

A Study on the Viability of Airborne Wind Energy Systems

Indraneel Das ¹, Nikita Chavan ², Purushotham Shenoy K ³, Dr. K.S Shanmukharadhya ⁴

U.G Student, Department of Mechanical Engineering, Sir M. Visvesvaraya Institute of Technology, Bengaluru, India ¹

Graduate, Department of Industrial Engineering and Management, Sir M. Visvesvaraya Institute of Technology, Bengaluru, India ²

Graduate, Department of Mechanical Engineering, Sir M. Visvesvaraya Institute of Technology, Bengaluru, India ³

Professor and Head, Department of Mechanical Engineering, Sir M. Visvesvaraya Institute of Technology, Bengaluru, India ⁴

ABSTRACT: Wind energy along with solar energy form a significant chunk of non-conventional energy sources on the planet at present and the concerns related to the ability of these sources to completely replace conventional sources are well documented. Wind energy is harnessed by wind turbines, which have concerns like high cost and complexity, noise pollution, threat to wildlife among which the fact that wind energy cannot be harnessed continuously is chief. Airborne Wind Energy Systems (AWES) makes use of the fact that winds at higher altitudes are stronger and more consistent than those closer to the ground, which may be both on-shore and off-shore. These systems operate at higher altitudes and maybe freely flying in the air or tethered to the ground and aim to tap into a resource which is both large and consistent. With the advent of this method of harnessing wind energy, there is an opportunity to not only reverse the drawbacks of wind turbines to a very large extent, but also to provide an upgrade on them in terms of power generation and efficiency. This paper attempts to explore the viability of using AWES on a large scale using tools like SWOT analysis and Decision matrix, in terms of power generated, efficiency, economic and technological feasibility so as to realise the full potential of wind energy that is presently under-utilised.

KEYWORDS: Wind energy, Wind turbines, Airborne Wind Energy Systems (AWES), Higher altitudes, SWOT analysis, Decision matrix.

I. INTRODUCTION

In recent years, implementing renewable energy concepts have received moderate to strong support across the world. Some types of renewable energies such as hydro power are considered to be fully developed, and others such as solar power are region specific [1]. Wind power has been used for more than two thousand years; windmills were capturing wind power since 200 BC using a constant speed rotor assembly [2]. Wind power as a free, globally available and green energy source is an obvious choice among all renewable energy sources for generation of electricity [3]. The term wind energy describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks or a generator can convert this mechanical power into electricity. A wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. Among all the renewables, wind is regarded as one the fastest growing renewable. Rising oil costs feature the abuse of sustainable power source applications. According to the study Geophysical limits to global wind power, Nature 2013 [4]: "There is enough power in Earth's winds to be a primary source of near-zero-emission electric power as the global economy continues to grow through the twenty-first century. Wind turbines come in all shapes and sizes, however bigger blades tend to produce more electricity – especially at higher altitudes. Even though many vary in size, they tend to operate in the same fashion. In addition to the turbine blades, other major components include the Gear Box, Generator and Controller. Fig 1 (a) shows the representation of a conventional Horizontal Axis Wind turbine (HAWT).

Since the early 2000s, industrial research is focused and being invested on offshore installations. In locations that are far enough from the coast, wind resources are generally greater than those on land, with the winds being stronger and more regular, allowing a more constant usage rate and accurate production planning, and providing more power

available for conversions. The foreseen growth rate of offshore installations is extremely promising; according to current forecasts, the worldwide installed power is envisaged in the order of 80 GW within 2020 [5].

With this regard, a totally new energy sector, Airborne Wind Energy (AWE) has emerged in the scientific community. AWE aims to capture wind energy at significantly increased altitudes and the devices used for harnessing this kind of energy can be referred to as Airborne Wind Energy Systems (AWESs). The high level and the persistence of the energy carried by high-altitude winds, that blow in the range of 200 m – 10 km from the ground surface, attracted the attention of several research communities. The basic principle was introduced by the seminal work of Loyd [6] in which he analysed the maximum energy that can be theoretically extracted with AWESs based on tethered wings. During the last decade, the sector has experienced an extremely rapid acceleration. Several companies have entered the business of high-altitude wind energy, registering hundreds of patents and developing a number of prototypes and demonstrators. Several research teams all over the world are currently working on different aspects of the technology including control, electronics and mechanical design.

