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Biomimicry Kinetic Facade as Renewable Energy

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Abstract. This article is an alternative research design for sustainable energy in high rise building through wind kinetic facade. This research purpose is to open the mindset of sustainable energy and to seek an alternative design for renewable energy facade through the wind while rising the diversity of building environments by sound in its process.

In the modern city, the existence of energy is crucial and energy consumption demand is rising through time. The mindset of renewable energy facade through wind is purposely to support energy consumption. And the absolute existence of wind makes it possible to harvest energy through the day without restrictions, especially in high rise buildings. Sustainable energy is about how a building capable to create energy, reduce energy consumption, and creating environment diversity for human health and well-beingness. The environment elements that perfectly match with renewable energy facade through wind is sound.

Keywords: Sustainable Energy, Renewable Energy, Wind, Kinetic Facade, Sound

1. Introduction

1.1 Cities, Energy, And Well-Beingness

Every city eventually will continue to grow, both economically and the numbers of its population. However, ground spaces are limited for each individual and their activities. For example, residential space is limited. Therefore, high rise building is a solution to expand more spaces in the city, usually called by vertical living. The concrete solutions are apartment buildings, it is simply a stacked residential. And those typical solutions are wide-spread to other activity spaces, ex. office buildings, shopping centers, indoor theme-park, etc. The question is 'is it make the city a better place?'. Unfortunately, it isn't, for the energy consumption spiked, and the human well-being is drastically reduced.

"..the adverse consequences of our human activity on psychology health and well-being are often accentuated in our urban environment.."
Ken Yeang, 2010[1]

An overcrowded poor-designed city is creating a repetitive and monotone environment that effecting psychological health and well-being in human activities. Comparing how environment diversity affecting psychology health and well-being, for example, at ground level we tend to

interact more with things that happen around us then when we are in few levels above the ground. That was because there are richer environment elements that we experience, ex. sounds, light-shades, breeze, colors, other activities, etc. The more interactions we do make us more active, and psychologically simulated through our senses. However, in high rise buildings, those rich environment experience gradually reduced. For example, we could see and hear a car crossing the street at the ground level: we could hear, see, and even feel the breeze when it happens. Few levels above the grounds we slightly hear it, and probably can't feel the breeze when the car passing by. We still somehow notice the car passing by seeing, but our other senses can't. This is when the sustainable design came in, by creating a new diverse environment, a design that enrich a space to mimic the psychological stimulation through our senses, for example: water fountain, textures, moveable or moving elements, balconies, facade designs, and fluidity of floor plans.

1.2 Sustainable Wind Energy

Renewable energy is an idea to replace biological energy consumption by generating energy through natural phenomena, ex. sunlight, wind, flowing waters, and even human movement. The natural phenomenon can be converted into energy through sorts of movement mechanisms, including electromagnetic spikes and rotating generators. In the case of high-rise buildings, the wind is the most stable phenomenon and less-explored renewable energy compare to sunlight. High rise building tends to receive wind loads on its structure. A higher building receives greater wind loads. Wind loads are the potential to generate energy through building surfaces.[2] Therefore, this research is mostly discussing wind capability to generate energy through high rise building facade design.

Sustainable energy is a concept to combine a mindset of human well-being and renewable energy. This research main goal is to create an alternative facade design that responds to both human well-being and renewable energy. The subject of this research is the wind, and the wind is compatible with making sounds. Wind makes facade to move and generate energy while creating sounds in its process as a part to add environmental diversity.

Study precedent about furin, Japanese chime. In Japan, heat is rising quite high in summer, and there is a habit to hang up furin at doorsteps, trees or places where the wind blows. When the wind blows, the paper on furin move and creating sounds. The sound is believed can cool the air, and that is an example where our senses triggered psychological stimulation.[3] The sounds are created because there is an impact between two objects when the paper on furin moves (usually glass, metal, or combined by the two). From that phenomenon, we learn that the impact of two objects can generate sound.

