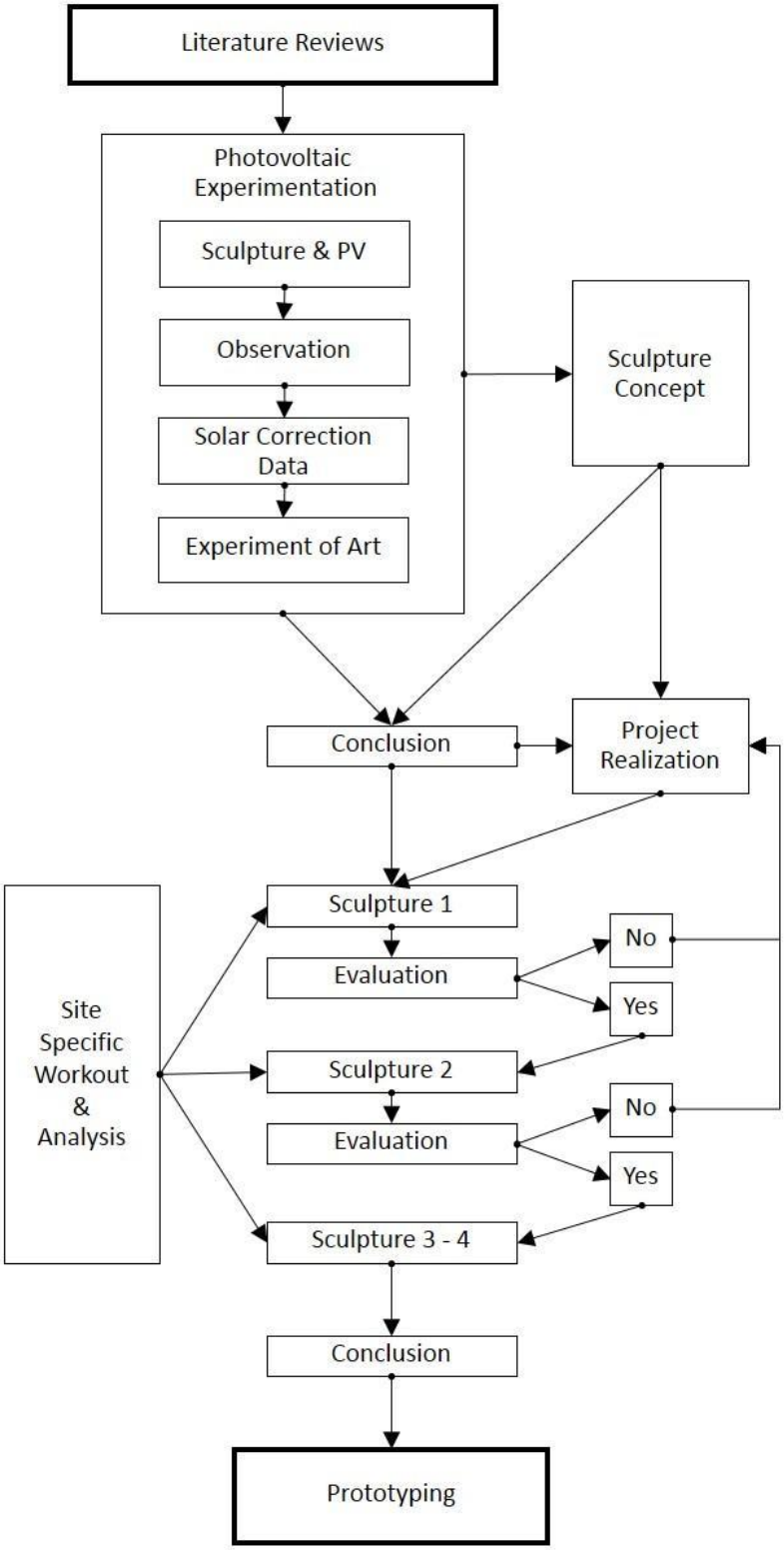


Diagram 1. Research methodology. By Researcher.

2. EXPERIMENTATION

According to diagram 2, shows the 10-steps study process used to assess the expected effects development of model appearance on specific site. The study process can be summarized as follows. In the first step, a site survey was performed using visual observation and a fish-eye lens camera to assess the area suitable for model situate. In the second step, the location for the model situate was selected and the shape of form was designed taking into for observation. In the third step, the possible light incident was recorded and estimated by entering the meteorological data and system design parameters into calculation software. Based on the appropriated angle of light incident of planar surface, the solar incident feasibility and development processes were assessed in the fourth step.

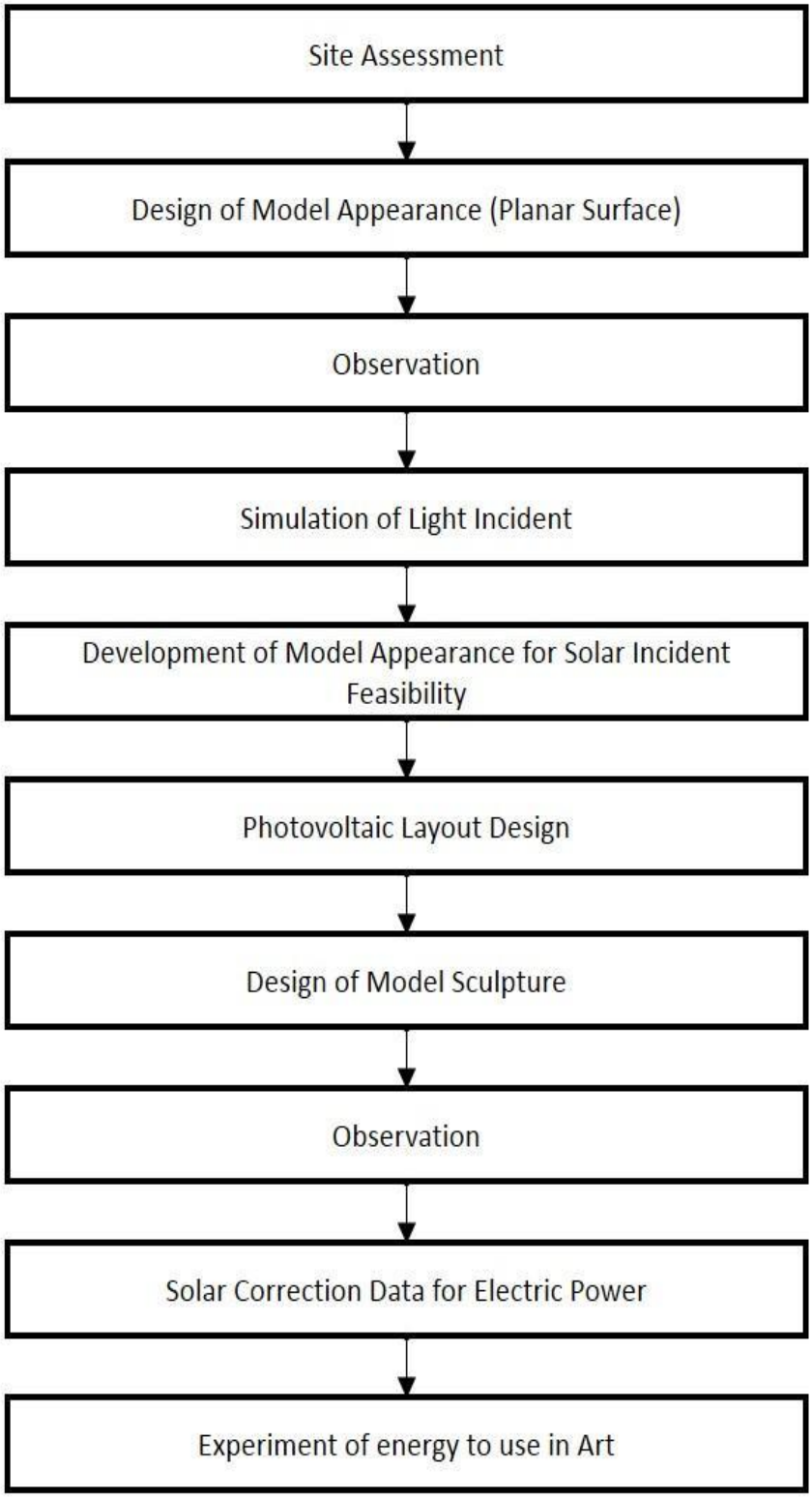


Diagram 2. Overall procedure to Development of model appearance in the study site. By Researcher.

I. Site assessment

The planar surface's orientation (azimuth, the direction it faces) or tilt varies from optimal solar incident's touch. The optimal combination of array tilt and azimuth will depend on a few variables, including geographical location, seasonal weather patterns. Azimuth and tilt are both required data from equation.

For the site assessment monitoring for light incidents on planar surface On Thursday 11th August 2016 (rainy season) at the top of a building close to Bangkoknoi canal in Bangkok, Thailand (13° 46' 44.3136'' N; 100° 28' 9.012'' E). The procedures were calculated for sunrise and sunset time from the date on particular day at the study site, using a digital topographic map to locate the specific site. In order to assess the effects of shadows on the model, researcher analyzed the daily sunshine hours on site using the solar radiation analysis method on the period of autumnal equinox (The moment when the Sun appears to cross the celestial equator, heading southward. Due to differences between the calendar year and the tropical year. At the equinox, the Sun rises directly in the east and sets directly in the west, day and night are of approximately equal duration all over the planet. They are not exactly equal, however, due to the angular size of the sun and atmospheric refraction.) To measure the shadow effects caused by small obstacles, such as vegetation, small building and the skyline was recorded and analyzed using a fish-eye lens camera. This enabled field analysis of the skyline at the solar site. The results of shadow-effect were recorded in the form of a shading data for shading elements surrounding the solar site, as expressed from approximately time and angle calculation by values between "0.0" (complete shielding of direct radiation reaching the PV system) and "1.0" (no shading effects). (Emerson G.Melo, 2013)

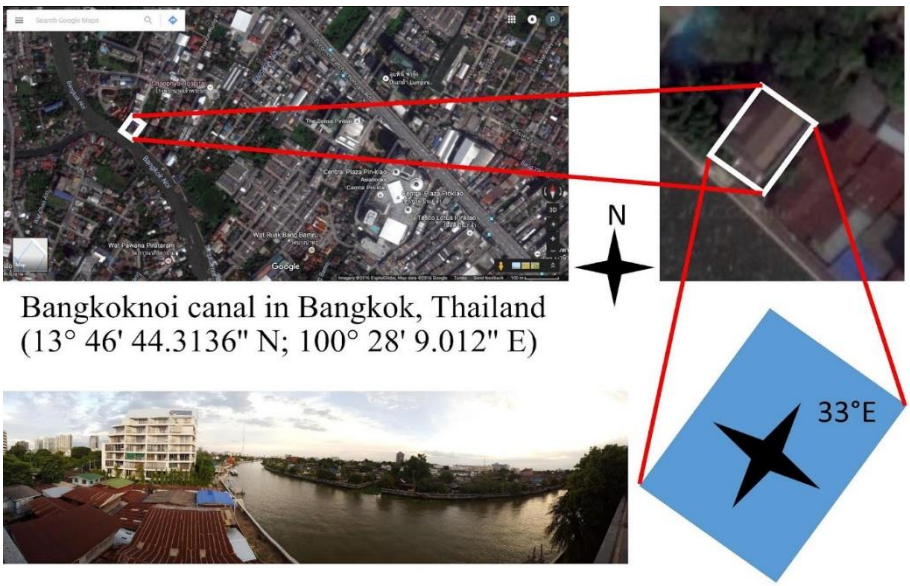


Figure 89. Shows observation site. By Researcher.

II. Design of model appearance (planar surface)

For the purpose of the study, it was hypothesized that planar surface of model constitutes a tilt array for the highest value of energy generation. The solar cell attached on the surface was designed with the following parameters: number of planar per model (if there are separated), long period receiving energy and array spacing.

a. Model Surfaces

(Kozlov, 2013) wrote about the structure of planar surface that it consisted of three major elements; the planar facets (F), linear edges (E), and point vertexes (V). When these three elements are combined, the sub-units of surface would become the larger surface with the new different forms. The folding of the two major elements; the planar facets (F) and linear edges (E) would especially become the hinged flat faces and the triangular surface as shown in figure 90a. Another type of structure, or the kinematical nets with non-triangle meshes is also possible as shown in figure 90b.

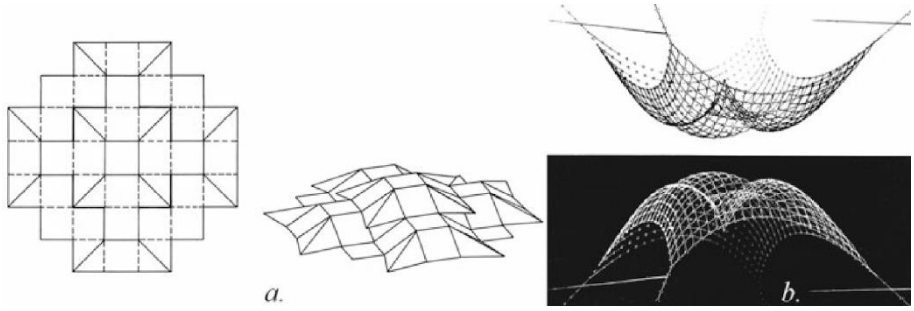


Figure 90. x.Transformable surface models: a) folding structure (Vranka 1990: 9) (Vranka, 1990);

b) kinematical net (Otto, Burkhardt and Hennicke 1974: 130) (OTTO, 1974)

Furthermore, the combination of the geometric forms and found that the emergence of space would start at the origin of the set of all points. Then the sets of points would be divided, and connected together by the line, which would led to the paths (both straight and curved). The crossing of the paths become the intersecting lines which divided the region and finally become the plane.

b. Shape

The various shapes could originate from the folding of the sub-planes in multi-direction, which would become the various shapes that constitute to the new form, as Dmitri Kozlov (2013) wrote that "The shape of architectural objects in general can be treated as envelopes: 2D surfaces embedded into 3D space. (Kozlov, 2013)

c. Proportion

According to the study by Katherine A. Liapi, it was found that the proportioning systems are crucial for the visual aesthetics, as the fundamental of division would be combined within the structure. For example, the golden ratio and other man-made geometric forms, which follow the example in the nature and re-arrange them to create the different beauty could be found clearly through the architecture and objects closed to human. (Liapi, 2002)

III. Observation

The observation of solar geometry consisted of 4 main factors; solar incident, time, date and atmosphere.

a. Solar Incident

A simple logic drives the whole design. The relative position of each facade component with the different seasonal sun paths defines its geometry (openness, deepness and panelling inclinations). Each component is defined globally yet resolved locally, and calculated individually, module by module, following the same shared rules. (Areti Markopoulou, 2011)

b. Time

The solar day is exactly 12 hours long at the equator during the equinoxes. During the summer solstice (June 21), the sun is at its northern extreme position and the declination is at its positive maximum. (Anderson, 1983)

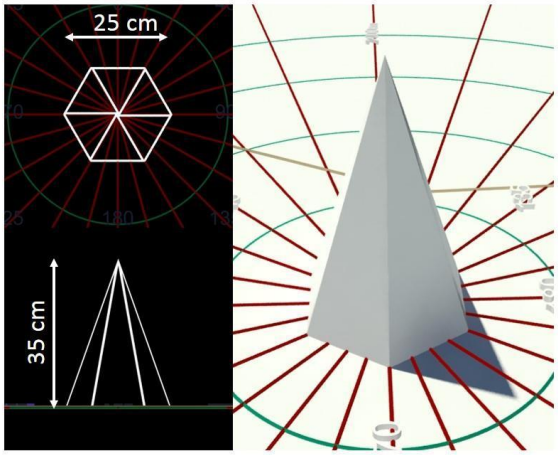
c. Date

As the earth progresses along its orbit about the sun, solar declination changes due to the tilt of the earth's polar axis with regard to its orbital plane. Solar declination then depends on the earth's position in its orbit, that is, on the day of the year. (Anderson, 1983)

d. Atmosphere

Solar radiation incident on any given surface can be decomposed into two components, the direct or beam component emanating from the sun and a diffuse component that results from multiple reflections and scattering because of particles in the atmosphere. The diffuse component may also include reflections from the ground and local surroundings, where the surface in question is sloped rather than horizontal. Differentiating between the two components is vital for accurate calculations in most solar energy applications; however, a number of steps may be required to arrive at realistic estimates at an appropriate level of detail for a given location depending on the basic data available. (Muneer, March 2013)

The model was putted on the roof of the building, see figure 91. For the characteristic and some details. The camera was set for 4 point align to the wall; front view (toward 33°NE), left view (toward 123°SE), and top view and perspective view observe atmosphere for clouds status. The time was assigned for 1 hour period started at 06:00 (Dawn) until 18:00 (Dusk) o'clock as shown in Figure 92. The model Edged Cone shape situated at the top of a building and set to point to Solar Zenith Angle.