An airborne wind turbine is a concept where the turbine rotor (or its equivalent in AWESs) is airborne, thus drawing its advantage from higher mechanical and aerodynamic options, higher velocity and persistence of winds at high altitudes, while avoiding the expense of tower construction or the need for slip rings, yaw mechanism. An electrical generator may be on the ground or airborne depending on the type of the AWES. Airborne wind turbines may operate in low or high altitudes; they are part of a wider classification of Airborne Wind Energy Systems (AWES) termed as high-altitude wind power or crosswind kite power respectively. When the generator is located on the ground, the tethered aircraft need not carry the generator mass and when it is aloft, a conductive tether is used to transmit energy to either to the ground, used aloft or beamed to receivers using microwaves or laser depending on the type of the system.

Fig. 1 (b) shows the WPD (Wind Power Density) (x axis) variation with altitude (y axis). High altitude winds carry several times more power than at ground level. We call "high altitude winds", those ranging around 700-1400 meters above ground level. WPD increases with altitude and high above the ground the wind carries several times more power than at ground level. A classical wind turbine works at altitudes where WPD is significantly lower than where kites can fly. As a conservative estimate, we can refer to the standard atmosphere and we can say that high altitude wind carry twice more power than low altitude ones [7]. However, this estimate depends a lot on the site.

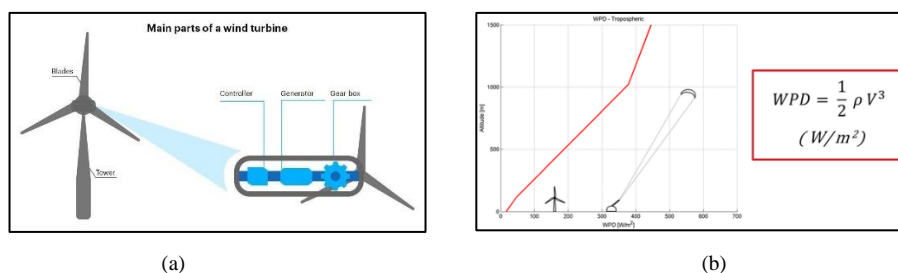


Fig. 1 (a) Main Parts of a Wind Turbine (b) Altitude (Y-axis) vs Wind Power Density (X-Axis) variation

II. CONVENTIONAL METHODS OF HARNESSING WIND ENERGY VS AIRBORNE WIND ENERGY SYSTEMS

Wind energy has been harnessed traditionally by ground based wind turbines in which the flowing wind is converted to mechanical energy through the turbine blades and in turn to electrical energy by means of a generator. The traditional method of converting aerodynamic force of the wind to electrical energy is as follows:

- 1) When wind flows across the turbine blades, having an aerofoil profile, a difference in air pressure arises between the two sides of the blade.
- 2) This gives rise to two forces – lift and drag, which are formed to compensate the difference in pressure. Out of the two, the lift force is the stronger force which lifts the blades and causes the rotor to spin.
- 3) The rotor is connected to the generator, either directly or through a shaft and a gearbox that speed up the rotation and allow for a physically smaller generator [8].

Wind turbines are of the following types:

- 1) Horizontal Axis Wind Turbine (HAWT), where the turbine is pivoted on the top of the tower and placed in such a way that the blades (usually three in number) face the wind, hence operating "upwind".

- 2) Vertical Axis Wind Turbine (VAWT), which is an upgrade on the HAWT in the sense that they need not be pointed towards the wind, hence eliminating the need for incorporating wind sensing and orientation mechanisms. These turbines can deal with turbulent and gusty winds and are less expensive to install than HAWTs due to simpler gearboxes. The main rotor is placed transverse to the wind which allows for the setting up of components like the gear box, generator closer to ground level which facilitates easier repair and maintenance [9].