Figure 1. Furin, japanese chime
(source: https://www.akibanation.com/furin-benda-khas-musim-panas/)

An advanced study precedent was Logan Airport Parking Garage facade, in Boston. Its facade is a small thin layer of aluminum, hanged by steel facade. When the wind blows, each of the aluminum layers moved back and forth, creating a pattern of visual traced wind from the

outside and the inside. There is a netting steel protector inside, and creating sound as the aluminum layer move backward because of the impact of two. This is the idea of how building facade design can provide the sound as environment diversity by the phenomenon of wind.

Figure 2. Logan Airport parking garage, Boston
(source: http://www.bldup.com/projects/logan-airport-central-garage-west)

1.3 Biomimicry Facade Design

Biomimicry is a mindset that seeks nature phenomenon and redefines it to another form that mimics its characteristics[4]. For example, Garden by the Bay, Singapore. A form that mimics a shape of flower blooms to gather water from the rain, and produce energy through photovoltaic on top of it. Biomimicry helps this research as a bridge that connecting renewable energy mindset and well-being mindset to create a facade design for sustainable high rise buildings.

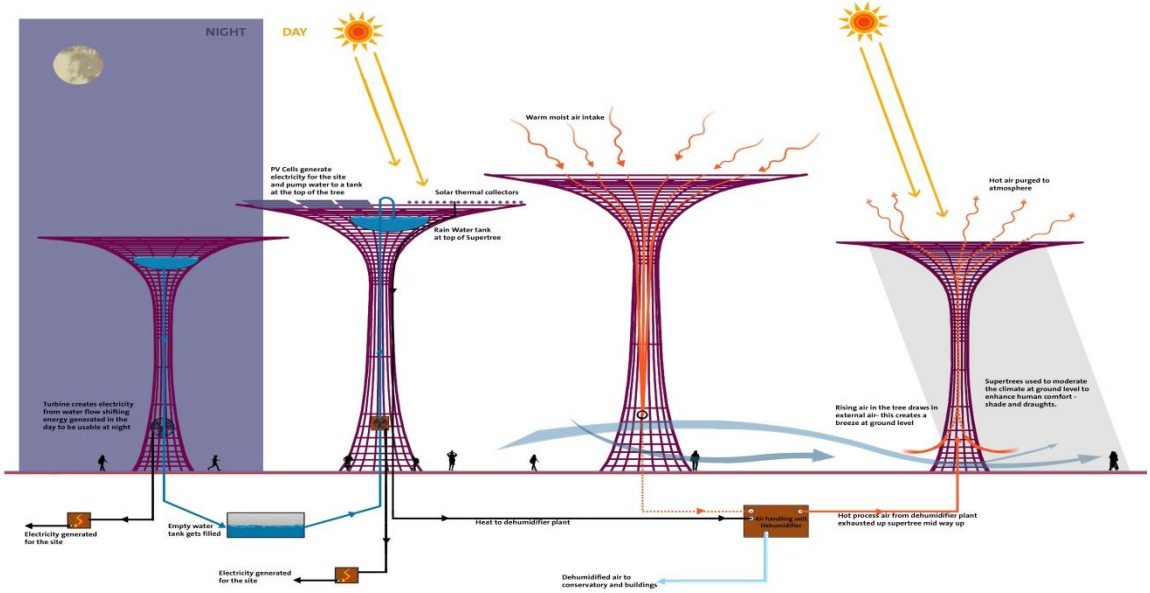

Figure 3. Garden by The Bay, Singapore
(source: https://www.pinterest.com/cheichang/diagram/)

For this research, the unique concept of how bird's feathers capture and release is used to create a design. Feather has a complex structure, created by thousands of tiny hairs that interlocking one with each other shaping a form centered in its quill (calamus). All of those components help birds to fly and ventilate the skins.