Model Characteristic

Length	: 25 cm
Height	: 35 cm
Planar surface	: 6
Color	: White

Figure 91. Shows the characteristic of model. By Researcher.

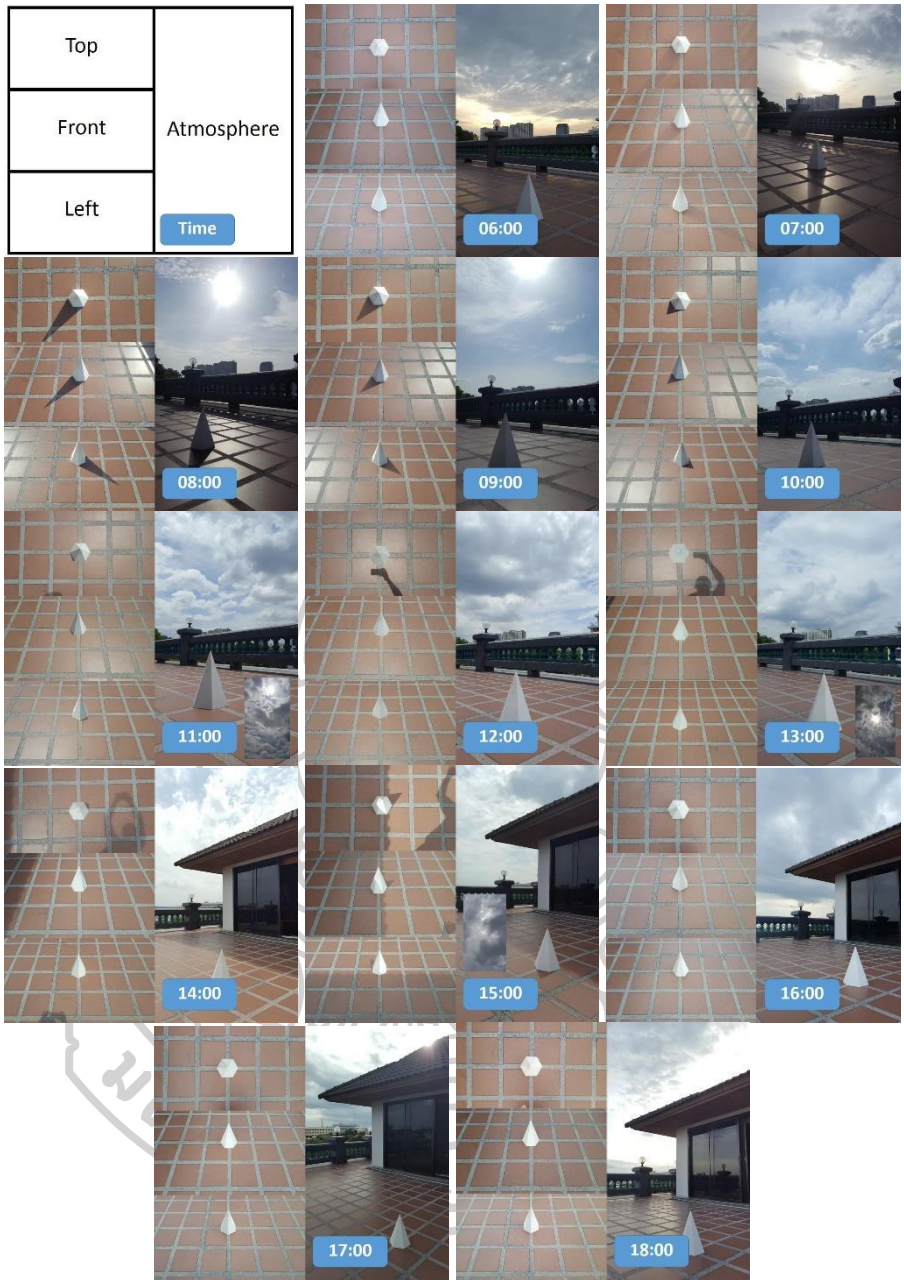


Figure 92. Shows different of shade and light direction for each period. By Researcher.

IV. Simulation of light incident

Equations was used for calculation for solar systems. It enables more accurate analyses of how to adjust planar surface to face most directly to sunlight, given the environment, all over model characteristics and the atmosphere conditions. For an explanation of the Excel formulas. In this study, after observation for primary data

collection. The solar time and solar altitude were calculated by entering the meteorological data of the study site and any values which needed, such as angle of planar, time, date and etc. The shading data obtained by onsite solar assessment according to the tilt angle of the model surface array, into the formulas. The following equation were used to calculate for results;

a. Solar Time

Time based on the rotation of the Earth with respect to the Sun. Solar time units are slightly longer than sidereal units due to the continuous movement of the Earth along its orbital path. For example, by the time the Earth has completed one full rotation on its axis with respect to the fixed stars, it has also moved a short distance in its orbit and is oriented slightly differently to the Sun, so that it must turn slightly more on its axis to complete a full rotation with respect to the Sun. For finding solar time, the equation is

$$\text{Solar time} = \text{Standard time} + 4(L_{st} - L_{loc}) + E \qquad (3a.1)$$

Solar time will use to correct in solar declination equation (John A. Duffie, 2006)

b. Solar Declination

The angle formed by the line from the center of the earth to the center of the sun on a particular day and the plane containing the earth's equator is called solar declination 8. As the earth progresses along its orbit about the sun, solar declination changes due to the tilt of the earth's polar axis with regard to its orbital plane. Solar declination then depends on the earth's position in its orbit, that is, on the day of the year. Solar declination for each day of the year is listed in The American Ephemeris and Naval Almanac for each year. (P.I.Cooper, 1969) suggests the approximate equation for calculating the declination.

$$\delta = 23.45\ 360365\ 284+n \qquad (3b.1)$$

In this equation, n is the day number with 1 being January 1 and 365 being December 31. This approximation is satisfactory for flat-plate and mildly concentrating collectors. (Anderson, 1983)

c. Solar Zenith and Azimuth Angles

In order to relate the solar zenith and azimuth angles to latitude, date, and time of day, we need to consider two coordinate systems. The first is the local coordinate system that sues the horizontal plane and the vertical axis on the earth's surface. Taking i, j and k to be unit vectors pointing, respectively, south, east, and vertically up, we can write the solar unit vector S as. (Anderson, 1983)

$$S = i \sin \theta_z \cos \gamma_s + j \sin \theta_z \cos \gamma_s + k \sin \theta_z \quad (3c.1)$$

In the earth-centered coordinate systems, S can be expressed as

$$S = i \cos \cos \omega + j \cos \sin \omega + k \sin \quad (3c.2)$$

Where i, j and k are unit vectors along the meridional axis *m*, the easterly asix *e*, and the polar axis *p*, respectively.

The components of S in the two coordinate systems are then related by

$$S_v = S_m \cos \phi + S_p \sin \phi, \quad (3c.3)$$

$$S_s = S_m \sin \phi - S_p \cos \phi,$$

$$S_E = S_e$$

Substitution of the components of S given in Eqs. (3c.1) and (3c.2) into EQ. (3c.1) gives

$$\cos \theta_z = \sin \phi \sin \quad + \cos \phi \cos \quad \cos \omega \qquad (3c.4)$$

$$\cos \gamma_s = \sin \phi \cos \delta \cos \omega - \cos \phi \sin \delta \sin \theta_z, \qquad (3c.5)$$

$$\sin \gamma_s = \cos \delta \sin \omega \sin \theta_z \qquad (3c.6)$$

The solar zenith angle and azimuth angle can be calculated with these results for a given latitude, date, and time of day. (Anderson, 1983)

d. Sunrise and Sunset

Neglecting the refractive bending of the sun's rays by the atmosphere, we can say that the local sunrise and sunset occur when the sun is in the horizontal plane at the point of observation. Then the zenith angle for either event is 90°. Hence, for sunrise or sunset, the corresponding hour angle:

$$\omega_s = \pm \cos^{-1}[-\tan \phi \tan \delta] \qquad (3d.1)$$

with the positive sign corresponding to sunrise and the negative sign to sunset. When γ exceeds 90°, the sun rises north of east, and when γ is less than -90° (say, it is -100°), the sun sets north of west. In the mid and lower latitudes of the northern hemisphere this occurs during the summer. (Anderson, 1983)

According to the equation above, solar data can be collected as follows: On Thursday 11th August 2016, Sunrise time was 06:04 at 74° and Sunset time was 18:43 at 286° from north. The site point to 33°E from N. And because of Rainy season, the atmosphere status was scatter clouds. So, all data such as time, date and location has been insert into 3D application for simulating the solar incident on model for check the correction of shade and light. See figure 93.

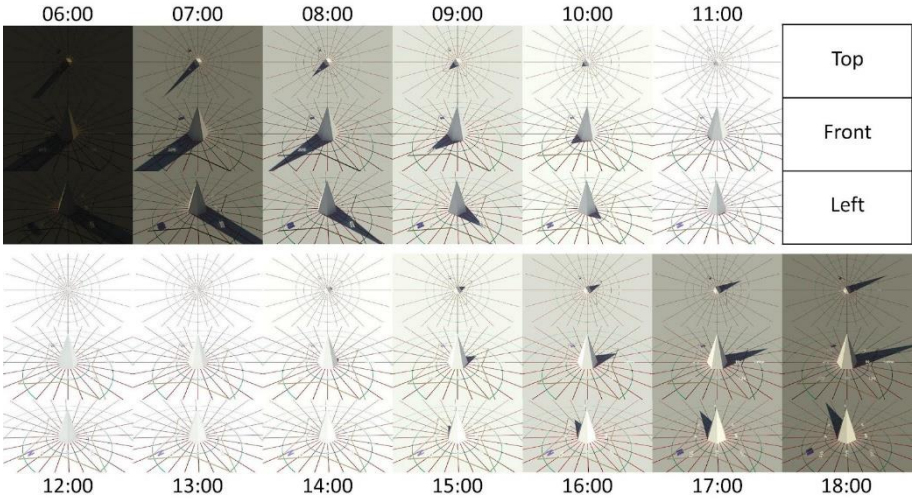


Figure 93. Shows solar incident in 3D simulation. By Researcher.

V. Development of Model Appearance for Solar Incident Feasibility

The newly designed was estimated in accordance with the initial shape of model. In order to change the appearance, 3d modeler application were used for create simulated model into real scale and assume present period sunlight in approximately location to observation situated site. According to topology, the development of model shape form were consists of three types of elements: planar facets (F), linear edges (E) and point vertexes (V).

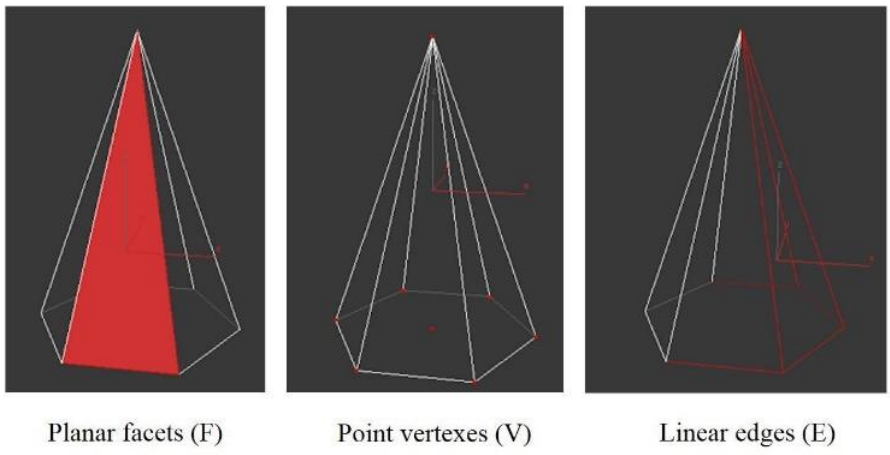


Figure 94. Shows three types of elements. By Researcher.

Firstly, original model was create to the same dimension of real model which used for observation, see figure 95. And after corrected from calculated data using equation, model have to be shorten because of it have to change its shape for contact more light from the sun. From the observation site, Bangkok. 15° is the average degree of sunlight direction in the sky, so planar surfaces have to point to 90°-15° (Solar zenith – average solar position) to face against the sun, see figure 96. So on, more FEV were added for more complex shape by simply method; two planar which have connected surface for 15° / 15°. Now, just minus 5° for the first one and plus 5° for the other and then become 10° / 20°. Average of sunlight will share the incident on both planar surfaces as shown in figure 97.

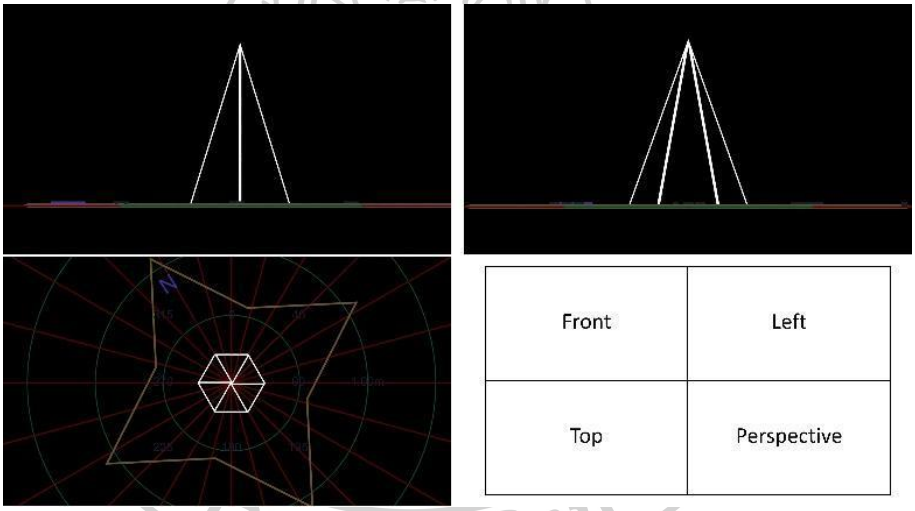


Figure 95. Shows 3D model in the same dimension of observation's model. By Researcher.

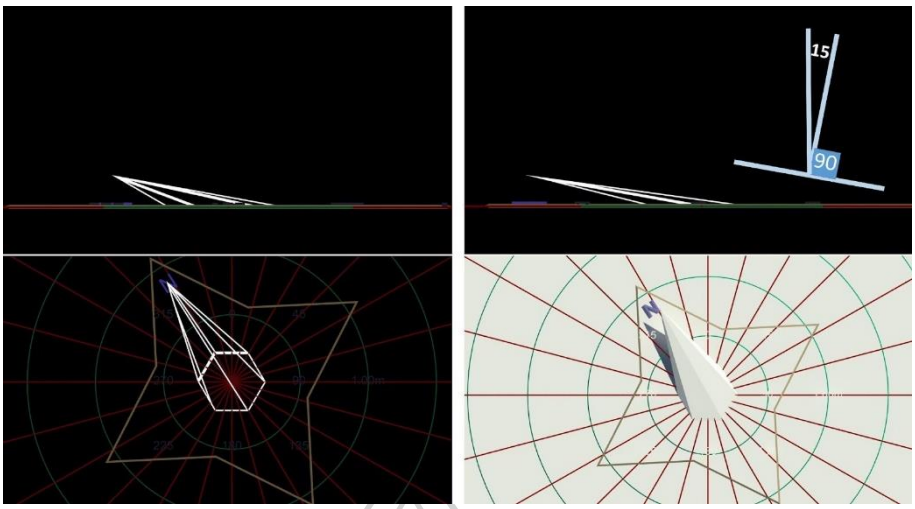


Figure 96. Shows 3D model after correction from calculated data. By Researcher.

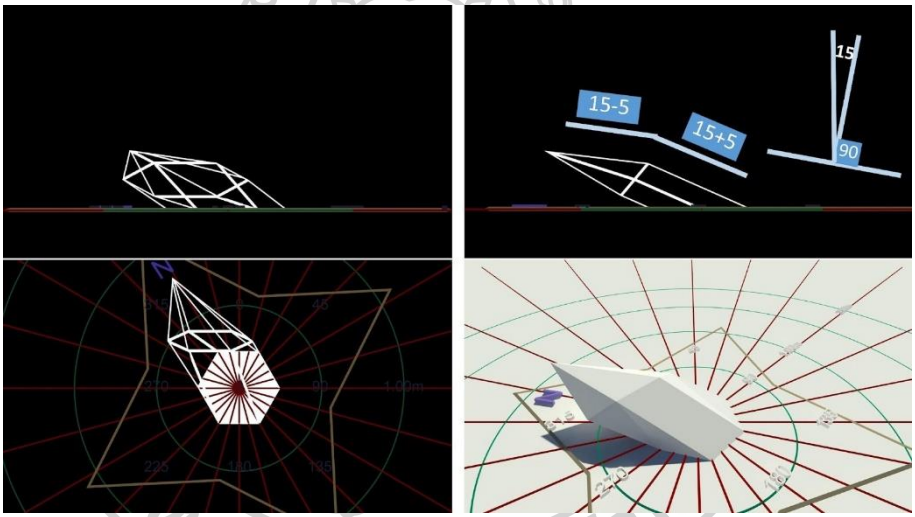


Figure 97. Shows 3D model develop for more complex. By Researcher.

