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Landscape and Visual Impact Assessment: Perspectives and Issues with Flying Wind Technologies

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Abstract: In the last decade, conflicts over the installation of classic wind-farm technology have created challenges for visual impact assessment in landscape architecture. Concerns regarding landscape aesthetics have been raised in advanced societies. Among these concerns, high-altitude wind power technology aims to not only sweep much higher zones and benefit from greater wind speeds but also to solve the negative visual impacts on landscape. Several research groups and industrial institutions around the world have been developing a new class of airborne wind energy technologies, including the usage of flexible power kites and balloons. This study examines a number of the issues surrounding landscape assessment of wind farms, particularly in light of the emphasis on flying concepts, and their potential effects on visual landscapes.

Keywords: Flying wind generator; High-altitude wind energy; Landscape architecture; Visual impact assessment; Wind farms

I. Introduction

From the earliest recorded history, man has been harnessing wind energy, and it considered an ideal renewable energy resource [1, 2]. In this concern, wind-farm technology has become more technically advanced in comparison with many other renewable energy technologies. However, wind energy has been marked by social controversy [3]. Recently, modern societies have hoped to harness the wind, and continuously expanding large-scale wind farms are available. In addition, many open and coastal sites are under environmental study for this purpose. As a consequence, wind-farm technology will rapidly spread into and become a major component in our environment. However, wind-farm technology is accompanied with many scientific challenges, in particular visual issues in landscape architecture that reflect the importance of researching and understanding the processes of public perception and acceptance.

Opinions about the siting and development of wind turbines in landscape architecture vary widely among modern societies. Developers, planners and regulators want to be able to protect the most scenically valuable or sensitive landscape areas [4]. To overcome these limitations, new axes of research have been initiated with flying-based technology. Several research groups and companies around the world have been developing a new class of wind generators, aimed at harnessing wind energy blowing at high altitude [5]. This type of technology is usually referred to as High-Altitude Wind Energy (HAWE) or Airborne Wind Energy (AWE) [1, 6].

Safety and related regulations are the most serious concerns about flying-based technology. However according to the research scope in landscape architecture, the study focus only about the visual impacts and aesthetic concerns leaving other concerns to more related industrial and mechanical researches. Historically, landscape assessment tends to focus on classic wind-farm technology, but innovative wind farms with flying concepts have not reached scientific frameworks in landscape assessments. The aim of this study is to identify landscape and visual assessment tools related to the determination of further proposals for wind-farm developments. In this context, the paper briefly reviews the literature on innovative wind farms that have developed HAWE technology in recent decades, highlights a number of aesthetic considerations in wind farm technology and investigates different landscape assessment approaches. Finally, the paper proposes the relative perspectives and opportunities of flying-wind technologies.

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II. Literature Review

A. Overview of Wind-Farm Technology

Wind energy represents one of the most important renewable resources and its benefits are considered greater than the negative potentials. However, even though wind-farms represent environmentally friendly projects, they frequently generate public resistance [7]. The construction and placement of wind energy generating facilities in the landscape, either singularly or as clusters of turbines in wind-farm development, has raised community concerns about the suitability of their siting and their visual impact on landscapes. However, this is particularly the situation with classic wind farms based on ground-based technology

Wind-farm technology still requires large amount of research and development to improve efficiencies at capturing stronger wind. At present, the highest wind turbine reaches 200 m, where the wind is still unstable with an acceptable speed. In fact, strong wind could be present at higher altitudes with little or no wind at low altitudes. Consequently, new solutions to extract energy from high-altitudes winds have been investigated in the form of HAWE. On the other hand, classic wind farms have ground-based structures that limit the turbine in height and location [1, 8]. Recently, innovative wind-farm technology has been introduced, including prototype generators capable of harnessing winds at higher altitudes and that allow extensively more dynamic positioning because of the cubical relationship between wind speed and the power that can be extracted from the stream of air. The size of these turbines can be relatively small compared with other ground-based systems [9]. While challenges include safely suspending and maintaining in high winds and unexpected storms still consider many serious obstacles.