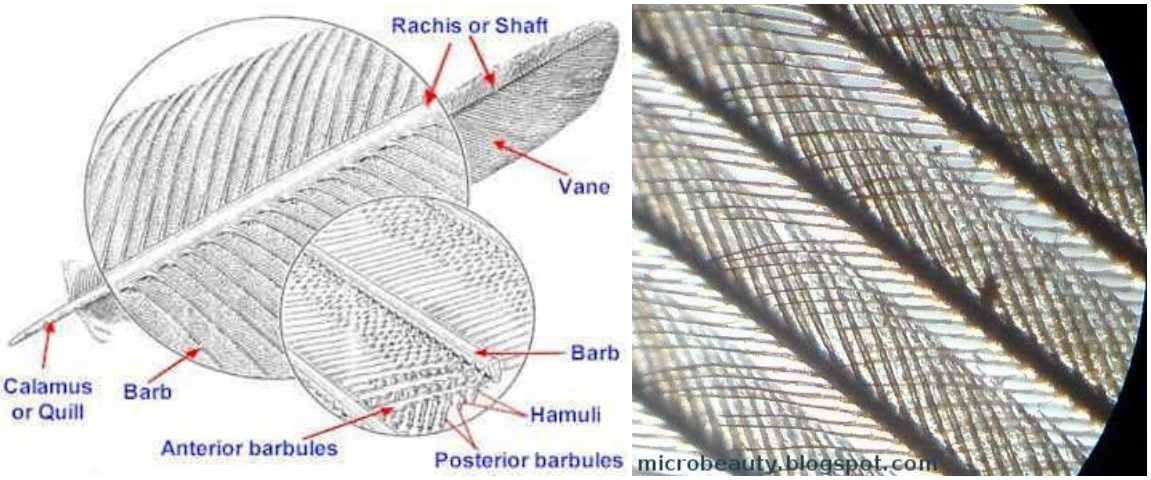

Figure 4. Bird's feather structure
(source: https://microbeauty.blogspot.com/2009/08/birds-feather.html)

From those studies, the facade is the most suitable building component to achieve sustainable wind energy. By combining the aspect of renewable energy and human well-beingness through sound, a design was created. Design transformation :