If model would be situated in the different location, the shape of model have to change for the most appropriately solar contact. Example, Iskenderun on the eastern Mediterranean coast of Turkey DMS latitude and longitude coordinates are 36°3501300 N; 36°10 0 2400 E which means the sun will be located approximately 36° up in the sky from Solar Zenith Angle, toward south. So, for the most appropriate angle of planar surface for solar incident. The model should be change the angle of shape point up toward the sun for 54° (90 - 36°).

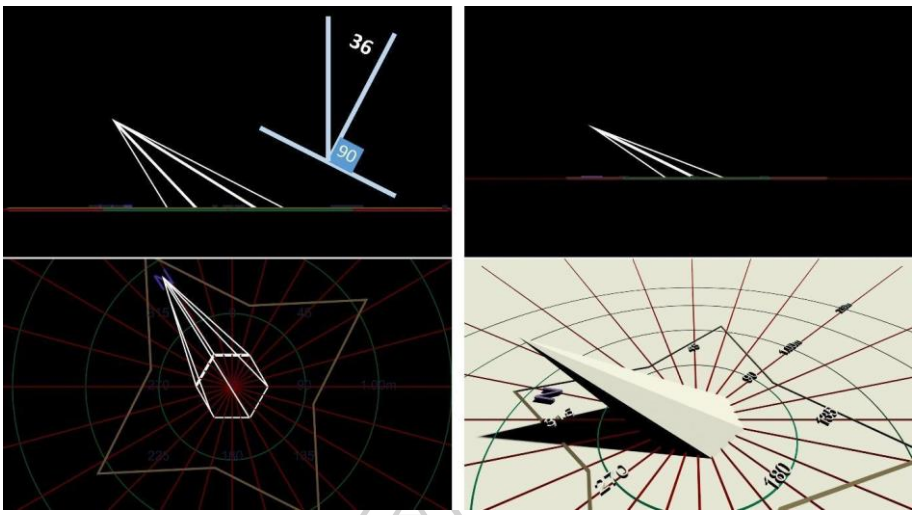


Figure 98. Shows the expected shape of model if it were built at the top of a building in Iskenderun (36°3501300 N; 36°10 0 2400 E), on the eastern Mediterranean coast of Turkey. By Researcher.

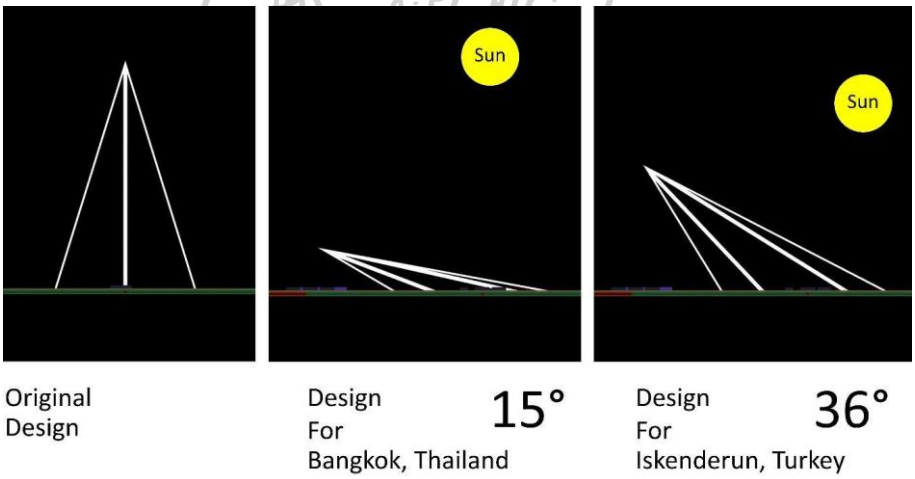


Figure 99. Shows comparison of different location cause of model changing. By Researcher.

VI. Photovoltaic Layout Design

In order to generate enough electricity for the components which would be incorporated, it was necessary to know how much energy should the component need in order to work. Afterwards, the solar cell layout must be designed, with the major concerns of the current and voltage. Firstly, the photovoltaic cell must be select with the

consideration of its current and voltage capacity. Then the amount of photovoltaic cell needed in order to generate enough electricity would be calculated.

a. The instrument used in this experiment

- Motor – a small type motor of 6V 150 mAh
- Solar cell (Monocrystalline) - 2V 45mAh size 30x30 mm Micro Mini Power Small Solar Cell for DIY light toy.

b. The design of electrical circuit

In order to generate enough power, it was necessary to consider the current and voltage. If any of them is not enough, the component would not work, or might work inefficiently.

Generally, any electrical circuit would be different in terms of flexibility and the characteristic of current and voltage, depending on the circuit connection and the resistor or the electric instrument connection. There are three types of circuit connection as following.

1. Series Circuit

Series circuit is the serial connection of components from one end of a component to the other component. The end of the last component would be connected to the cell. The sum of voltages across the circuit will be higher than the voltage in the parallel circuit

2. Parallel Circuit

When more than two components are connected together in a separate loop, by connecting the same end of each component together, and connect the end of the connected wire to the cell. The sum of the currents would be higher than the series circuit.

3. Compound Circuit

Compound circuit is the use of both series and parallel circuits together, which is mostly found within electronic usage but also possible for other type of applications depending on the appropriate usage. There is no fixed rule for the compound circuit.

All of Solar cell would be added with parallel and series wiring combination. In the series circuit, the total voltage is equal to the sum of the voltage of each cell, and the current is the same as any single cell. In the parallel circuit, the total current is equal to the sum of the current of each cell, while the voltage remain the same for each individual cell. Power is voltage times current.

In this experiment, the researcher incorporated the small motor, which required 6 V 150 mAh, with the photovoltaic cell and could generate electricity of 2V 45 mAh. In order to reach the required power, the compound circuit was used so that the current and voltage would reach enough level for the motor. However, as the photovoltaic cell did not all face the sunlight directly, the total power would be decreased. Thus, the researcher added more solar cell to compensate for the loss of electrical power when the planar was tilted. The solar cell panels were increased from 6 rows and 4 columns, which would generate 6V 360 mAh, to 6 rows and 5 columns, which would generate 6V 450 mAh. The photovoltaic cell layout followed the diagram in figure 100.

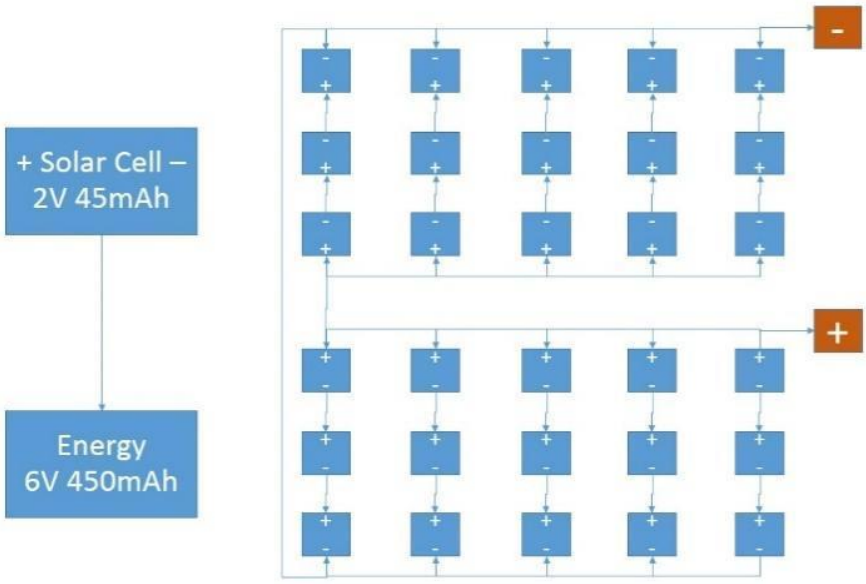


Figure 100. 30 pieces of Solar cell DIY light toy would be added with parallel and series wiring combination in 6 rows and 5 columns. By Researcher.

VII. Design Improvement of Model Sculpture (For Photovoltaic Cell Attachment)

Generally, the standard solar panel layout design would be in the form of array facing sunlight at the spot with best average light exposure all day, after already considered the changing position of the sun although the year. The planar array would be without any curve nor tilting in other direction as shown in figure 101. However, the researcher started by laying each solar cell panel into grid with 6 row and 5 columns in this model, then used the calculation table to plan the tilting of each plane. The rotation axis would refer to the horizontal X and vertical Y axis. For example, the horizontal plane at X3 and vertical plane at Y3 would be tilted towards X,Y = 0,-15 degrees. And after the tilting angle of each plane was input into the table, the total tilting angle for all 30 panels could be shown as demonstrated in figure 102.

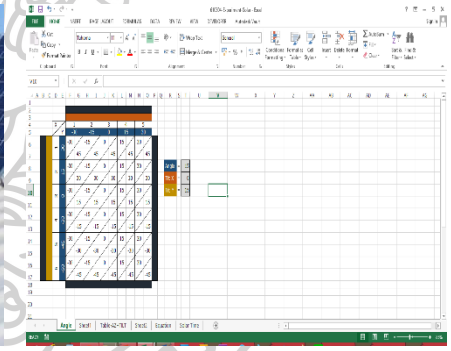


Figure 101. Standard solar panel which have flat surface intend to face against to sunlight (Left). By Researcher.

Figure 102. Calculation table suggest for an angle of each planar surface should rotate (Right). By Researcher.

From the above principles, the model was mainly designed to receive sunlight from morning until evening. Each pieces of solar cell may generate and compensate energy for each other, as each panel would be tilted towards different angle (figure 103). For an example, the model in this experiment was basically design for the observation site on Thursday 22th February 2018 (Summer season) at the top of a building close to Bangkoknoi canal in Bangkok, Thailand (13° 46' 44.3136'' N; 100° 28'

9.012'' E), which the solar noon period, or the moment when the sun appeared at the highest part of the sky compared to its positions during the rest of the day, was 12.33 PM. At that moment, the angular direction of the sun in the sky could be projected perpendicularly onto a reference plane (at an observer point) call True North-Based Azimuths, which equals 180 degrees from the north in this case (Figure 104), or around noon time.

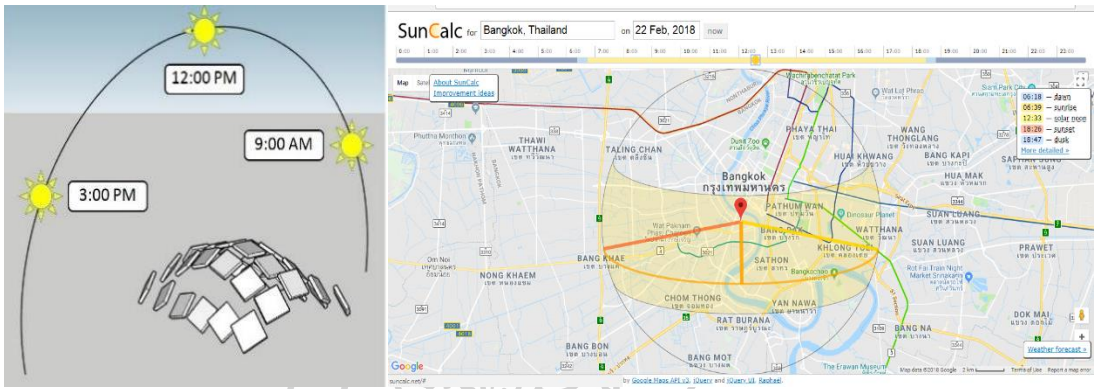


Figure 103. Shows 3D model of Solar cell position and facing to impact sunlight during day period (Left). By Researcher.

Figure 104. Zenith angle of the Sun on Thursday 22th February 2018 in Bangkok, Thailand (13° 46' 44.3136'' N; 100° 28' 9.012'' E) in 12.33 PM (Right) http://suncalc.net.

After tilting each panel to the desired angle, the researcher incorporated the curve plane so that the overall look of the model would resemble the earth's curve, in order to track the change of the sun's position in the north and south during the different season althrough the year. Figure 105 showed the front view, side view, top view, and perspective of the model. The top row was the regular image, while the below images were the model after the curve plane was incorporated. The overall look would be protuded up and allow the model to receive light in multiple periods.

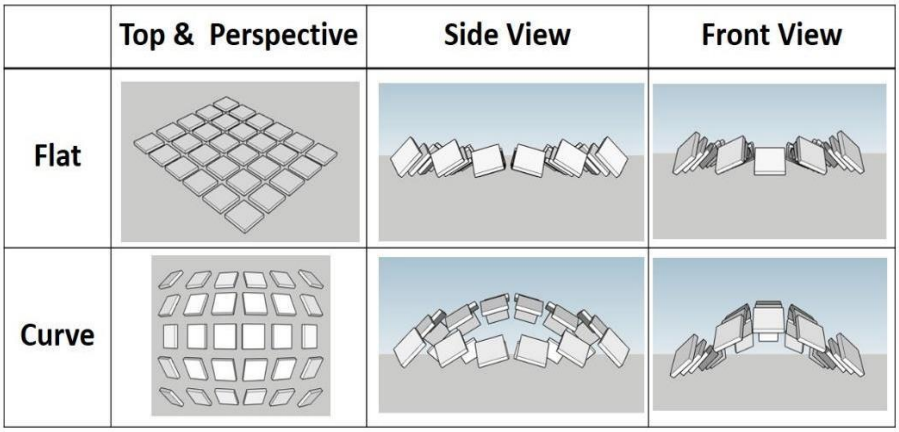


Figure 105. Design of model included curve of earth's surface plane in Front, Side, Top and Perspective view. By Researcher.

The curve in the X axis was designed to face the sun during the day, from dawn until dusk, which the sun would rise from the east towards the west at the end of the day. When looking from the top, the sun would seems to move from right to left. Therefore the tilting towards the sun in the X axis would allow the solar cell to be exposed to light in multiple period. Thus, the energy generation could be compensated this way

On the other hand, the curve in the Y axis was designed to face the sun during the year. As the earth's axis was tilted at 23.5 degrees, seasons could be observed when the earth's position was changed. When looking from the earth's surface, the sun's position would seems to move from the north to south. Therefore, the tilting towards the sun in the Y axis would allow the solar cell to be exposed to light in the wider periods in each month (or season) and could also compensate the energy production as well.

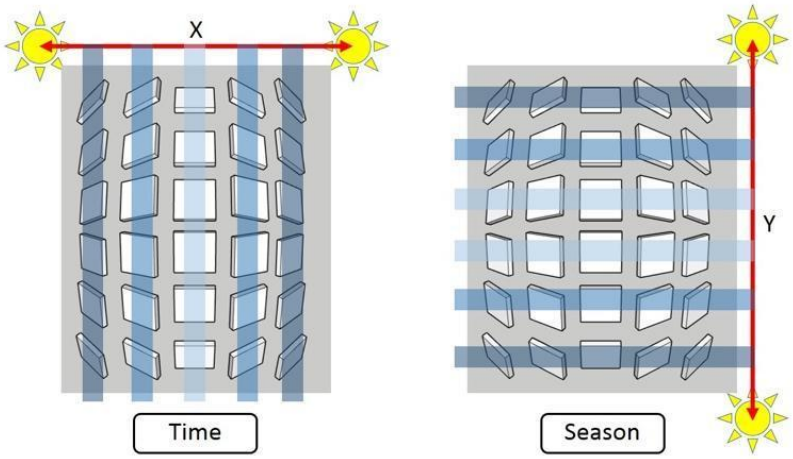


Figure 106. The curve of the layout would allow the wider period of light exposure, as the tilting in the X and Y axis served different functions. By Researcher.

In order to proof the effectiveness of this design, a simple model was constructed with wooden base which was drilled in grid of 6 rows and 5 columns, with equal gaps between the grid. Afterwards, the researcher put the aluminum wire connected to the photovoltaic cell panel through each hole. The solar cell panel was 30x30x30 cm in size, with the adjustable joint which allowed the adjustment of tilting angle. The leg was also screwed to the wooden base so that the angle was tilted at 15°, in order to face the sunlight directly, as shown in figure 107.

Figure 107. Observation model upper-left : front view, upper-right : side view, lower-left : top view, lower-right : perspective view. By Researcher.