Wind Turbines, placed either onshore or offshore, still have drawbacks like:

- 1) Inconsistency of winds, leading to inconsistent power supply and lower power generation efficiencies.
- 2) High capital and operating costs due to complicated components and mechanisms.
- 3) Noise Pollution.
- 4) Adversely affect wildlife, especially birds.
- 5) Require massive land area to set-up and operate.
- 6) Susceptible to tremendous damage in the event of natural calamities like hurricanes, tornadoes and earthquakes.
- 7) Harnessing of wind energy is highly location specific, i.e., places with high wind density like coastal and hilly areas.

2.1 Betz Criteria

The Betz Equation is analogous to the Carnot cycle efficiency in thermodynamics suggesting that a heat engine cannot extract all the energy from a given source of energy and must reject part of its heat input back to the environment. The Betz Equation deals with the wind speed upstream of the turbine V_1 and the downstream wind speed V_2 . Fig 2 (a) represents the inlet and outlet wind velocities of a wind turbine. The limited efficiency of a heat engine is caused by heat rejection to the environment. The limited efficiency of a wind turbine is caused by braking of the wind from its upstream speed V_1 to its downstream speed V_2 , while allowing a continuation of the flow regime. The additional losses in efficiency for a practical wind turbine are caused by the viscous and pressure drag on the rotor blades, the swirl imparted to the air flow by the rotor, and the power losses in the transmission and electrical system.

The more kinetic energy a wind turbine pulls out of the wind, the more the wind will be slowed down as it leaves the left side of the turbine in the picture. If we tried to extract all the energy from the wind, the air would move away with the speed zero, i.e. the air could not leave the turbine. In that case we would not extract any energy at all, since all of the air would obviously also be prevented from entering the rotor of the turbine.

The Betz' law says that only a maximum of $16/27$, or 59.3%, of the kinetic energy in the wind can be converted to mechanical energy using a wind turbine.

2.2 Airborne Wind Energy Systems (AWES):

One of the main concerns in the harnessing of wind energy through wind turbines is the inconsistency of winds, which leads to inconsistent and inefficient electric power generation. Airborne energy systems utilise the strong and continuous winds found at higher altitudes which leads to much improved power generation efficiencies [10].

Archer and Caldeira [11], through their work estimated a large amount of kinetic energy that can be utilised for the world's wind energy needs to be available at 0.5km – 12km altitudes above the ground with a clear depiction of geographies and topologies coupled with persistency maps containing information about wind power density available at different altitudes.

Marvel et al [12] estimated the total amount of kinetic energy that can be harnessed from high altitude winds to be 1800 TW when compared to 400 TW that can be harnessed from near-surface winds. Out of this the amount of power actually required globally can be estimated to 18 TW which seems like a comparatively small quantity. Miller et al [13] placed the figure of sustainable global power extraction at a conservative 7.5 TW by only focusing on winds at altitudes between 6km and 15km above the ground.

In order to utilise this vast amount of energy available, various organisations and groups have undertaken work in this field, the progress of which is a cause of much optimism.

Delft University of Technology and Karlsruhe University of Applied Sciences have jointly collaborated to develop a mobile 20 kW experimental pumping kite generator with the main focus towards a generator operating continuously for 24 hours. The prototype that was already developed and being improved for continuous power generation has a wing surface area of 25m², is single-tether based, has a control unit (called control pod) that is airborne and also has an automatic launch setup [19].

KiteGen Research developed a system that has integrated electronics on-board and its design is based on a C-Kite tethered to the ground control station by means of two power-ropes. This prototype was further developed by winding the power ropes on special winches and by driving them using a pulley system through a 20m flexible rod called stem. A power of 3 MW was obtained [10]. Fig 2 (b) shows the prototype developed by KiteGen.

The AWESs developed by SkySails GmbH consists of a foil kite that is controlled by a rope and a control pod. The mobile variant of this system has a capacity of 250kW – 1MW and the offshore variant has a capacity of 1-3.5MW [20]. Fig 2 (c) shows the depiction of the offshore variant prototype developed by SkySails GmbH.