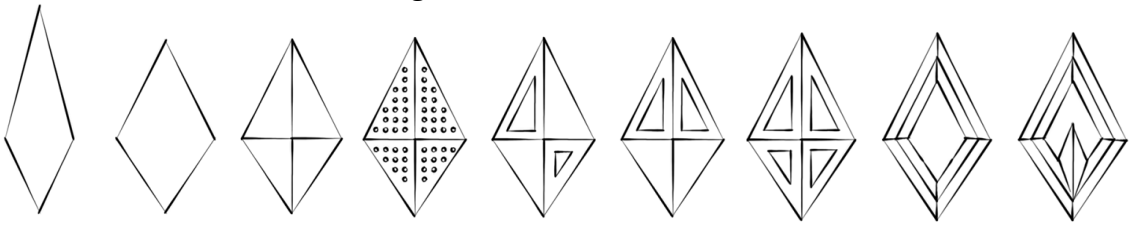

Figure 5. Design And Model Transformation

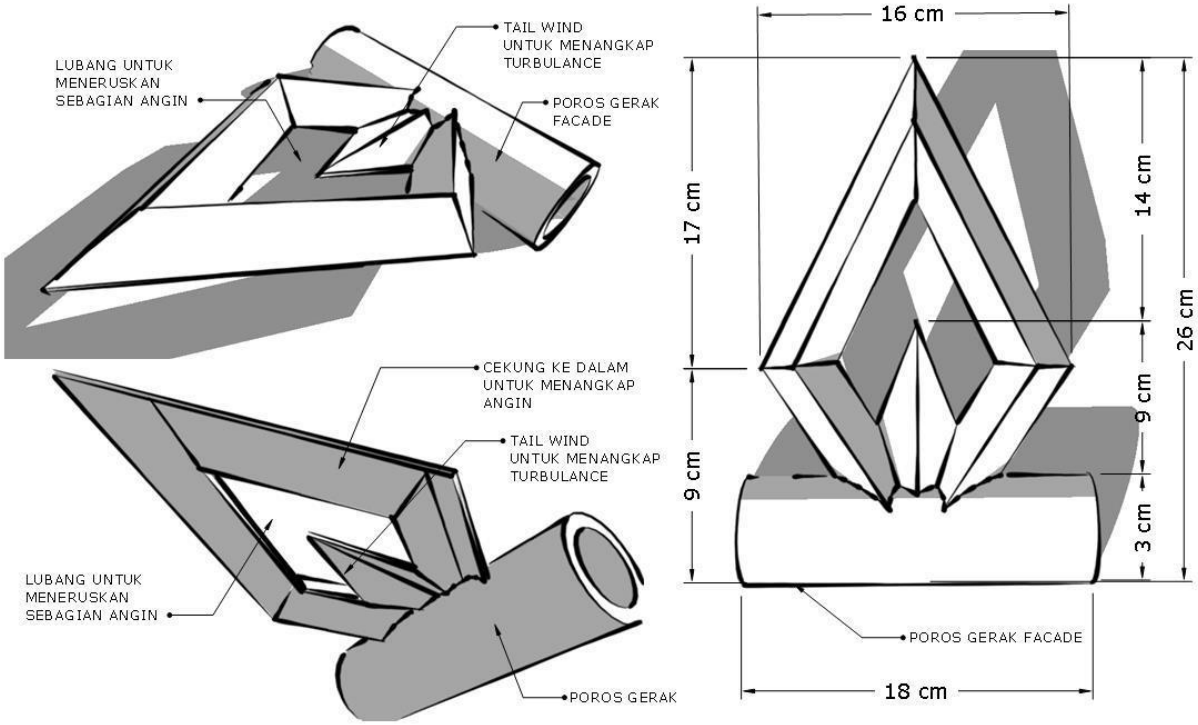

Figure 6. Design mimic based on how feather works

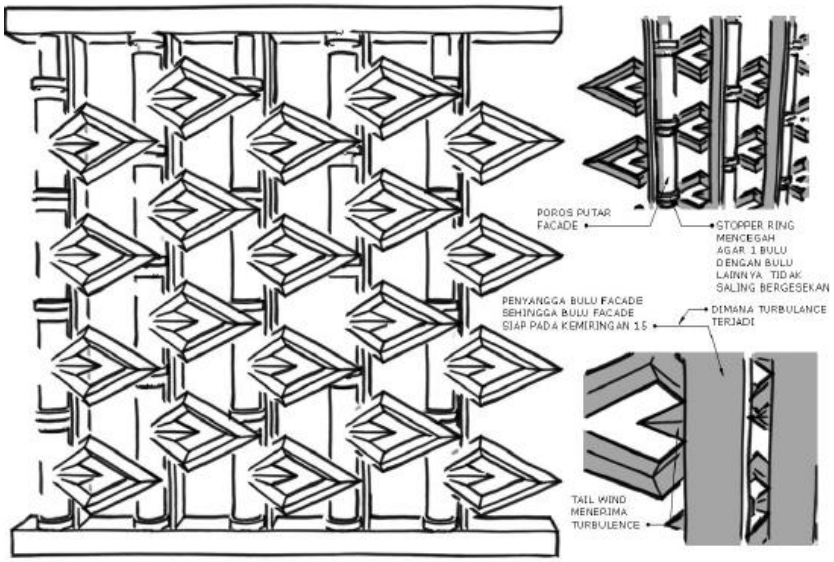

Figure 7. Structure design mimics based on how feather compiles into a set of a wing.

1.4 Generating Renewable Energy

Michael Faraday (1931) did an experiment of electricity and magnetism, well-known as Faraday's Law. The law proves the correlation between electricity and magnetism. Electricity will be created when there is a fluctuation in the magnetic field. Fluctuation in the magnetic field indicates electrons movement, generating EMF(electromotive force)[5]. The verdict is electricity created from the magnetism movement of electrons, that build a fluctuation in the magnetic field.

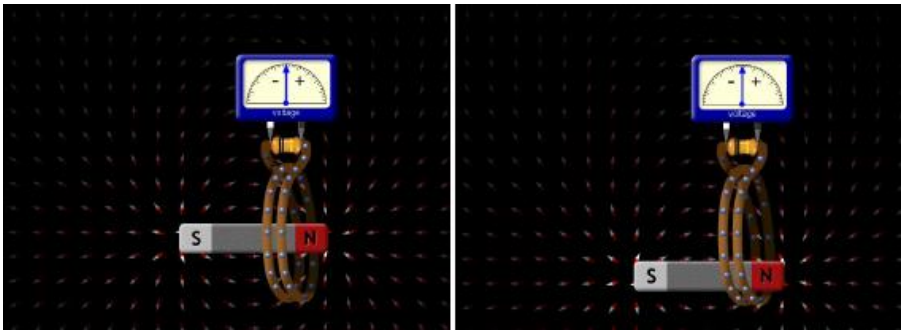

Figure 8. EMF won't generate in the static state despite the magnet position. (simulated by PhET Colorado Faraday Law)