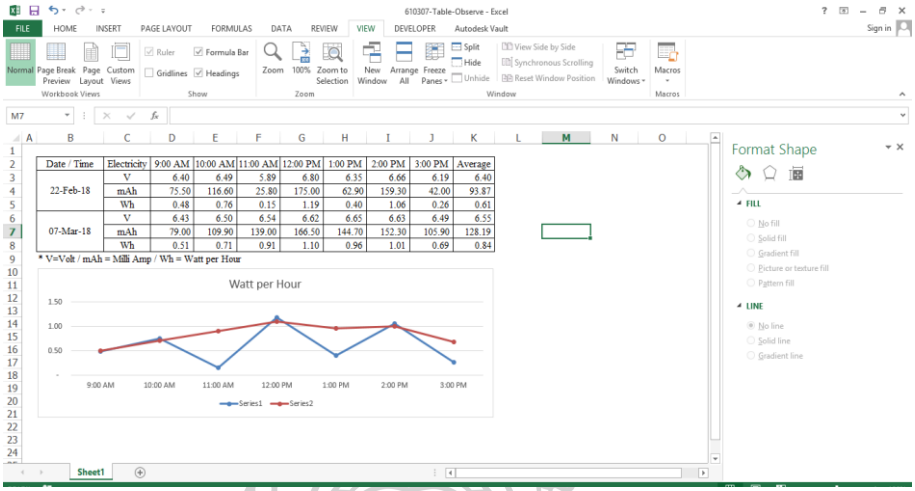
VIII. Observation

The observation process included data collection by the wattmeter at every hour starting from 9:00 – 15:00, on Thursday, February 22nd, 2018. The data was fluctuated due to the weather condition, which was partially cloudy and rainy as shown in figure 108. Therefore, the researcher added another observation day on Wednesday March 7th, 2018, and find the average data from both observation.

Figure 108. Exposing the model to the sunlight with wattmeter, in order to observe the design effectiveness (Left). By Researcher.

Figure 109. The weather condition of bright sky and partial shade (Right). By Researcher.

IX. Solar Correction Data for Electric Power



Date / Time	Electricity	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	Average
22-Feb-18	V	6.40	6.49	5.89	6.80	6.35	6.66	6.19	6.40
	mAh	75.50	116.60	25.80	175.00	62.90	159.30	42.00	93.87
	Wh	0.48	0.76	0.15	1.19	0.40	1.06	0.26	0.61
07-Mar-18	V	6.43	6.50	6.54	6.62	6.65	6.63	6.49	6.55
	mAh	79.00	109.90	139.00	166.50	144.70	152.30	105.90	128.19
	Wh	0.51	0.71	0.91	1.10	0.96	1.01	0.69	0.84

* V=Volt / mAh = Milli Amp / Wh = Watt per Hour

Table 1.The number of watt measured by wattmeter, with the unit of V, mAh and Wh. By Researcher.

According to table 1, the electricity power was fluctuated on February 22nd, 2018 due to the cloudy weather condition, while the measured data on March 7th, 2018 was more stable. In both observations, the peak hour of energy generation was at noon, when the solar radiation intensity peaked. When calculate the measured current and voltage into watt-hour, the overall power was enough to run the prepared motor.

X. Experiment of Energy Usage in Art

Creativity requires complex thinking from various perspectives, active thought, initiation, flexibility, and details as well as connecting the relationship of things together. Only then could the new innovation could be created and led to the problem solving. Mixed-media art is a genre of visual arts which combine visual art materials together with other artistic disciplines, such as light, sound, movement, or olfactory object. Other visual art works which are above the mentioned criteria are also under the swift and continuous development, and might be called differently. Drawing is the most fundamental form of artistic expression which could be found generally in visual arts. Human usually draws by hand, holding the instrument such as pencil, pen, or brush. As

the researcher attempted to combine the art and science together in order to explore the new possibility of artistic expression, the motor which was powered by the model mentioned above was connected to the brush pen. When the motor rotated, it also moved the pen. The researcher then adjusted the pen vertically and let it touch the paper as shown in figure 110. After a while, the drawing in figure 111 was generated.

Figure 110. Connecting the model with the motor and the brush pen over the paper (Left). By Researcher.

Figure 111. Artwork from the brush pen rotated by the solar energy (Right). By Researcher.

NOTATION

The following symbols are used in this paper:

= Solar declination angle

θ = Solar incident angle

ϕ = latitude

γ = Azimuth angle

ω_s = Sun's hour angle at sunrise or sunset

L_{st} = standard longitude for the time zone in question (reckoned as positive west of the Greenwich meridian)

L_{loc} = true longitude of the site for which the calculation is to be made

E = Equation of Time correction

INSTALLATION SITE

The Learning Garden (LG) is located in the King Mongkut's University of Technology Thonburi, as a part of the public learning space under the concept of a green campus. The objective of this learning garden is to enhance the sharing of knowledge and opinion creatively and sustainably. The sculpture design itself also correspond to the concept of learning, that the design resembles the dispersing atomic particle, which is the metaphor of the knowledge that could disperse in all directions. Moreover, the movement of kinetic sculpture accentuate the idea of dynamic learning.

In this location, the sculpture would be installed in the middle of the pool, which is surrounded by various buildings but also wide enough to allow the breeze to blow in. The location is exposed to sunlight all day; therefore, it is highly suitable for the installation of sculpture which could be moved by both types of energy. The water underneath the sculpture could also reflect the image in the wave, and the lines of light from the reflection in the water could create the pattern on the sculpture as well.

1. Context of the Installation Site.

I. Concept of the area

The Learning Garden (LG) is located in the King Mongkut's University of Technology Thonburi, or KMUTT. The university has been designated one of the nine national research Universities with the international-level capabilities and strength in Architecture, Bioresources, Energy, Engineering, Environment, Linguistics, Science, and Technology. Therefore, the identity of the campus is heavily related to science and technology.

The Learning Garden, where the sculpture would be installed, is a part of the public learning space, under the concept of green campus which aim to enhance the sustainable and creative sharing of knowledge and opinion. This Learning Garden would be the place for relaxation, so that the students would be ready to learn new things and be active in knowledge exchange, while practicing to learn naturally. This

area consisted of the renovated building that is connected to the existing building through the major axis of walkway, designed to be convenient, pleasant, safe, and healthy, as a part of the true walking society.

Moreover, the garden itself could also serve as the innovation common ground, where the students or staffs could conduct various activities in all level, including the activities between the university and the community around it.

Figure 112. : The location of King Mongkut's University of Technology Thonburi (KMUTT) and Learning Garden (LG) (Image from Google Map).

2. Elements within the site

The space of Learning Garden (LG) is a clearing, which is connected by the cement and wooden walkway alternately. There are seats available for sitting in both the shaded spot and the clearing. The green area is in the rectangle shape, with walkway and large trees around it. On the west and the east of the garden are the buildings. On the south is the major circulation plaza, with sculptures installed in some spots. On the north of the space is a reservoir where the water level is controlled and well-maintained.

12

Figure 113 : The area of Learning Garden.

(Image from google map)

3. Direction of the sun

Learning Garden is located at the 13.651390, 100.494425 (13° 39' 5.004'' N; 100° 29' 39.93'' E). The solar noon period, or the moment when the sun appeared at the highest part of the sky compared to its positions during the rest of the day, would be 12.06 PM. The average altitude angle is 75 degree on the south throughout the year. The sun would travel from the east to the west, approximately parallel to the edge of the reservoir. Thus, it is easier to install a sculpture to face the correct angle of exposure, by following the edge of the pool, which would also enhance the harmony between sculpture and its installation site.

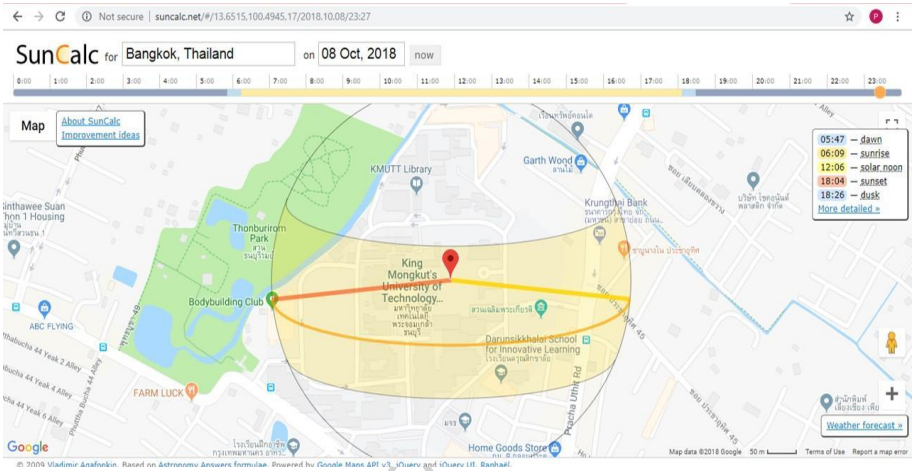


Figure 114. Zenith angle of the Sun on Wednsday 8th October 2018 in Bangkok, Thailand 13° 39' 5.004'' N; 100° 29' 39.93'' E) in 12.06 PM – (Image from http://suncalc.net/.)

4. Wind Direction

The wind blow towards the site from the southwest, at 229 degree, at the normal wind speed of 4 knots. Thus, if the sculpture installation is expected to face the wind, it should turn 49 degrees (229 degree minus 180 degree)

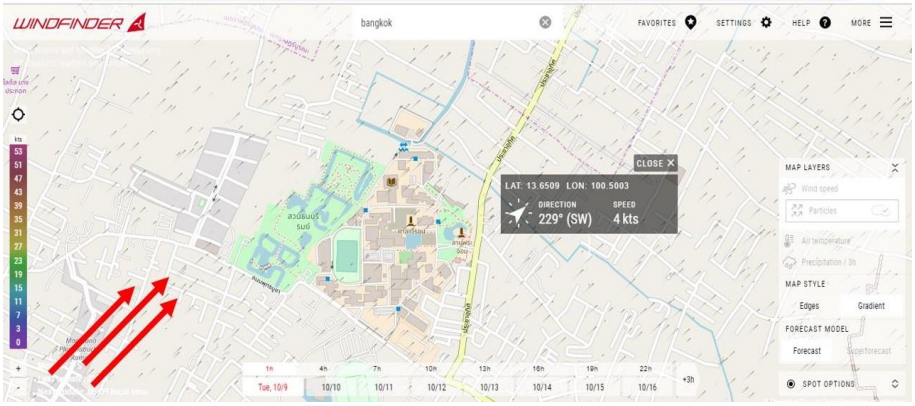


Figure 115 : Direction of the wind at the site, on Wednsday 8th October 2018 in Bangkok, Thailand (https://www.windfinder.com/)

5. Installation location within the site

The sculpture would be installed at the southern part of the reservoir, where the wind would flow through the building and thus is the prime site to pick up the wind which would allow the sculpture to move. As for the photovoltaic cell, the sculpture would be installed around the center of the pool, where it could avoid the shadow of the tall trees in the morning and the shadow of the building in the afternoon. The approximate distance between the center of the sculpture and the edge of the pool is around 5 meters, which is enough for the anyone who spend time in the Learning Garden to enjoy the encounter with this sculpture.

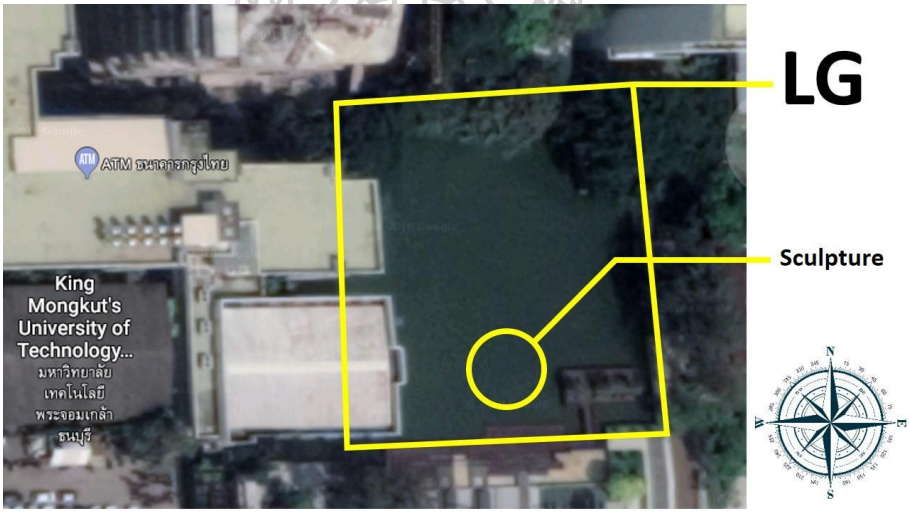


Figure 116. Installation location within the reservoir of the LG (image from google map)

Figure 117. Location where the Kinetic art would be installed. By Researcher.

Figure 118. Atmosphere of the Learning Garden during daytime and nighttime. By Gritin Prapaiwan, 2018.

6. Communication with the Stakeholder

The stakeholder of this project is contacted through the Office of Building and Ground Management, which is the one-stop center of facilities, landscape, safety, hygiene, and vehicle management in order to support the art and cultural activities according to the policy and mission of the university. The Learning Garden is also under the responsibility of this office.

The researcher contacted this office and submit the proposal to construct a sculpture for the university under the concept of infinite self-learning, which Mr. Prapon Ruengvuthchanaphuech, Consultant to the Dean of Building and Ground Management expressed gratitude and accepted the project, as well as suggest the installation spot for the sculpture in the reservoir of the Learning Garden. Moreover, he also suggest the officers who could be consulted about the construction and installation of the sculpture

as well as the solar energy involved in this work. When the proposal was submitted in the meeting, it was approved by the university's management board to continue, as recorded in the project document which could be found in the appendix.

7. The Construction of the Kinetic Art

Concept

As the Learning Garden of KMUTT should reflect the scientific and engineering aspects of the university, the concept for the Kinetic art thus bring the unique characteristic of an atom as the major concept.

Atom means the very small groups of particles which is the basic unit of the matter. Atom cannot be separated chemically. The particles in an atom are proton, neutron, and electron. The proton and neutron reside within the nucleus, which is a small part at the center of the atom, where an electron would orbit around at the high speed, as if it is a cloud of particle surrounding the nucleus.

Dimocritus, the Greek philosopher, once said that everything is consisted of a very small particle that it could not be seen. The particles would gathered in some way, and it could not be changed nor splitted down. Dimocritus named the particle "atom", from a greek word "Atoms", which means inseparable. According to him, atom is the smallest unit of a substance which can exist.

Atom is the smallest part of a substance with chemical properties. It could be found in the solid, the fluid, the gas, and plasma. Atom is a good metaphor of an education, which initially start from a very small place and enlarge continuously and dynamically by growing infinitely. According to this concept, the researcher design a form which extend outward from the center. There would be the reflection on the water surface, which metaphorically represent the knowledge application as two-sided as the bright side and the side underneath. As the sunlight shine over the glossy texture of the work, it would be as bright as the light of wisdom, which could be reflected around and bring light everywhere.

8. Structure of the Kinetic Art

As the form of structure has passed the screen and selection process, it was developed to be more unique. The moving joint was further adjusted to be more fluid by the mechanical science in many parts. The selected material is stainless, which is durable enough to withstand the outdoor climate with sunlight, rain, moisture, and wind. The material is strong and firm, with a long lifespan, especially the joint which require high level of durability, and the axle column which must receive the weight and installed in the pool with constant contact with water. Moreover, the sculpture's scale is quite large, with the diameter of the sculpture is approximately 5.4 meters, with 4 meters height. Therefore, the column must be strong enough to support the whole work and prevent it from collapsing. The sculpture would be installed on the base underwater. And the base would incorporate with the arm and photovoltaic cell, in order to transmit the energy to use with the underwater bulbs, which would light the sculpture at night. And finally, after the three preliminary sketches were presented, the advisor suggested that the third design should be developed and represent the concept of extension randomly in all directions. The balance would be created by using the weight, and the repetition would be lessening. Afterwards, the researcher designed 3 more works, in order to select the most appropriate design for actual construction. The design process can thus be divided in 4 steps; Sketch design, Elevation drawing, Elevation drawing in Detail and Final work rendered.

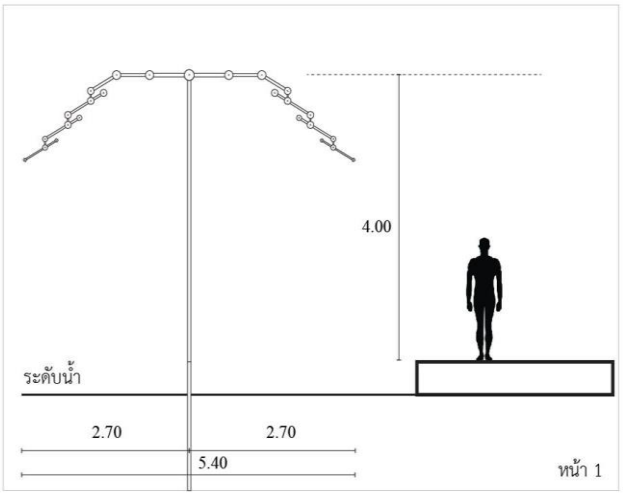


Figure 119. The overall size of the sculpture, 5.40 m wide and 4.00 m tall. By Researcher.

9. Sketch Design

The sketches were done on paper by considering the image output according to the principle and design process from the literature review and the experiments in chapter III. Additionally, the researcher imagined the movement from the natural wind power, with the balanced weight on three arms, which could spin with the wind independently.