Makani Power has developed an AWES with the capability of 600 kW energy generation having eight rotors and a wing span comparable to that of a small jet airliner. This high-performance carbon fiber kite has a width of 85ft and houses eight on-board rotors each. After eight generations of prototypes of increasing size, the company now has the high-performance carbon fibre kite which measures 85 ft. across, and has eight on board rotors, each of 7.5 ft. diameter. The eight rotors are spun by the wind in energy-generating crosswind flight. Each rotor drives a permanent magnet motor/generator that generates electricity on board [21]. Fig 2 (d) shows the AWES developed by Makani Power.



Fig 2 (a) Inlet and Outlet wind velocities (b) C-Kite developed by KiteGen (source: www.kitegen.com) (c) Depiction of the Prototype developed by SkySails GmbH (d) Makani Power's AWES

III. CLASSIFICATION OF AWES

AWES typically consists of two main components, a ground system and a minimum of one aircraft which is either mechanically or electrically connected by ropes (often referred to as tethers). AWES can be categorized into two systems, as shown in Fig. 3 (c):

- 1) Ground-Gen systems: Conversion of mechanical energy into electrical energy takes place on the ground.
- 2) Fly-Gen systems: Conversion of energy generated by the rotor to electrical energy is done on the aircraft [14].

3.1 Ground-Gen systems

In a Ground-Gen AWES (GG-AWES), the mechanical work done by traction force is transmitted from the aircraft, producing electrical energy on the ground. The transmission is done through one or more ropes, which produce the motion of an electrical generator. GG-AWESs can further be classified as:

- 1) Fixed-ground station devices: the ground station is fixed to the ground.
- 2) Moving-ground-station systems: the ground station is a moving vehicle [15].

3.1.1 Fixed-ground-station

Fixed ground station GG-AWES are also referred to as Pumping Kite Generators. In this the energy conversion is successfully brought out by a two-phase cycle that consists of a generation phase and a recovery phase. During the generation phase, electrical energy is produced. The aircraft is driven in such a way so as to produce a lift force. Consequently, a traction (unwinding) force is produced on the ropes such that it induces the rotation of the electrical generators. During the recovery phase, where in a smaller amount of energy is consumed, motors rewind the ropes

which brings the aircraft back to its original position from the ground. To ensure a positive balance, the net energy produced in the generation phase has to be larger than the energy spent in the recovery phase [16] [17].

3.1.2 Moving-ground-station

In these systems, unlike the fixed ground station, the rope winding and unwinding does not produce or consume significant power. It is eventually used only to control the aircraft trajectory. The generation takes place due to the traction force of ropes, inducing the rotation (or linear motion) of a generator which exploits the ground station movement rather than the rope winding mechanism.

Moving-ground-station GG-AWES are further classified into two:

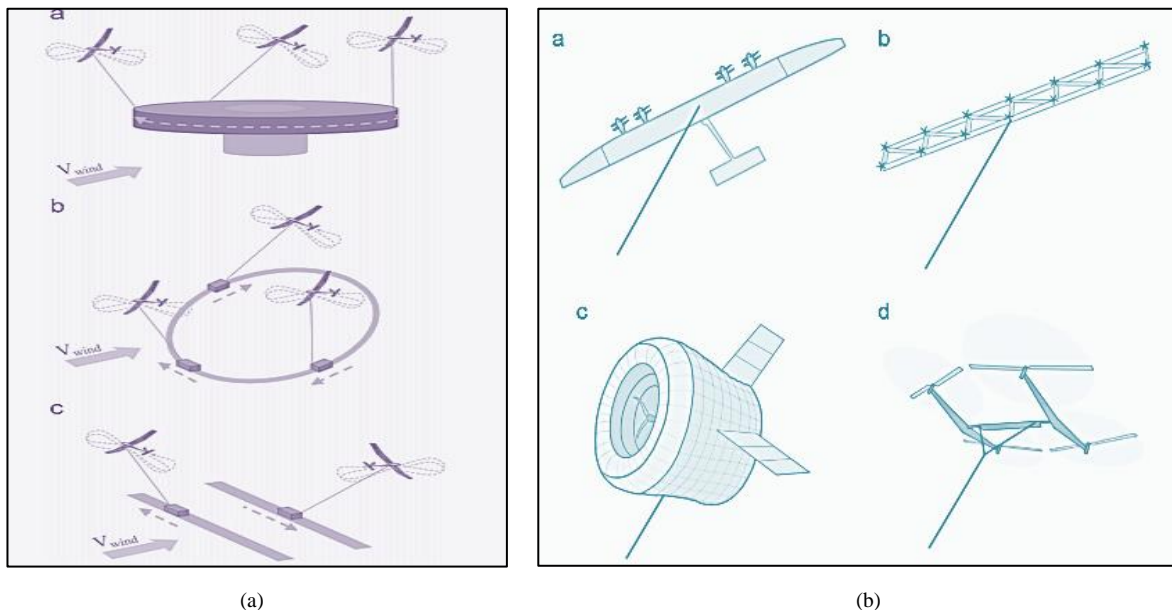
- 1) Vertical axis generator: In this type of generator, the ground stations are fixed on the periphery of the rotor of a large electric generator having a vertical axis. In such cases, the forces of aircraft make the ground stations rotate together with the rotor. This in turn transmits torque to the generator (Fig. 3 (a)-a).
- 2) Rail generators: They are of two types - closed loop rail (Fig. 3 (a)-b) and open loop rail (Fig. 3.1 (a)-c). The ground stations are integrated on rail vehicles and electric energy is generated from vehicle motion. [10]

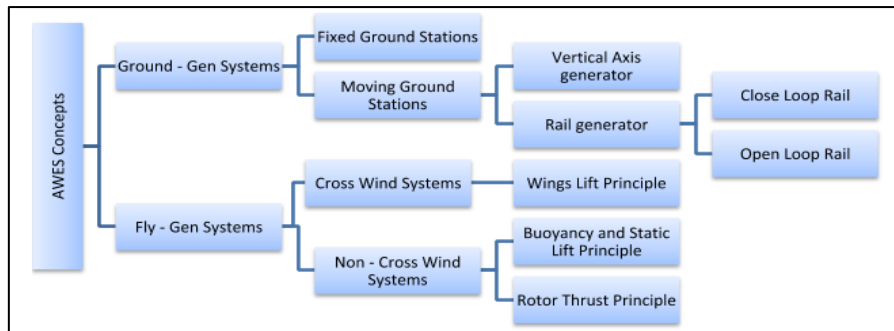
3.2 Fly-Gen systems (FG-systems)

In Fly-Gen AWESs, it is during the flight of the aircraft that the electric energy is produced. This energy is then transmitted to the ground through a special rope which integrates electric cables. Using one or more specially designed wind turbines, electrical energy conversion in FG-AWESs can be achieved. The general classification of FG-AWESs are crosswind and non-crosswind modes. Under these modes, they can further be distinguished based on their flying principles as mentioned below:

1. Crosswind
 - Wings lift: Successfully brought about with a tethered flight of special gliders (Fig. 3 (b)-a) or frames with multiple wings (Fig. 3 (b)-b). These aircraft harvest the relative wind.
2. Non – Crosswind
 - Buoyancy and static lift: Successfully brought about with aerodynamically shaped aerostats filled with lighter-than-air gas (Fig. 3 (b)-c). These aircraft harvest the absolute wind.
 - Rotor thrust: Successfully brought about with the same turbines used for electrical power generation (Fig. 3 (b)-d). These aircraft harvest the absolute wind.

There also exists an FG concept that exploits high altitude wind energy not by using aerodynamic lift. Instead, it uses a rotating aerostat which exploits the Magnus effect [18].





(c)

Fig. 3 (a) Vertical Axis and Rail Generators (b) Flying Principles of Fly-Gen System (c) Classification of AWES – Flowchart.

IV. SWOT ANALYSIS

The SWOT analysis is an extremely useful tool for understanding and decision-making for all sorts of situations in projects, businesses and organisations. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. Strengths and weakness are frequently internally-related, while opportunities and threats commonly focus on the external environment. The name is an acronym for the four parameters the technique examines:

Strengths: characteristics of the business or project that give it an advantage over others.