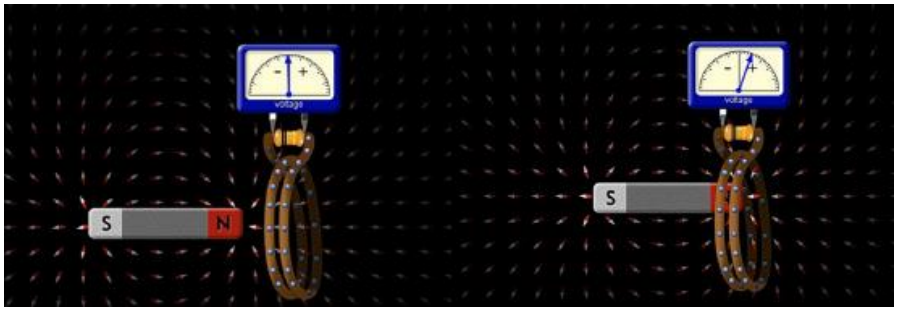

Figure 9. EMF will generate while the magnet or/and the coil moved in sort of rhyme. (simulated by PhET Colorado Faraday Law)

2. Research Methods

The computerized simulation will be used to test the design capabilities. The design must capable to generate energy and sound through wind movement. The design simulation parameters will be :

- How wind affecting the design's movement.
- How the design will react to the wind blows and generating energy.
- Did the design create sounds as they react to the wind movement?

The boundaries of this research determined by research variables and locked variables. The research variables are :

- The design response to wind movement,
- Facade design movement,
- Movement mechanism,
- Capabilities facade to generate energy,
- Capabilities facade to generate sound.

While the locked variables are :

- Wind speed in Surabaya 10m/s (source: bmkg.go.id),
- Generate energy calculation by an optimal single cycle of movement
- A single unit facade that will be tested (not the whole structure of building design),
- Facade design material (made by a thin aluminum sheet).

First, a 3D design created with Sketch Up and being tested with Autodesk Flow Design. This step will produce an analysis of how the facade unit reacts to wind movement. the simulation will indicate when and how this design shows its maximum potential to wind movement, indicates by the pressure that wind makes on its surface.

Second, a structure of unit design will be made and tested using the same method as the first stage. The result is for perfected further design. By testing a whole structure, the capability of movement in the facade can be adjusted and maximized.

Third, the mechanism of facade design will be tested. The mechanism is tested with Sketch Up and PhET Colorado Faraday Law to analyze the capabilities of generating energy. This simulation will help how energy will be calculated. A mock up will be created to test its capability to generate sound.

Last, a 3D animation is created with Blender for presentation. A note, that Blender is a 3D animation, not a 3D simulator. The output will only show how the wind will react to the design, the result is invalid for further analysis.

3. Result and Discussion

3.1 Design Sound and Wind Pressure Tests

A unit design effectively receives pressure from the opposite direction of the wind, especially at the bottom. This design is created that allows wind to push and move the unit from below, while the top side is designed to break excess wind blows. The center part of the design is hollow, it designed to pass excess wind blows while the unit blew up. Near the pivot area designed as a spade like the model as a tailwind to capture any turbulence created underneath near the pivot. This design to maximizing generate the energy, and mitigate the noise sound.