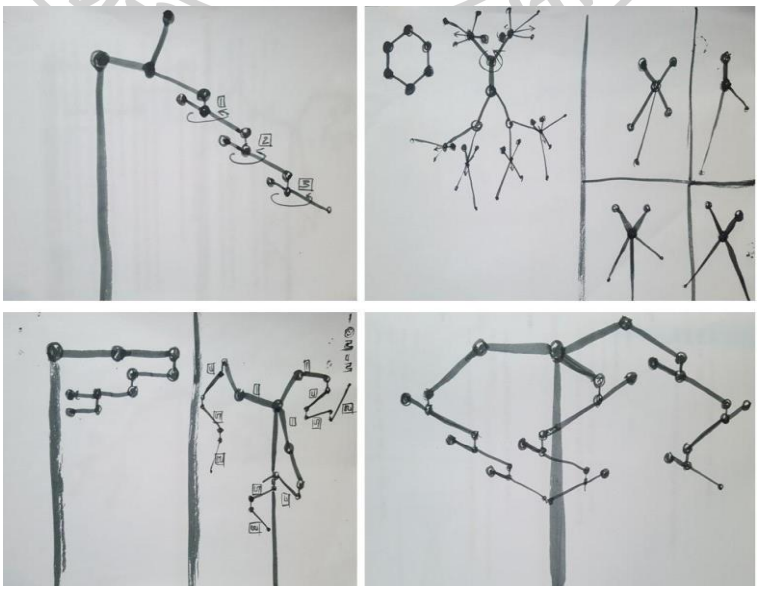


Figure 120. Sketches of the final design. By Researcher.

Chapter 4
DEVELOPING THE KINETIC ART SCULPTURE

The construction of Kinetic art sculpture have divided into 2 parts ; upper and lower part. In this chapter is the extension of the findings from PHASE I : Experiment of the sculptural form design from previous chapter. This chapter would thus describe elevation drawing of the Kinetic art would be construct, and the detail of the sculpture including the mechanism which allows it to move and the incorporation of the renewable energy by wind. The kinetic art could be divided in two parts; the upper part and the lower part. And this chapter is upper part of the kinetic sculpture.

1. Discussion

As the experiment required consideration of the rather smooth surface in order to attach Photovoltaic cell to collect solar energy for utilization, the researcher started from applying the geometric forms. The assembled geometric surface allowed convenient modeling of sculpture. The angle of the smooth surface could be adjusted. So the photovoltaic cell could be attached as designed.

In searching for the suitable form, the development process started at selecting the appropriate geometric shapes such as triangle, rectangle, pentagon, hexagon, heptagon, and octagon with equal length in each side of the shape. The shapes were assembled in simple forms such as sphere by using paper. After the experiment, it was found that the most suitable shape was pentagon and hexagon, which resulted in the appropriate and clear spherical form, with few edges and the most continuous roundness.

After the suitable surface was found, the structure model was developed. As the construction of planar surface required large amount of component for assembly, such as planar surface, connecting joint, and the additional beam to increase strength, it was necessary that the construction of each piece must be precisely equal in size. Therefore, the acrylic sheet which could be cut by laser cutter was selected. However, the photovoltaic cell was not yet assembled in this step. So the researcher experiment

with motif design by perforating the sheet surface for aesthetic function. Due to the experiment, the correct angle for construction of surface planar to face the designated direction was found.

As the basic mathematic calculation was used to find the appropriate angle, the researcher used the same principle to find further value in modeling the new form. The work in this process was inspired by the circular form of Mandala, which the pattern was divided into equal area with the joint at the center. According to the principle of Mandala construction, the structure was developed from 2 dimension into 3 dimensional structure, through the cut, fold, joint, and piercing. The new shape was found with different angle which allows its surface to face the wind from all direction. This mean the structure could move by when the wind blows.

The finding led to the knowledge that apart from using solar energy, the sculpture could generate electricity from wind energy as well.

When the actual construction was about to begin, the researcher entered the site to study its context which would be the criteria in construction as well. After the site analysis, it was found that the location in the middle of the pond might be inconvenient for maintenance of photovoltaic cell, as the sculpture rose 4 metres high from the water surface. Therefore, it would not be enough to bring a boat for maintenance, as it would require the scaffolding. Apart from the inconvenience in maintenance, it could also be harmful to those who responsible for maintenance. Hence, the researcher divided the sculpture in 2 parts; upper part and lower part.

In the upper part, the researcher would not incorporate photovoltaic cell. However, the work could pick up the wind and spin from the natural wind energy. And in the lower part, the photovoltaic cell would be attached in order to generate electricity from solar energy, which would be used with LED light in the underwater part of sculpture that will light the sculpture at night. And when the photovoltaic cell could be access conveniently, maintenance would no longer be a problem and it would be safer for the responsible person.

The material used in this sculpture is stainless steel, as it is durable and thus suitable for the location surrounded by water and located outdoor. Furthermore, shiny stainless could reflect the image of architecture, trees, and the natural environment around it clearly. This would ensure that the sculpture would blend with its surrounding.

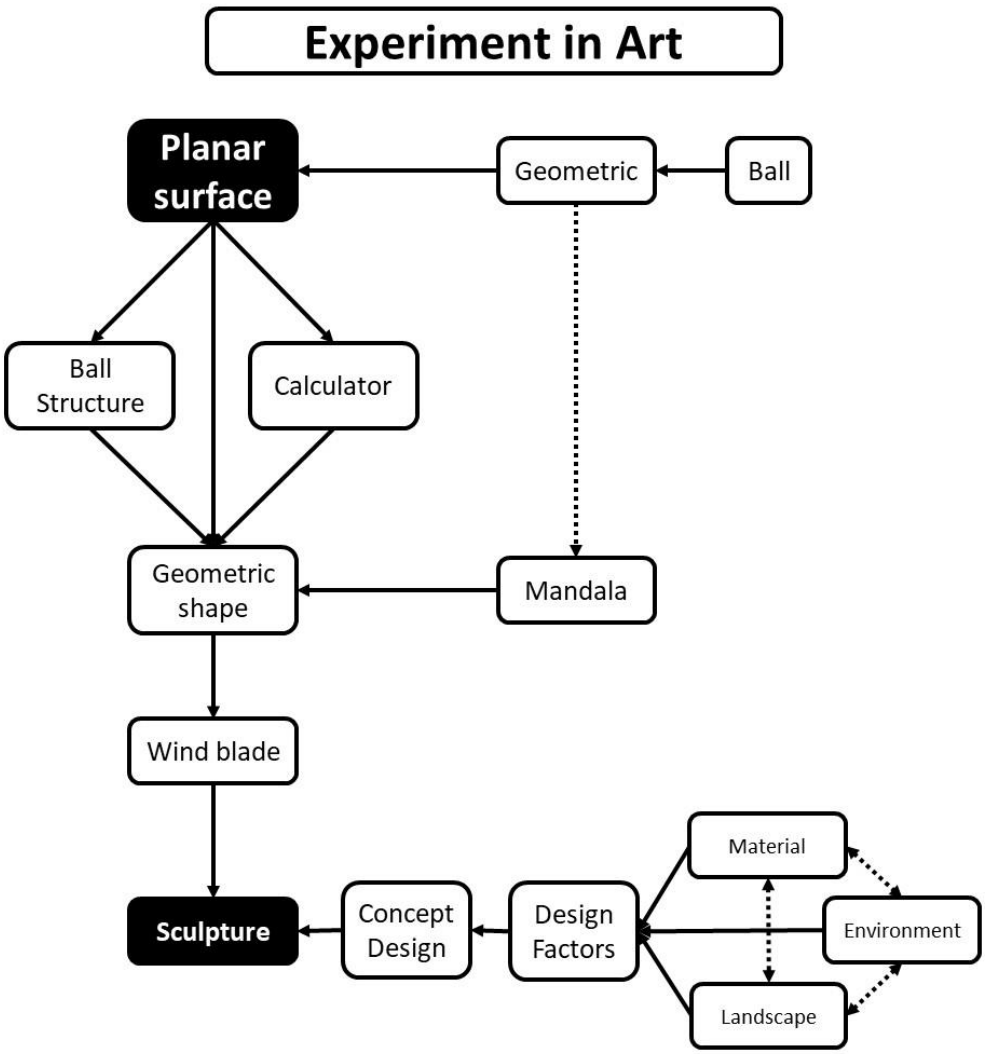


Diagram 3. Experiment in art. By Researcher.

2. Elevation drawing

There would be two major elements; the sculpture and the column beneath it. The sculpture would be above the eye level of the audience, and the column would be embedded to the ground underwater.

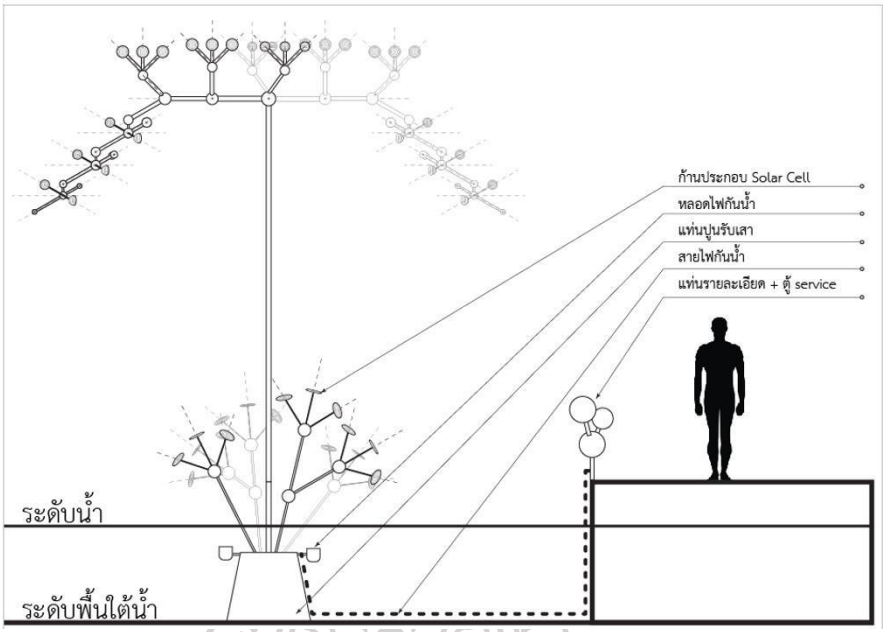


Figure 121. The overall design. By Researcher.

From the top view, there are three arms, which is divided into 6 joints. Each joint consisted of an axle connected by the spheres which gradually change in size from large at the trunk to small at the tip, which can be called A joint at the tip to F joint at the trunk, according to figure 122. Each arm would be installed in different direction, at the angle of 120 degrees. Joint D and E would be twisted counter-clockwise at 30 degrees each. When the arms are fully spread, the diameter of the sculpture would be 5.4 meters. Each arm of the joint A, B, and C could spin with the blades installed according to the picture.

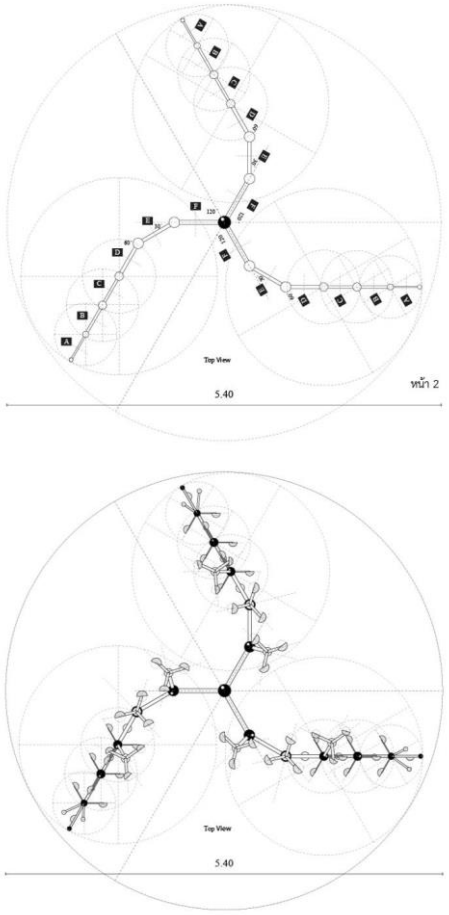


Figure 122. Top view of the structure, with three arms which incorporate the blades for picking up the wind at the upper part. By Researcher.

From the side view, at the joint E and F would be parallel to the floor, while the joint A, B,C, and D would equally tilt down at 30 degree. Each joint would be installed with a sphere at the end, which serves as the joint that can rotate around. The axles and the spheres would change in size gradually from large, to medium, to small at the tip of the arm.

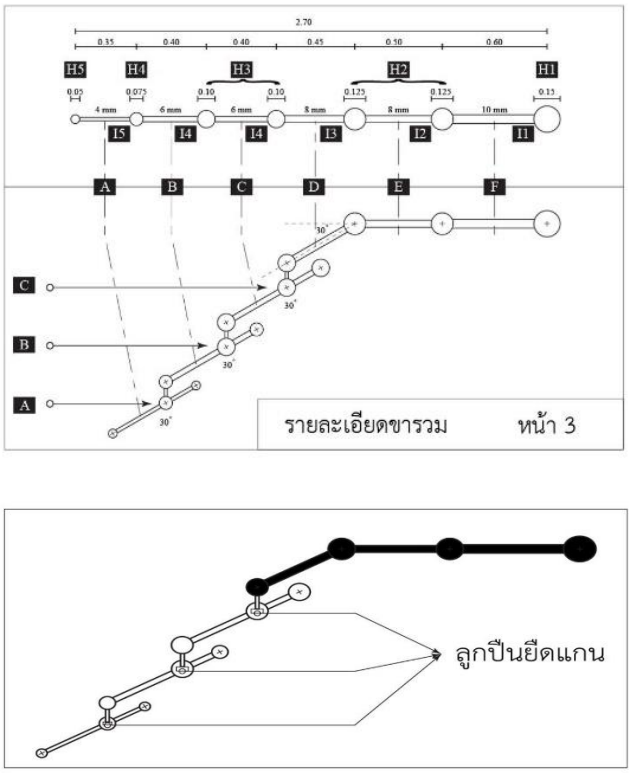


Figure 123. Side view of the arms and joint, with the ball inside the sphere. By Researcher.

3. Elevation drawing in Detail

Each sphere would be separately represent by code H1 to H5, and each axle would be represent by code I1 – I5, with different diameters and length.

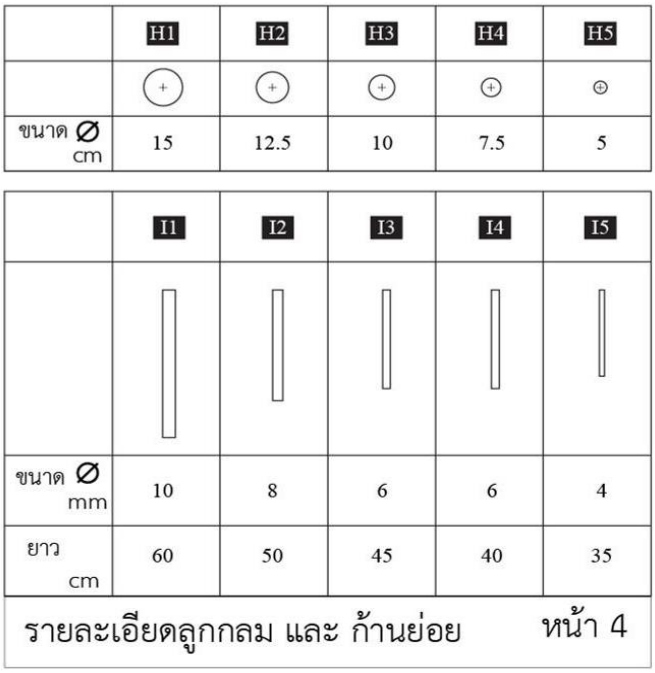


Figure 124. Detail drawing of each joints and axles. By Researcher.

The overall look of the joint A, B, and C are similar, with the difference at the size, in which the joint A is smallest and the joint C is largest. These three joins can spin, as the blades for picking up the wind are also installed as describe in the next detail drawing.

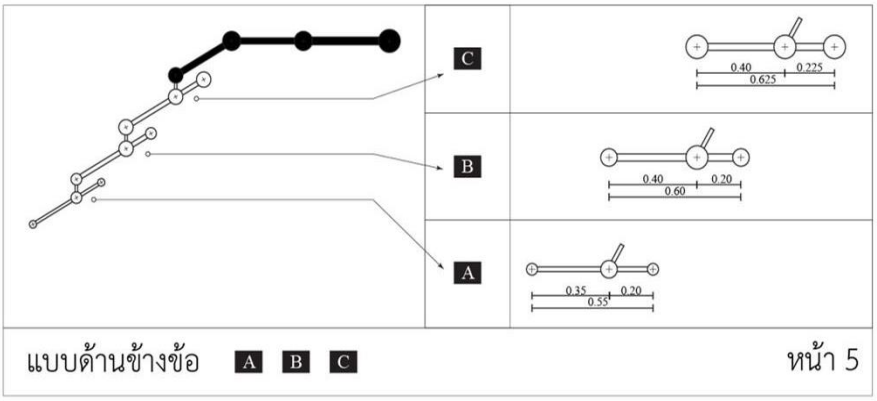


Figure 125. Side view of the the joint A, B, and C. By Researcher.