Weaknesses: characteristics of the business that place the business or project at a disadvantage relative to others.

Opportunities: elements in the environment that the business or project could exploit to its advantage.

Threats: elements in the environment that could cause trouble for the business or project.

It is typically employed for strategy building, corporate planning, market management, match and converting and so on.

In this paper, we attempt to use SWOT analysis, to create a comparison among the various wind energy systems with the goal of understanding and analysing the various systems to find its competitive advantage.



4.1 SWOT Analysis of Conventional Wind Turbine

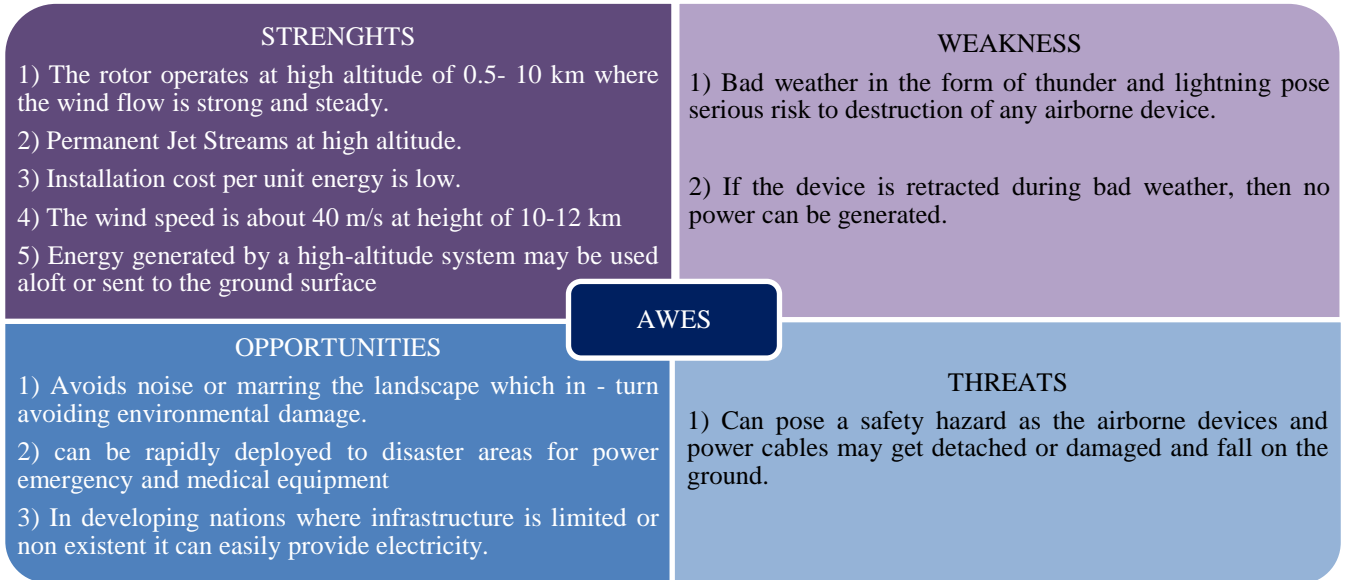
<p>STRENGTHS</p> <ol style="list-style-type: none"> 1) High power generation- for a rotor diameter= 190m and hub height=125m, maximum power generated = 10 MW. 2) Higher peak efficiency (approx. 50%) compared to Vertical Axis Wind Turbines. 	<p>WEAKNESS</p> <ol style="list-style-type: none"> 1) They need to be positioned facing the winds which gives rise to the requirement to incorporate wind sensing and orientation mechanisms. 2) Need to be set up far away from human settlements thus leading to higher chance of power transmission losses. 3) Require higher wind speeds of 11-15 km/hr to start generating power. 4) Higher complexity of components like gearboxes and yaw mechanisms which are necessary to align the turbine with the wind. 5) Requires larger land area to set up a sustainable wind farm. 6) Adversely affects wildlife, especially birds.
<p>OPPORTUNITIES</p> <ol style="list-style-type: none"> 1) Use of materials like Carbon Fibre, Fibre Reinforced Polymers (FRPs) as blade material to improve performance. 2) Research towards use of natural polymers as blade materials. 	<p>THREATS</p> <ol style="list-style-type: none"> 1) Seasonal variation in power generation. 2) Harnessing of wind energy is highly location specific, i.e. places with high wind density like coastal and hilly areas. 3) Greater susceptibility to damage in the event of natural factors like hurricanes, earthquakes, variable wind loads, lightning etc.