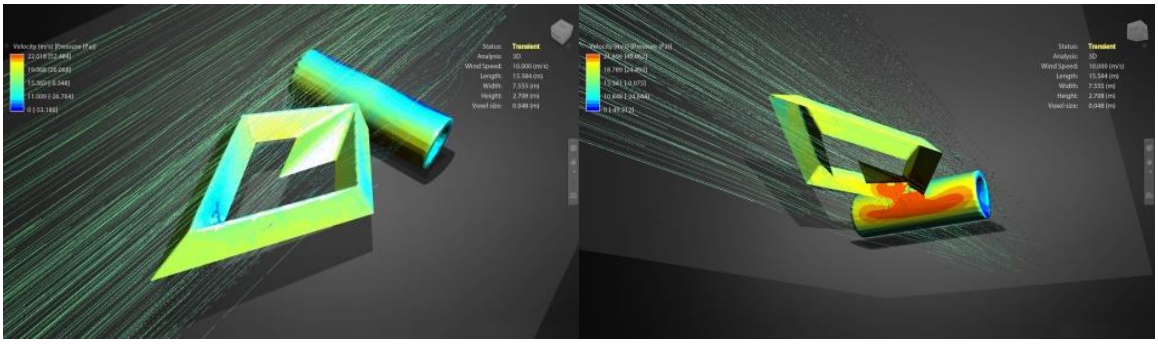

Figure 10. Simulations of facade unit when the wind blows.

The orange area indicates high pressure that wind created (up to 49,02 Pa), the green area indicates low to moderate wind pressure (from 0 Pa to 24,49 Pa), the blue area indicates no wind pressure (0 Pa to -24,64 Pa and below).

Next, the structured facade design will be tested, as if :

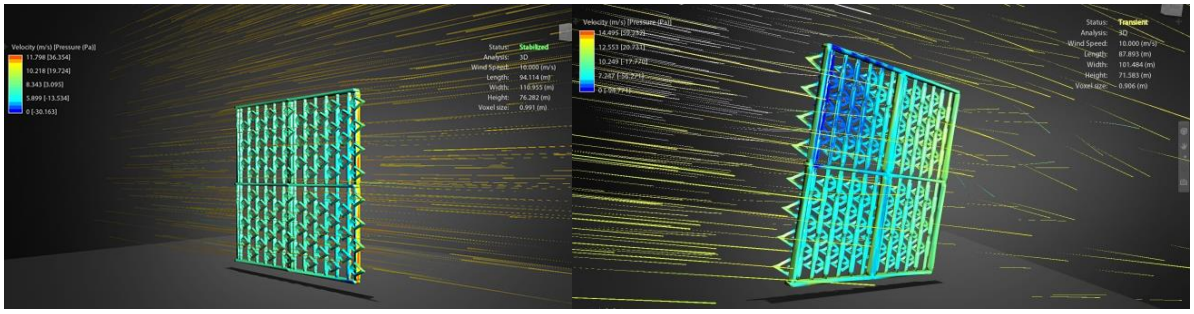

Figure 11. The structured facade design simulation result.

The result gives information that the facade mostly not moving because of low wind pressure (around 20,73 Pa to -94,77 Pa, mostly no wind pressure by a huge gap) its capture. Because of the top unit design that breaks the wind flow and how the wind blocked by the facade structure itself, the possibilities it will move are minimum.

The design is modified by adding a support structure as a slope that makes each facade units is 15^0 ready above the main structure.

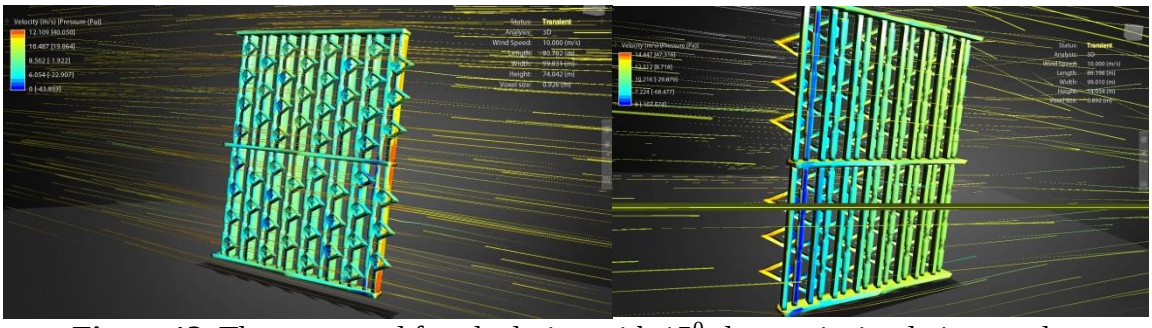

Figure 12. The structured facade design with 15^0 slope unit simulation results.