The detail of the joint A is the smallest one. And as it is the ending joint, three decorative arms were added on the left part of the joint, with two additional balancing

arms on the other side. The whole arms would be tilted down 30 degrees, and the blades would be tilted up 30 degrees on the opposite direction. The three blades are 120 degrees apart from each other, and would rotate counter-clockwise when they pick up the wind and thus spin the joint A simultaneously.

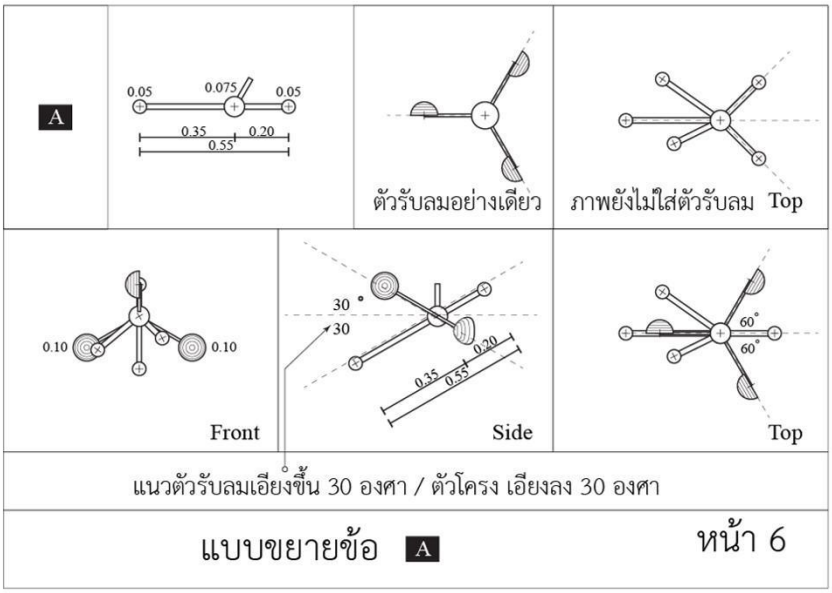


Figure 126. Detail Drawing of Joint A. By Researcher.

The joint B and C are similar in detail and different in size. The joint B would be bigger than the joint A but smaller than joint B. There is only one longest arm, with three balancing arms installed on the opposite site. The whole arms would be tilted down 30 degrees, and the blades would be tilted up 30 degrees on the opposite direction. The three blades are 120 degrees apart from each other, and would rotate counter-clockwise when they pick up the wind and thus spin the joint A simultaneously as well. And as the joint A, B, and C can all spin with the blades installed within each arm, while connected to each other by the balls which would allow each arm to spin independently and randomly.

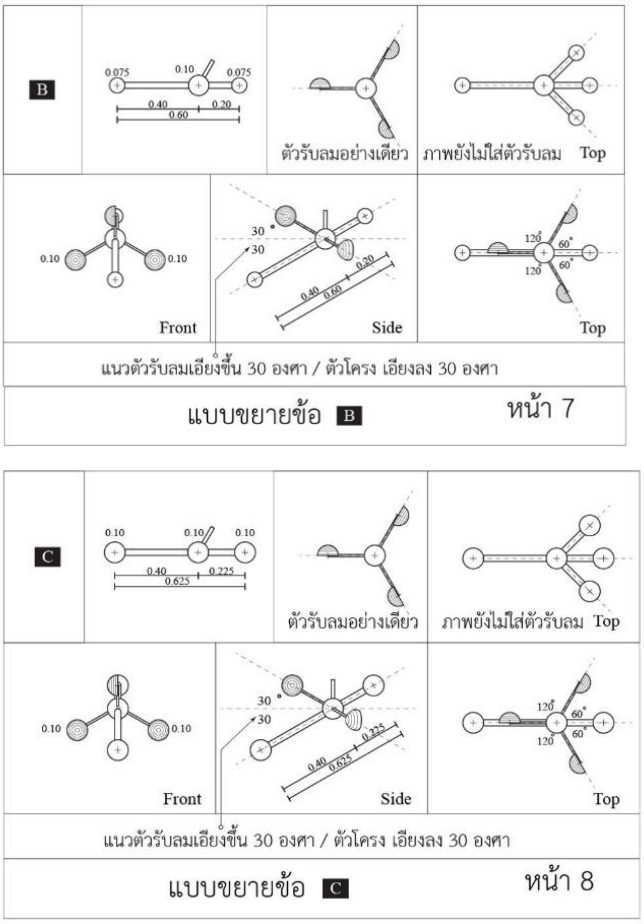


Figure 127. Detail drawing of the joint B and C. By Researcher.

From the top view, the joint D, E, and F would tilt down 30 degrees and 60 degrees consecutively. But the side view of the joint D would tilt further down 30 degrees, while both the joint E and F would be installed horizontally. Each joint would incorporate the wind-picking arm. And the arm of the joint F would tilt forward 45 degrees, and the joint D would tilt backward 45 degrees, while the joint E would tilt upward to the sky.

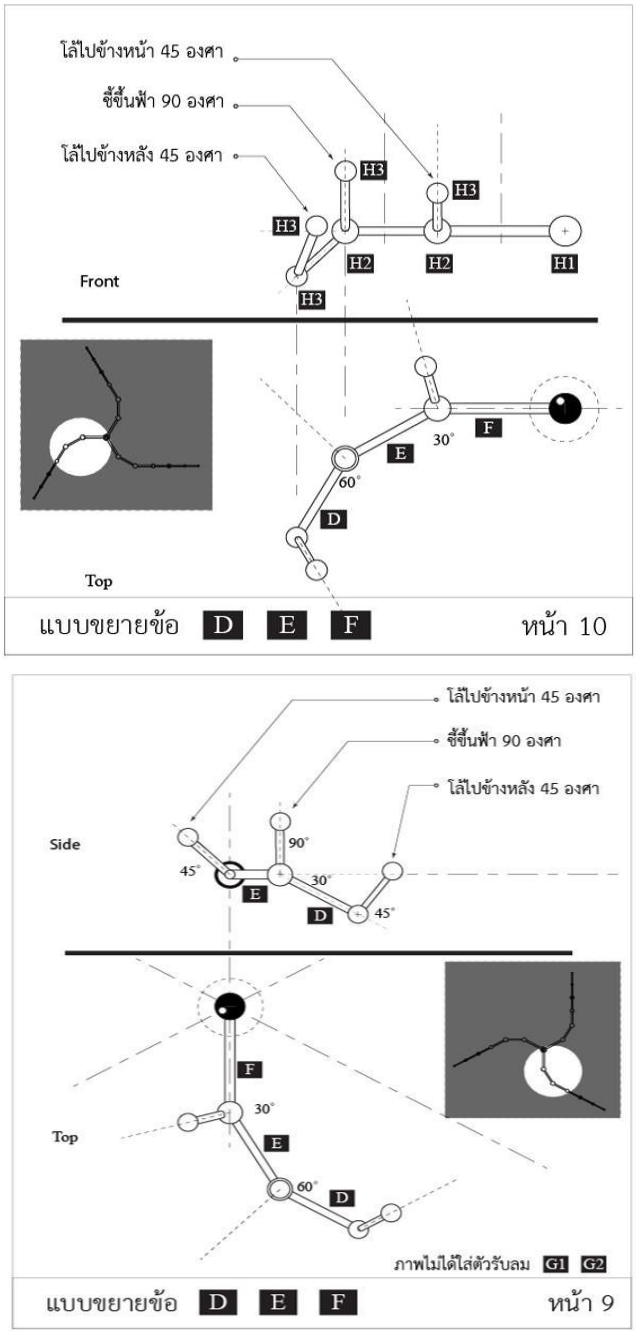


Figure 128. Detail Drawings from the top view, front view, and side view of the joint D, E, F and the tilting. By Researcher.

The wind-picking arm, as mentioned above, would incorporate three blades with 120 degrees distance, and vertically tilt 45 degrees as in figure 129. The blades are in the half-circle shape in order to blend with the spherical joint. One side of the blade would pick up the wind, and the other side would let the wind flow pass it.

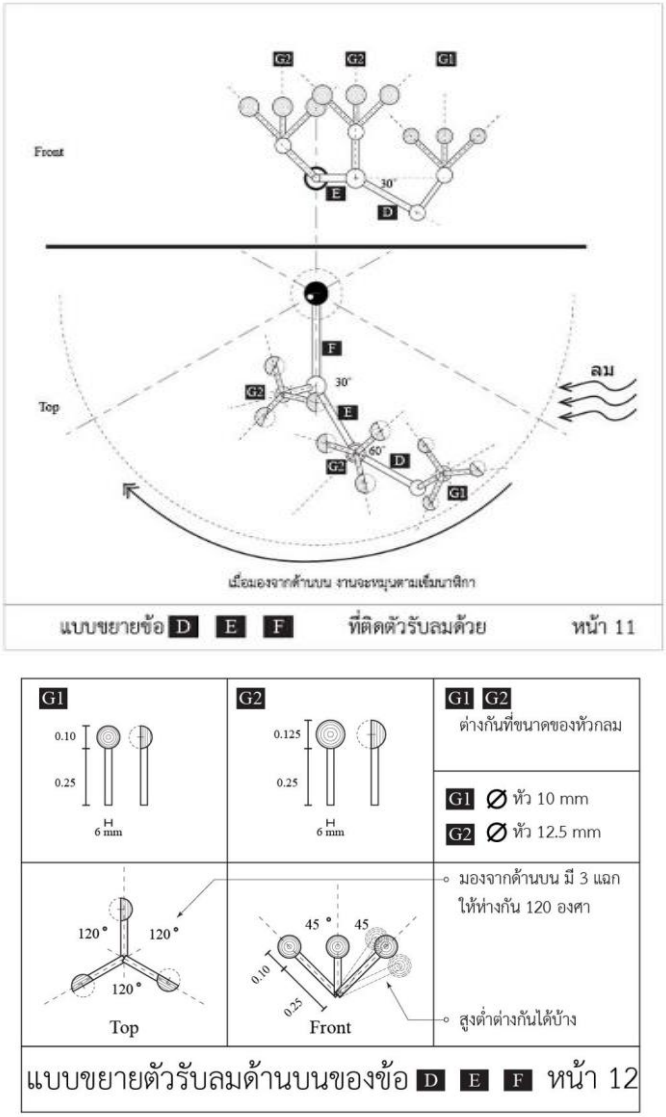


Figure 129. Direction of the blades and the detail drawing of the wind-picker. By Researcher.

The wind-picker would always turn its section towards the center, in order to distribute the wind-picking to all blades. When each blade move vertically towards the center, it could be seen that the section of each blade are all in the same vertical plane, which would drive all of the wind-picking side to the right.

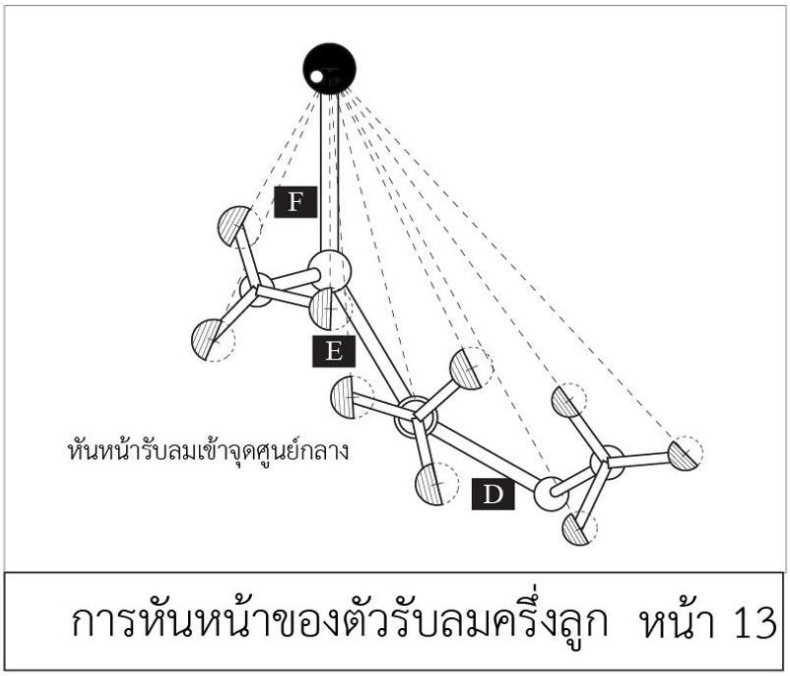


Figure 130. Angle of the wind-picker blades installation. By Researcher.

Chapter 5
DEVELOPING THE KINETIC ART SCULPTURE

This chapter is the extension of the findings from PHASE II : Experiment with the Photovoltaic cell . This chapter would thus describe elevation drawing of the Kinetic art would be construct, and the detail of the sculpture including the electric device which allows it to generate electricity and the incorporation of the renewable energy by sunlight. And this chapter is lower part of the kinetic sculpture.

1. Discussion

It was necessary that the design of photovoltaic installation must ensure maximum facing of sunlight in order to use the full capacity of light wave. However, the sculptural form must be aesthetically pleasing as well as efficient in energy generation. Therefore the balance between scientific efficiency and artistic beauty must be kept.

Initially, the researcher experimented with the design of planar surface in different angle in order to observe the brightness at the surface when it face the sun in different time of the day from dawn to dusk. Then the angle of planar surface in different direction was found and later tested by using the application. The 3-d model would be lighted by the virtual sun which follow the path of the sun in the day of experiment which the most suitable angle would be confirmed again.

After the difference in angle and amount of light was found, the researcher built a model with photovoltaic cell attached on the equipment which could be adjusted in different angle. Each piece was adjusted in various direction, resembling the curve of turtle's back. This form could collect solar energy throughout the day, and when the generated electricity was transmitted to the motor, it could work well and could be used in the design. For example, the motor could be used to move the brush on the paper and create lines and patterns from the ink and brush which was moved.

According to the result, it was found that the planar surface does not necessary turn to face the light directly. It is possible to compensate for the loss of electricity power

by increasing the photovoltaic cell in order to generate enough electricity for the component.

In this sculpture, the upper part could move with the natural wind which flow through the architectural void and the trees into the location. And the photovoltaic cell would be installed at the lower part and the generated electricity would be stored in the battery. There was the control board which would ensure that the light would turn on and off at the particular time. And the battery would be used for the underwater LED light at night.

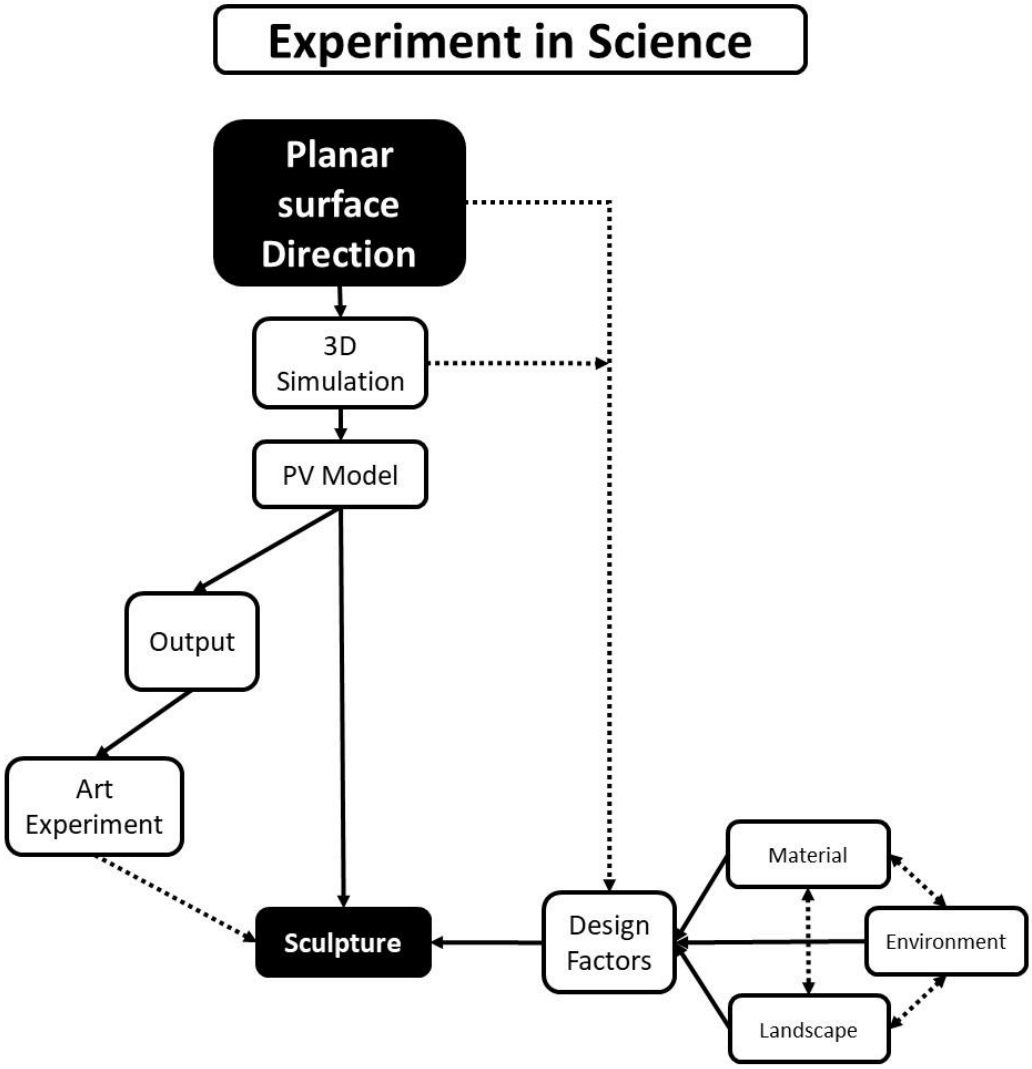


Diagram 4. Experiment in science. By researcher.