4.2 SWOT Analysis of Vertical Axis Wind Turbine (VAWT)

<p>STRENGTHS</p> <ol style="list-style-type: none"> 1) Omnidirectional, yaw-less design. 2) Can use both lift and drag forces. 3) Can generate power with wind speeds as low as 7 km/hr 4) Scalability: The design can be scaled down to small sizes, even as small as what will fit on an urban rooftop. In cities, there may not be room for all renewable energy technologies, but vertical turbines provide a viable alternative to hydrocarbon energy sources. 	<p>WEAKNESS</p> <ol style="list-style-type: none"> 1) Only a fraction of blades contribute to power generation. 2) Generates less power than Horizontal Axis Wind Turbines. (200W- 10kW) 3) Vibrations because of air flow near the ground creates turbulent flow. 4) These types of turbines aren't typically well suited for use in areas of high wind speeds.
<p>OPPORTUNITIES</p> <ol style="list-style-type: none"> 1) Efficiency can be improved by using accessories like deflectors, to direct the wind towards the blades. 2) Zero energy buildings provide a chance to exploit this technology 	<p>THREATS</p> <ol style="list-style-type: none"> 1) Higher chance that the turbine would stop rotating and fall out during rough weather conditions. 2) The tendency of blades breaking is higher due to high centrifugal forces.



4.3 SWOT Analysis of Airborne Wind Energy Systems (AWES)



V. DECISION MATRIX

A decision matrix is a decision making tool that allows one to list and evaluate different criteria on the basis of priority and weightage and then narrow down the choices to make the best possible decision. Here, a decision matrix is being used in order to evaluate the viability of using AWES as an alternative to conventional turbines and HAWT by evaluating it against the most essential criteria. The methodology of constructing the decision matrix is as follows:

- 1) The most important criteria for evaluating the viability and sustainability of Conventional wind turbines, HAWT and AWES are listed. They are Rated Power, Overall Efficiency, Overall Costs and Base Wind Speed.
- 2) Due weightage is given to each of the above criteria in relation to this study such that their sum would add up to 10.
- 3) A rating scale was employed to evaluate each of the above technologies against the specified criteria:
 - 1 – Low (**Least favourable**)
 - 2 – Medium
 - 3 – High (**Most favourable**)
- 4) A rating based on the above rating system is given to each system against the specified criteria by also taking into account the relative weightages of each criterion. This is done by multiplying the rating of a particular system with the weightage of the particular criterion. Therefore, **Rating = (Rating according of scale) x (Weightage of criterion)**

Table 5 (a) is the decision matrix employed to study the viability of using AWES compared to the other systems already in use.

Table 5 (a) Decision matrix for the study of viability.

Criteria \ System	Rated Power 4	Overall Efficiency 2	Overall Costs 3	Base Wind Speed 1	Total
Conventional	High 3 X 4 = 12	High 3 X 2 = 6	Low 1 X 3 = 3	Low 1 X 1 = 1	22
VAWT	Low 1 X 4 = 4	Low 1 X 2 = 2	Medium 2 X 3 = 6	Medium 2 X 1 = 2	14
AWES	Medium 2 X 4 = 8	High 3 X 2 = 6	High 3 X 3 = 9	High 3 X 1 = 3	26

The above decision matrix was constructed after considering a host of parameters that help us to evaluate the performance of each system technically as well as its economic feasibility from the SWOT analysis carried out in the previous section. In order to make this study more comprehensive, the following criteria were selected that help us broadly evaluate each system:

1) Rated Power :

A turbine's power is determined by its ability to convert the wind energy to rotational mechanical energy and in turn to electrical power. Rated power is the maximum power that the particular wind energy system can generate and is the quantity used by manufacturers to measure the maximum capacity of the wind turbines.