The result increases the wind pressure that each unit receives (from 8,72 Pa to 47,32 Pa, probably more pressure when the units start to move). Apparently, the tailwind design doesn't seem effective (-26,88 and below), but when the units start to move, the tailwind will generate additional up to 24,49 Pa (possibly more, depends on the wind conditions).

3.2 Facade Motion Simulation and Energy Calculation

To understand how the facade moving a facade motion simulation will be done. Facade motion simulation will show the result of how far the facade can move. This simulation will help to determine how energy will be calculated and how much it will generate.

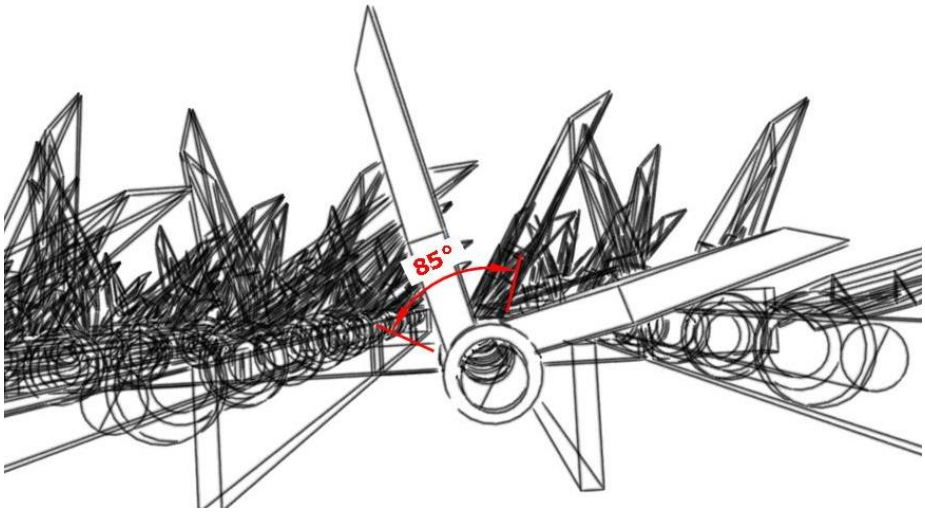

Figure 13. Facade motion simulation

The result gives information that each unit efficiently will move 85°, up to 135° before it crashed with the other unit behind it. And by this simulation, energy calculation will be using this equation[6].

$$\Delta\phi = NABcos\_ \quad (1)$$

$\Delta\phi$ = EMF, electromotive force (V(volt))
N = number of coils
A = conductor area, $A = \pi r^2$(0,00012717 m3)
B = static electro magnetic (194 Tesla)
cos_ = degree angle (85° efficient, and a maximum of 135°)

Table 1. Energy calculation for every full movement both with 85° (above) and 135° (below)

N Jumlah lilitan kumparan	A Area konduktor A=πr2t (m3)	B Medan magnet konstan T(tesla)	cos_ Sudut angle yang terbentuk		Δφ EMF = perubahan medan magnet V(volt)	
			derajat	cos_	volt	microvolt
1	0.00012717	194	85	0.08716	0.002150323	2.15
3	0.00012717	194	85	0.08716	0.006450968	6.45
5	0.00012717	194	85	0.08716	0.010751613	10.75
8	0.00012717	194	85	0.08716	0.017202581	17.2
10	0.00012717	194	85	0.08716	0.021503226	21.5
N Jumlah lilitan kumparan	A Area konduktor A=πr2t (m3)	B Medan magnet konstan T(tesla)	cos_ Sudut angle yang terbentuk		Δφ EMF = perubahan medan magnet V(volt)	
			derajat	cos_	volt	microvolt
1	0.00012717	194	135	0.71	0.017516396	17.51
3	0.00012717	194	135	0.71	0.052549187	52.54
5	0.00012717	194	135	0.71	0.087581979	87.58
8	0.00012717	194	135	0.71	0.140131166	140.13
10	0.00012717	194	135	0.71	0.175163958	175.16

From the table, each unit can produce a minimum of 2,15μV with a single-coil, at maximum 85° full movement, and up to 21,5 μV with 10x coils. Each unit has extreme capability up to 175,16 μV 10 coils, at a maximum of 135° full movement. A reminder each unit only 18cm x 28cm each, it could be hundreds and thousands of it each building design. Imagine how much energy it will produce in a single full movement, yet wind movement is constantly there with different rhythm every blow.