2. Elevation drawing

The lower part underneath the water consisted of the foundation with micro piles of I-beam. The steel structure would be buried in the concrete, and could safely support the weight for 25-30 ton per each foundation pile. The concrete thickness is about 6-8 centimeters, with the length of 1.5 meters. The length can be added by joining the foundation pile with the bold welding. The piling with micro pile would require a special drop hammer system. At the top of the foundation is located a small sculpture with a long tube and spheres which resemble the sculpture above. At each end of the tube would install the photovoltaic cell, which would be connected to the water-resistant electric wire in the tube linking downward to the foundation, the floor of the pool, and the edge of the pool. At the edge of the pool, there is another small sculpture base which display the sculpture name and the concept. This base also serves another function as a service cabinet which stores the battery where the electricity from the solar cell would be stored. The circuit board in the cabinet would control the electricity transmission towards the underwater lighting at the sculpture base, which would give the glowing light for the kinetic art at the upper part at night.

The lower part of the sculpture, as seen in detail drawing in figure 131, would be underwater, with the foundation built from micropile, where a semi-functional sculpture would be installed. This sculpture would resemble the atomic form of the upper part, as the main elements are the sphere and axis. But the tip of the arms would incorporate 15 panels of Photovoltaic cell 4.8W, in order to generate electricity from solar energy. The electricity would be used with the four underwater LED bulbs of 18 w, which are installed on the foundation, connected with the sculpture's title display box on the edge of the pool by the water-proof wire. Inside the display box, the battery and the electricity circuit will be stored, so that the generated electricity can be stored and later used with the underwater LED bulbs to illuminate the water surface and the kinetic art.

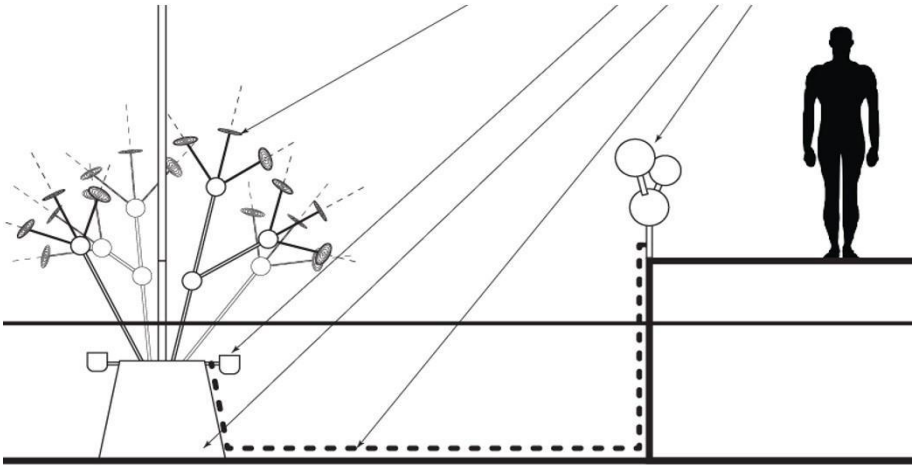


Figure 131. Detail drawing of the foundation. By researcher.

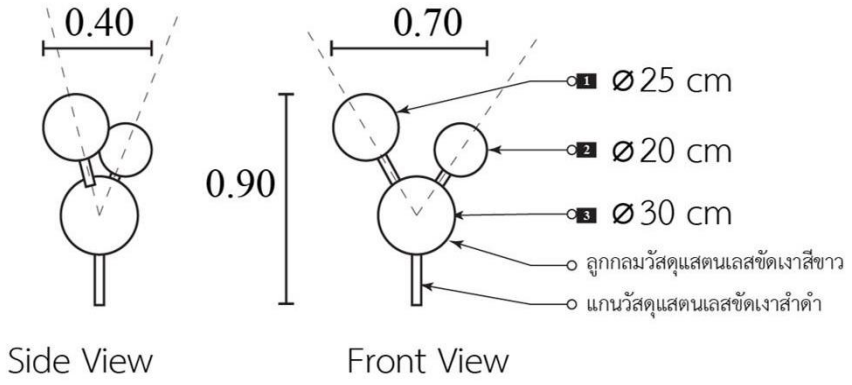


Figure 132. Detail drawing of the sculpture's title and concept display box. By researcher.

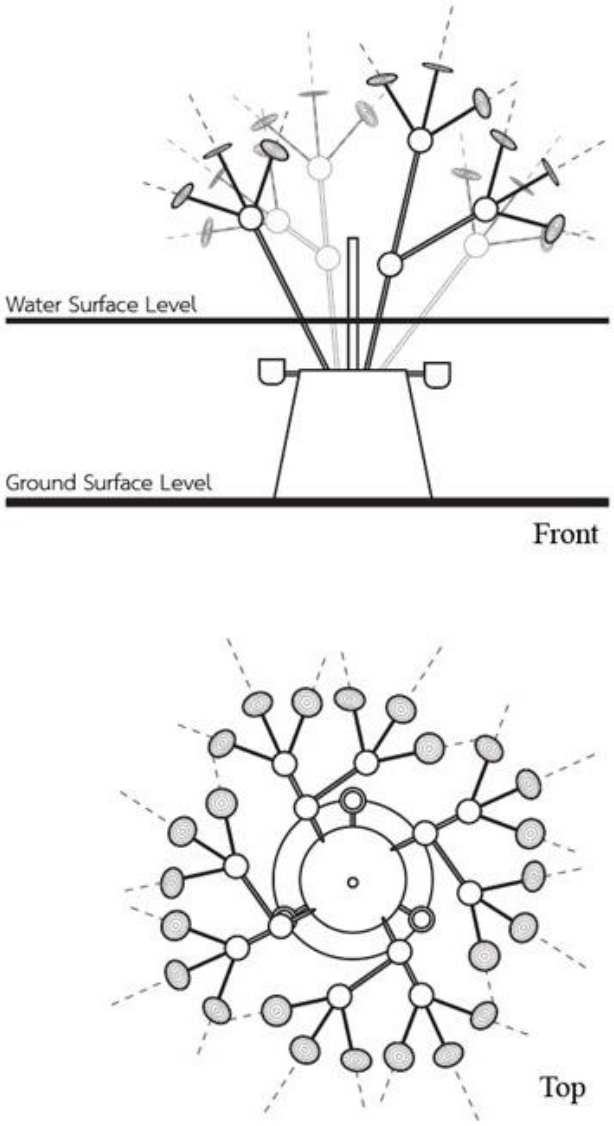


Figure 133. Detail drawing of the sculpture's title and concept display box. By researcher.

The structure from the top view was divided in 4 big branches with 2 medium branches extended from each branch. Three smallest branches which extended from each medium branch were attached with the photovoltaic cells which were aligned in curve in order to face the sun all day.

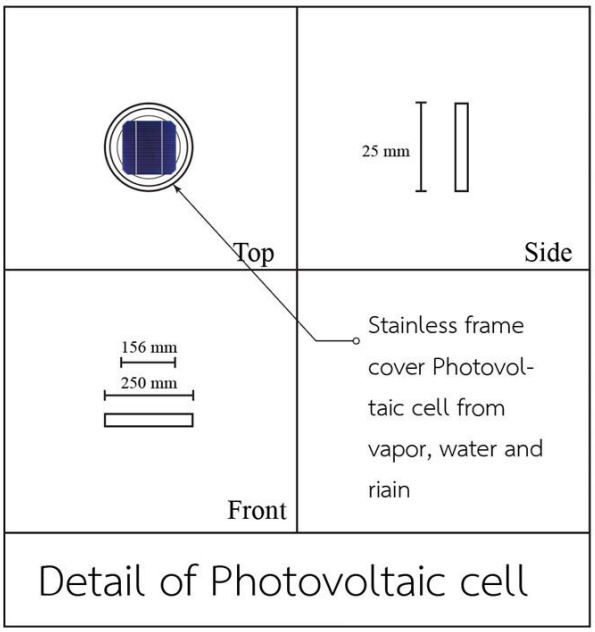


Figure 134. Detail drawing of the sculpture's title and concept display box. By researcher.

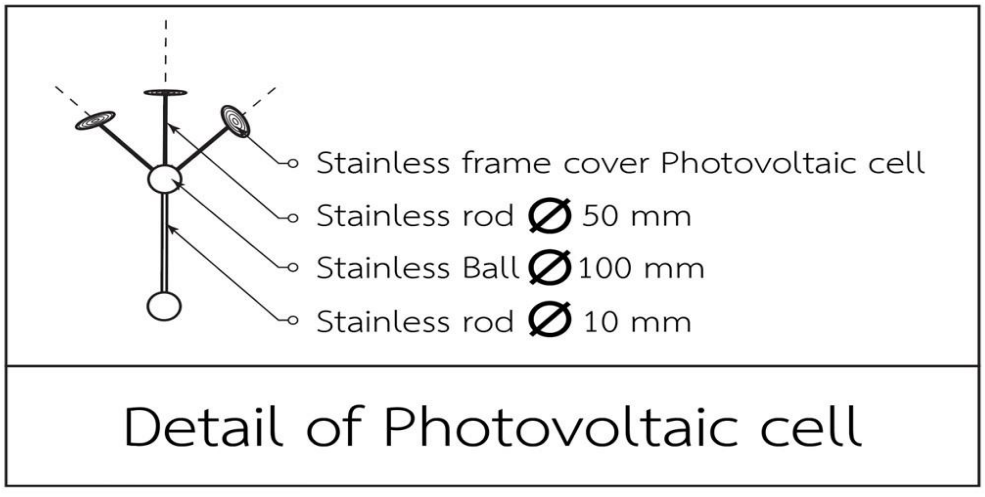


Figure 135. Detail drawing of the sculpture's title and concept display box. By researcher.

Figure 136. Underwater LED light, 18W.

From "18W Marine Underwater LED Lights for Boats.", by LightingNext, 2009,

https://www.lightingnext.com/18w-marine-underwater-led-lights-for-boats.html.

Copyright 2009 LightingNext Ltd.

*Figure 137. Photovoltaic Mono Cell 4.8W 156 *156MM.*

From "Monocrystalline Silicon Cells.", by Dricus, 2011,

https://sinovoltaics.com/learning-center/solar-cells/monocrystalline-silicon-cells/.

Copyright 2019 Sinovoltaics Group

3. Final rendered work

Prior to the installation, the researcher created the three-dimensional model of the sculpture, as seen in figure 138.

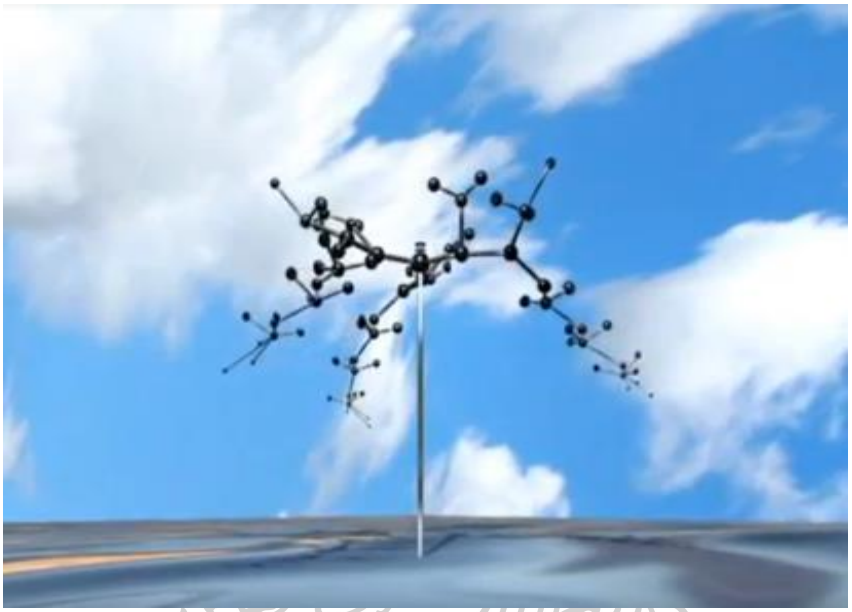


Figure 138. 3D Model of the Sculpture Design 3.3. By researcher.

4. Conclusion of the Kinetic Art Construction Project.

The construction project for this Kinetic sculpture require co-operation from two major partners. First partner, or the scientific and engineering side of the project, is the Office of Building and Ground Management, who gave suggestion about the construction of foundation and the specification of the water-proof equipment used in this project, such as underwater wires, lightbulbs, photovoltaic cell, including the connecting and the amount of photovoltaic cell required for enough electricity generating, as well as the specification of the battery and the control circuit for the lighting timer. The second partner, or the artistic side of the project, is the Southeast Empire co., ltd., who suggested about the structure and mechanical parts of the kinetic sculpture, especially the equipment which would enable the sculpture to move and the appropriate material for the construction of sculpture.

After consulting both partners and receiving the data, the researcher progressed with the detailed elevation drawing in order to submit a proposal to construct the sculpture within the Learning Garden, a part of King Mongkut's University of Technology Thonburi. Meanwhile, the researcher submitted the same detail drawing for cost estimation, in order to incorporate the estimated price as a part of the proposal for the university. When the project had been approved, the construction eventually began.

Chapter 6
CONCLUSIONS AND RECOMMENDATION

1. CONCLUSIONS

The aim of the research is to create Kinetic Arts Design with Renewable energy for Learning Garden in KMUTT with Photovoltaic cell. Solar energy has been widely used in many parts of the world. If being used appropriately, it has more potential in energy production than the world's current energy consumption. Solar energy can be used directly for electricity or heat production, or even cooling. Nevertheless, the word "solar energy" means a direct transformation of sun light, rather than a production of heat or electricity for using purpose. To elaborate, a photovoltaic cells process is an electricity production from light.

Nowadays, architects have increasingly use photovoltaic cells as essential design attributes. The example is; the use of photovoltaic cells, attached to ceramic or slate tiles, to replace the commonly used roof materials.

Design and art does not only comfort the soul, but adding functions can also add more value to the art itself. Imagine a sculpture displayed outdoor, weathering by the sun and rain. Would it be better if it can produce energy from sunlight besides being aesthetically appreciated?

Thus, the focus of this study is qualitative "practice based research". The methodology consists of two parts as follows; I. The photovoltaic cells experiment: This experiment aimed to find a suitable planar surface and angle for receiving of sun light for Photovoltaics cells related development. The experiment began at testing the sun direction that reflects on the experimental surface. The result was used for sun radiation calculation afterwards. The sun radiation value was used in mathematic calculation to find a suitable electricity voltage. The related photovoltaic cell size could then be calculated before being assembled to the sculpture. For the second phase of this research, II. The sculptural appearance design experiment: was aim to find the most suitable design direction for mechanics and techniques creation of the actual sculpture.

The creation of Kinetic Art was an artistic work that focused on a movement of an object which usually stay still. The arts then made alive by several mechanics such as; retract, expand, tract, impulse, rotate, sway, swing move and bend. These actions could be generated from any energy source, both renewable and non-renewable energy, such as electrical and natural energy. Due to this reason, the Kinetic Art creation with movements from renewable energy, for example solar energy, could be an interesting option. This method can also be considered for the art work that is located in a difficult electrical wiring location or location with high cost.

According to Kinetic Arts Design with Renewable energy for Learning Garden in KMUTT: Photovoltaic, the study results of this sculptural creation could be presented in three aspects as follows;

1.1 Designing a sculpture by using Photovoltaic cell;

I. Art

In order to design the sculpture appearances with Photovoltaic cell, all sun light related factors were needed to be studied for decision making. The design was a combination of the designer's identity and a sculptural form modification for solar energy receptors.

The receptors were intended to collect and distribute the solar energy to specific parts of the sculpture. Using the method mentioned previously, an art work relies on solar energy could be created anywhere in the world. The mathematic calculation was also needed to find the right *Angle of Incidence* of that location.