The following ratings were given to the 3 systems:

- Conventional – High
- VAWT- Low
- AWES- Medium

This remains the biggest advantage of conventional wind turbines over the other systems. Although the actual power depends on factors like wind power density, variations in wind, etc. these still remain the highest power producers compared to the others. While VAWTs are effective only in areas of low availability of energy, AWES although having the highest potential among the three haven't been developed to the scale of conventional turbines. The rating given to AWES is to keeping a balance between the figures achieved by AWESs in current times and the high availability of energy.

2) Overall Efficiency:

The true capacity of power generation of a wind energy system is obtained by taking into account all losses that include mechanical and transmission losses and multiplying them to the rated power. Considering the above, a factor of efficiency is defined that determines how effectively the available wind energy is finally converted to electric power.

The following ratings were given to the 3 systems:

- Conventional – High
- VAWT- Low
- AWES- High

It is here that both, conventional and AWES score highly as the available wind energy is converted to electric power more efficiently than VAWT. This truly provides a measure of how effectively the available wind energy is converted to useful energy by keeping complexities of the components to a minimum. The ratings above give a fair balance between energy conversion efficiency (where conventional turbines score highly) as well as the ease with which this is carried out (where AWES score highly).

3) Overall Costs (= Material + Production + Transmission + Repair and Maintenance)

It is extremely important to evaluate the viability of a particular technology from an economic perspective. The benefits obtained from the technology get rather dwarfed if the associated costs outweigh them. This makes the technology highly impractical and unsustainable for the future.

The following ratings were given to the 3 systems:

- Conventional – Low
- VAWT- Medium
- AWES- High

AWES is the most cost efficient alternative by far due to its comparative simplicity in terms of construction coupled with the high potential domain of wind energy that it operates in. The complexity and cost of conventional turbines makes it least favourable in this particular comparison, with VAWT holding to a neutral rating.

4) Base Wind Speed

Base wind speed is the speed of the jet streamline that is converted to wind power. The greater the wind speed, higher is the power generated (Power generated is proportional to the third power of wind speed). The following ratings were given to the 3 systems:

- Conventional – Low
- VAWT- Medium
- AWES- High

AWES, located at higher altitudes, where the wind speeds are greater, tend to generate power at ease, whereas in the case of a conventional wind turbine, the base wind speed is relatively lower. Vertical turbines are subjected to low and turbulent wind, since they are mostly located in urban areas.

VI. FUTURE SCOPE

On the technological and construction front, research communities are addressing on the various improvement opportunities such as to ensure adaptability of the system to various wind and weather conditions, to design the wings such that they are durable and light weight, efficient methods to reduce costs and automate during initiation and landing, the ability of the tethers to cope up to many duty cycles of various loads and so on [22].

Also, the amount of wind power generation to a given ground surface is yet to be estimated in the case of large scale wind farms, for which the same estimation of only 2 MW per Km² was made by MacKay for convectional wind turbine parks [23].

On a business front, considering the scale of potential markets, several tens of millions of dollars (which is comparatively low cost) have been utilised for the development of AWES; for which the major financial contributors are big companies that are involved in the energy markets [24].

The AWES is not yet devised to commercialize as companies are focusing on remote locations to satisfy market need than to find a market fit [25]. Nevertheless, research teams are thriving in contributions of patents and scientific research.

VII. CONCLUSION

Due to the sheer potential of harnessing energy from high altitude winds, Airborne Wind Energy Systems stand out in comparison to the technology already in use. The most important factor that suggests that this system of wind energy conversion could be the future, is the relative simplicity of build and compactness that most tested prototypes have demonstrated. Although the numbers, in terms of power generation haven't been comparable to those produced by conventional wind turbines, the fact that power that can be measured in Megawatts, has been achieved by various research groups and organisations have only added to the optimism. From the study conducted in this paper, it would be safe to conclude that the benefits that can be derived from Airborne Wind Energy Systems outweigh the concerns substantially and with further advancements could be viable for use on a large scale.

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