To achieve its fullest capability to generate energy and sound, each unit needs an ability to recover their original state. It is necessary to repeat the process being blown again and generate more frequent energy. The test indeed including adding small spring to bounce it back and forth, but it will require more wind pressure. In this case, gravity is the most suitable way to achieve a consecutive repeat of the facade unit movement.

The last simulation was a 3D animation to analyze the facade unit movement. Using Blender and adding a rhythmic wind flow towards the facade unit to analyze its effect.

Figure 14. Simulation facade units arrange perpendicular to the water level with Blender 3D animation

From the result above, the facade unit moves when the wind blows, and when the wind stops blowing, the facade unit didn't recover to their original state. That concludes whether the facade unit will stay in their last movement or hopefully there's another wind blows from the opposite direction to move back each unit in their original state. Which means less energy will produce. Either the facade units will move to both directions it still generates energy, as long as the magnetic field at the pivot gets fluctuation, EMF is generated. To achieve the maximum result, another test is made.

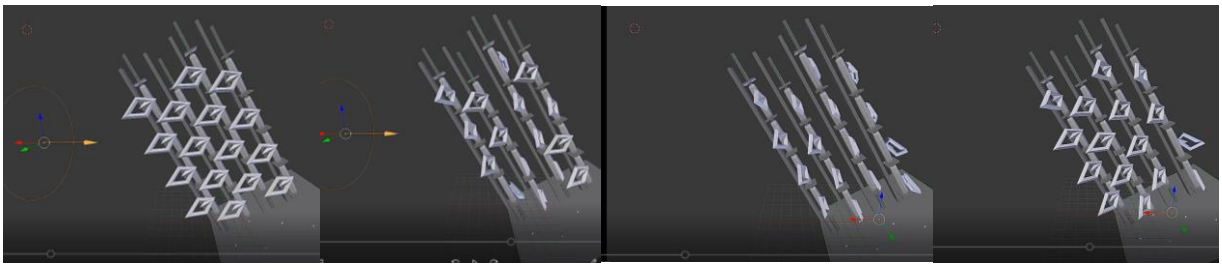

Figure 15. Simulation facade units arrange 75° from the water level with Blender 3D animation

The result above proven that gravity helps each facade unit naturally recover to its natural state. This phenomenon is crucial to generate more energy. Consecutive repeat movement equal to consecutive energy generating.

4. Conclusion

Sustainable energy is not all about how to generate new energy resources, its also about the human who lives within. Human well-beingness is determined by the quality of their living environment. This research is mainly to open the mindset by reaching those two worlds into a single design that impacts both of them. The design itself impacting environment diversity and

generating energy to supply daily needs. Through analysis of wind phenomenon, a biomimicry facade design is created to answer the needs of energy and sound as environmental enrichment.

This design has proven its capability to conceptually generate energy, for each unit can produce a minimum of 2,15μV with a single-coil, at maximum 85° full movement, and up to 21,5 μV with 10x coils. This design is conceptually capable to produce sounds in its process of generating energy. Yet this design concept is far from perfection.

This design can be further developed as more variables will be added. Its sound capability is still minimum. The material specification needs to be researched for achieving its maximum potential to provide an enrichment environment. The material aspect needs further research, switching material affecting each unit's capability to move by particular wind speed. Wind pressure needs will be higher by increasing the weight of a unit. The characteristic of the wind is still locked, building design variable needs to be added for practical used. Its mechanism needs to be detailed and proven by expertise.

May this research be another idea for another breakthrough of something else, because this world of mind is a fast field of improvement and innovation. As much as this will be the conclusion of Biomimicry Kinetic Facade As Renewable Energy research.

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