As Thailand's average altitude is 15 degree south, this means that from dust till dawn, the sun rises in the East, travels above our heads slightly to the South, as Thailand is located above the equator, and sets in the West. This information determined the work's installation direction and some parts of its appearance.

II. Science

The sun light study allowed us to learn about the relationship between the sun and the earth. The sun ray shines from the sun, reflecting to the earth in a spherical form. Therefore, the earth receives different amount of sun light across its surface. Moreover, the earth tilts at 23.5 degree angle and results in the seasonal changes. Seasons differences create atmosphere variations. Heat or cold, everything will affect the earth atmosphere which filters sun light intensity that is reflected to the earth. For this reason, each area will receive different solar intensity, including light receiving direction.

When Photovoltaic cells were used to receive solar energy, to turn it into electrical energy for applicable purpose, mathematical calculations were involved as follows;

a. Sun ray

b. Photovoltaic cell installation and surface inclination to receive sunlight

c. The amount of Photovoltaic cells in case the surface is not installed to fully received the sun light as the surface was distorted due to overall form complication.

d. The installed electrical device for sculptural purpose.

III. Area

a. The Landscape

Each location has its own story. Some stories were defined by the human using the area, in the form of culture, tradition, etc. Some stories were defined by the area's natural environmental features, for example; mountains, rocks, rivers, trees, climate, etc.

The learning garden (LG) in this study is located in the university, surrounded by buildings, people, trees, ponds, walkway, and other functional spaces. As the sculpture is located on the pond's surface, the adjacent natural features are; water, wind and sun light. The sculpture is also surrounded with the man-made features, such as buildings and recreational garden.

People participated in this study travel, make use, and participate in this area all the time. Everything moves under the drive from nature and organism. Therefore, a moveable sculpture can take part of this society.

1.2 Concept

The sculpture is located in Learning Garden (LG), King Mongkut's University of Technology Thonburi (KMUTT). KMUTT has been designated one of the Nine National Research Universities, with World-Class Capabilities. Its academic strengths are Architecture, Bioresources, Energy, Engineering, Environment, Linguistics, Science, and Technology. It appears that KMUTT focuses mainly in science. Therefore, the concept design of the Kinetic Art was drawn from the significant quality of Atom.

Atom, the smallest part of general matter with chemical elements, in a form of solid, gas and plasma, was integrated with a non-stopping, moving, and endlessly expanding study concept. Therefore, the sculptural appearance extends from the center. The reflection from the water surface refers to the two-sided knowledge use. Moreover, the reflections from all around itself imply the knowledge that shines and reflect wherever it is.

1.3 People, audiences in circumstance.

People

Learning Garden (LG) is located at the center for the university, where people travel pass-by. Moreover, there is a rest area, for people to spend a peaceful spare time, review the knowledges from studying. Experiences and learning happen here all the time.

Participants involved in the installation area can be divided into two major groups as university residents and non-university residents.

The first group was university residents such as; lecturers, staffs and students.

The second group was non-university residents such as; general public that come to use university's facilities such as; libraries, canteens or travel pass-by.

When these two groups saw the Kinetic Art, they showed appreciation in the beauty and felt pleasured when the art moved along with a natural wind. Moreover, they felt impressed and relieved as feeling comfort; the brain relaxed as the thought could rest.

Overall, this Kinetic Art was expected to be an inspiration source for other body of knowledges creation continuously, not only restricted only for art, but also other type of sciences, as though the dissociation of the atom that as much as they collide, the more they continue to regenerate.

1.4 Learning

Kinetic Art form branches as lines, connecting to a sphere, resembles to the tripod-branch atom that spaced wide-range. Looking from any side, the Kinetic Art had a dimension depth. When moving, the elongate limps swirled across each other, creating a diplopia. The moving sphere then looked like a drifting star.

By looking at these complex images, the viewer who was immersed in his study might be able to think more creatively. He could adapt these phenomena to his other thoughts, creating new personal knowledges.

1.5 Inspiration

If the designer artist has seen this Kinetic Art, his impression could lead to additional an art-creation inspiration. He could then build a unique piece of art according to his own identity. He will be determined to create an outstanding masterpiece which will then foster art advancement.

2. Innovations

This study yields the new approach which could be further developed into many other applications. The sculpture form could be changed by rotating, scaling, and moving three types of elements which were the planar facets (F), linear edges (E), and point vertexes (V) according to the desired topology. The more complex manipulation of the element, the more possibility of aesthetic could the sculpture become. However, the manipulation of form must be done with careful consideration, for it must also follow the sunlight-related factors such as different latitude, environment, and period. (Saitum, 2018)

I. The design of new forms could be accomplished with the FEV design fundamentals, which would allow the designer to achieve more type of surfaces. The design would be more complex from the original prototype and could follow the concept with the desired level of curve or smoothness. But as the solar zenith angle must be considered in the calculation of the planar surface tilting, the form would require crystallization as shown in figure 139.

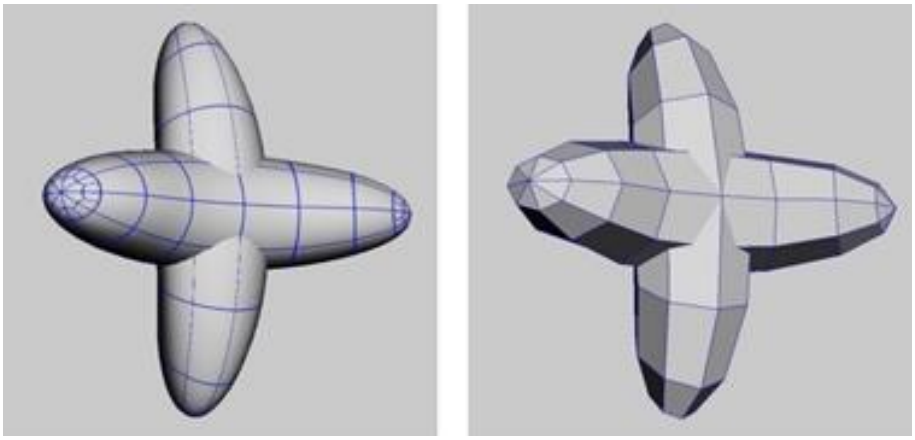


Figure 139. The design of more complex sculpture while considering the solar zenith angle. The left picture illustrated the example of free form designed, while the right picture demonstrated the crystallization. By researcher.

II. The major limitation of the sculpture design for sunlight exposure is that it could be exposed to light from the top direction only. This problem could be solved by placing the mirror underneath the sculpture to reflect the light towards the sculpture plane, which might allow the sculpture to generate twice more energy. This technique of using mirror to reflect the light could also allow the sculpture in shady area to be exposed to the sunlight and generate electricity. Or in the case of the sculpture which would be installed over the water, the reflected light from the water surface might also allow the surface plane underneath the sculpture to generate electricity. However, it would require more study about the reflection of the moving water surface which would be different from the regular mirror.

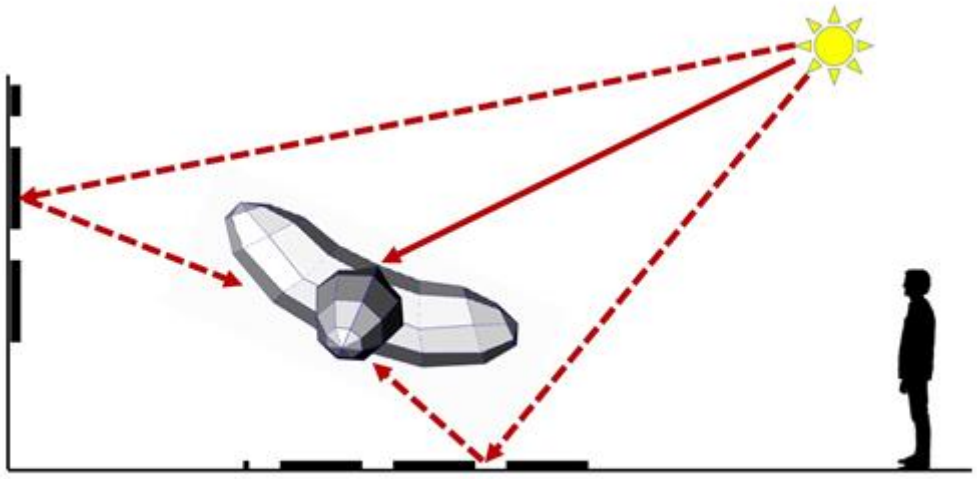


Figure 140. The reflection of sunlight onto the sculpture surface in shade. By researcher.

III. If the sculpture could generate electricity by its own, the energy application could be used for both outside the sculpture and with the sculpture as well. Therefore, the sculpture could be developed into kinetic arts, or the art works consisted of movable parts or movement driven by the electric power.

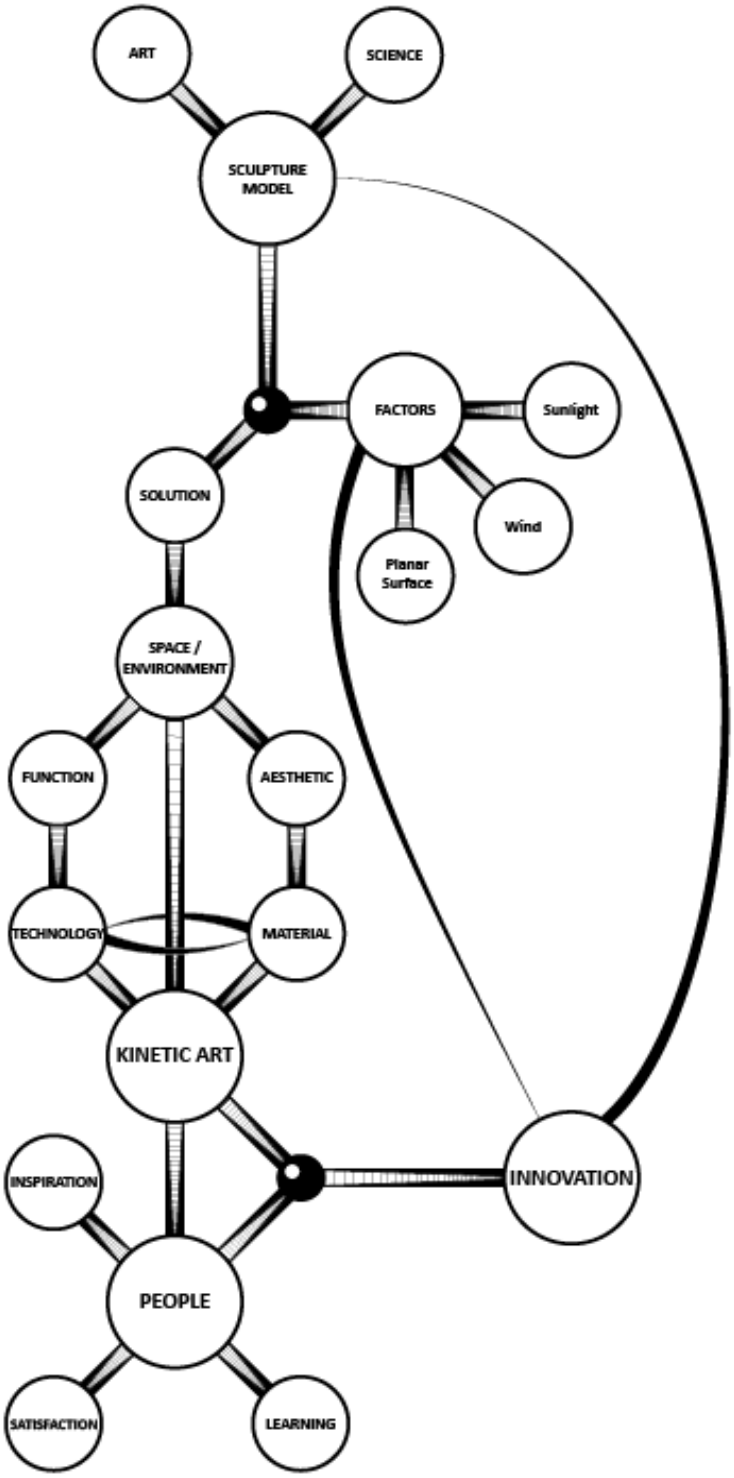


Diagram 5. Conclusion Diagram of the Contribution. By researcher.

3. Summary

According to the diagram 5, the researcher can summarize Kinetic Art creation into seven main processes as follows;

3.1 Art & Science in Sculpture model

The creation of the sculpture involving a technology needs to consider two major parts. The first part is the art that create an aesthetic experience. The other part is science that uses a specific technology, blending these two disciplines together creating a sculpture made from basic materials, integrating a present technology, creating a unique piece of art.

3.2 Factors : Sunlight, Wind and Planar Surface

In order to integrate technology with art, related factors need to be considered inevitably as all technologies have both capacities and limitations. Therefore, all-around factors needed to be considered. In this research, renewable technology, especially solar and wind energy were the sculptural creation topics. In order to use this energy beneficially to the sculpture, the adjustment of the installed applications quantity was needed to be taken into consideration. Moreover, the appearances needed to be designed to fit with the mentioned energy retrieval.

3.3 Solution for Space and Environment

The harmonious integration of Art and Science becomes a new balanced design direction resulted from restrictions. In the other word, the success came from systematic problem solving procedures. This creates a design pattern for new sculptural format to follow. Variations in the sculpture design depend on many factors such as; installation area, surrounding environments, color of the surrounding architecture or nature, bird sound echo direction, etc. The soil's smell and humidity also affect the art work's construction material. Climate is another factor that will impact the artwork creation, if the sculpture relies on natural energy such as sunlight and wind.

The factors mentioned above will differentiate the art work as it will result from the cause and effect of the surrounding contexts.

3.4 Function and Aesthetic through Technology and Material

Technology was invented to serve some human needs. Thereby, technology must come along with some using abilities, or what we called “function”. Function determines material use that will respond to a specific use, creating a proper efficiency. Another additional thing to consider is a material compatibility as it affects the sculpture’s visualization, which will enhance the aesthetic dimension in the work of art.

3.5 Kinetic Art

From the design with an integration of function and aesthetic, a sculpture work that associate a natural energy occurred. When an energy source generates movements, we call this an illusion-move Kinetic Art. This art works by using visual elements that shake and overlap. It moves by itself from the mechanic powers.

3.6 People and their Satisfaction, Inspiration and Learning.

Viewing the Kinetic Art, the first impression of the viewers is a movement along rhythms of natural creation. Satisfaction of the viewing aesthetic can lead to the source of inspiration that produced art creation, as well as, encourage the continuously learning in other topics which can be adapted with.

3.7 Innovation

The nature cannot change itself. However, human can adapt, finding a new way to change some realities. All these changes are to benefit human living. In other words, human can use their own intelligences to design and adapt surrounding things to benefit an everyday comfortably living. Each design is an advancement of thoughts that sums up, which results in new design innovations that evolve from the past, and then continue to the future. However, the pros and cons of the design must be taken into account inevitably to improve the next

design. Moreover, inevitable factors such as the natural energy impacts must also be considered.

4. Recommendation

4.1 The researchers found that the creation of an artwork that relies on other external factors must thoroughly study those factors, before consider them as associated factors. Those factors shall comply with art work contexts, not only sketching coloring, sculpture but also architecture, to be consistent in order to create the art smoothly and with fine qualities.

4.2 The complete change of the design forms, from their previously existing, can lead to design directions, even the design has not completely solve the problems. This change could be adjusted to the design improvement in the next stage. This is the discovery of the design that suits the artist identity.

4.3 Regards the site-specific design, the essential thing is to collect all surrounded details that occurred naturally, such as direction and shade if sunlight, winds that flow through the building, waves ripples that hits the stone. These are important information for a design. Very small things that seem irrelevant can also still affect the overall.

4.4 Some of the problem occurred due to the context of the site such as the area, surroundings, requirement from the contributor, which led to the suitable artistic design for the particular context. Hence, the designer must create the balance between beauty, suitability, and function.

4.5 The design which incorporate electric component is one of the factor which must be considered in adjusting the form, as it became the criteria for design to cover the required parts for the particular component. However, the component must be connected in order to function. This might disturb the beauty of design and thus require the solution which would harmoniously ensure both function and beauty.

4.6 n studying the work from successful designer or artist through literature review or the actual installations, the designer must be careful not to let the influences from those works to manifest in one's own work. The study could be just the point of inspiration for developing one's work, by redefining and refining such works in order to create progress. Utilizing the existing concepts without any further development would led to the plagiarism, by recreating the works without any originality from oneself in the work. Then it would be just another old and ordinary work, not a creative one.

4.7 Apart from creating beauty in the area for people's relaxation, there could be the public function of the sculpture. But the sculpture which could move by the wind energy together with electrical component utilizing solar energy from photovoltaic cell would require regular maintenance. Therefore, the convenience in maintenance is another concern, as it would ensure that the sculpture would not be ignored and would be well-cared for. In some case, the adjustment for easy maintenance might require the adjustment of sculptural form for this reason. Hence, it is the direct duty of the designer to balance the design for aesthetic, function, and maintenance.

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