B. Siting Wind Farms in the Landscape

The search for new locations for wind-farm development is a challenge in which architects and planners must explore and weigh landscape and environmental aspects. The landscape architects engage with social issues, and when thinking about generating more renewable energy, they are also responsible for maintaining and developing a beautiful landscape. Landscape planning includes landscape and visual impact assessments, which involve identifying how a proposed development may affect the existing landscape and visual amenity of an area. As part of this process, landscape architects are in a unique position to develop and provide solutions to mitigate any negative impacts [10, 11]. The design characteristics that contribute to potential landscape impacts of wind energy facilities are summarized as follows.

- *Siting and location.* The highest wind speeds are found in open, higher and coastal environments. They also need to be sited for economical delivery of the generated electricity to consumers. This makes it difficult to locate wind farms in isolated areas. Accordingly, the majority of wind turbines tend to be highly visible or in prominent locations. In this context, there are three potential siting options for wind turbines: a) mask or hide, b) merge or integrate, or c) highlight. With this in mind, there are a range of designs and siting options that reduce the unpleasant impacts of wind farms and improve their appearance, and, therefore, their acceptability.
- *Height of towers/turbines.* The height makes them potentially visible for long distances and can make them prominent features on the landscape. However, the height of wind turbines is a design constraint, as the higher the rotor and the longer the diameter of the rotor blade are, the greater the electricity produced. Therefore, a reduction in rotor height or diameter may lead to an increase in the number of turbines, and that increase may have other negative visual impacts and require increases in land use.
- *Spacing and density*. Just as a turbine can become the dominant element by virtue of its height, collections of turbines are potentially highly visible in open landscapes with negative impacts for some viewers. However, negative impacts caused by groups of turbines can be decreased by avoiding dense spacing that creates visual clutter and clustering turbines into functional units, with substantial open space between them. In addition, clusters of wind turbines provide an opportunity for greater power output and reduced infrastructure requirements.
- *Movement.* Wind turbines are different from other landscape features because they include large moving parts that could potentially impact on the enjoyment of a place.
- *Turbine lighting.* In some locations it may be necessary to light wind turbines for reasons of civil or military aviation safety. Where lighting is needed, this should be designed to minimize landscape and visual impacts whilst satisfying safety requirements. This may, for example, be achieved by incorporating shields so that the lights can only be seen from above [12- 15].

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C. Potential Impacts Associated with Wind Farm-technology

Wind farm-technology implementation is always likely to remain a highly complex process, with conflicts between wind energy developers and the public being a common occurrence, usually in relation to visual impacts. Much of this is due to wind turbines' appearance and function. Typically, wind farms with several wind turbines may become prominent landscape features. This means that adequate landscape impact assessment procedures are extremely important [10, 16, 17]. Landscape impacts are involved in the study of changes in the elements, characteristics, character and qualities of the landscape as a result of wind-farm development. These effects can be positive or negative and direct or indirect. It is important to landscape architects to investigate these impacts.

It is important to bear in mind that the landscape is an important attribute related to the human need for beauty and the feeling of happiness. Landscapes fulfil basic emotional needs for relaxation, identification or stimulation. In addition, a beautiful landscape is the keystone of tourism all over the world. However, changes to landscape quality may result some of the negative effects associated with wind farms like impacts on: a) landscape character and scenery, b) local cultural values, c) amenities, and d) impacts on cultural heritage [12, 18].

III. Landscape and Visual Impact Assessment (LVIA)

The landscape around us offers a wide variety of benefits in terms of quality of life, well-being and economic activity. However, pressure has progressively altered familiar landscapes in the past and will continue to do so in the future, creating new landscapes. As a consequence, studies of landscapes occur in different fields, including art, geography, natural sciences, architecture and economics. It is subject that can be explained from different perspectives, from indigenous to scientific and landscape architecture perspectives. This results in differing conceptions about what should be considered to be part of landscapes, particularly in regard to determining the impacts that large-scale development projects on landscapes [16, 17]. Wind turbines are generally large structures/ projects with the potential to have significant landscape and visual impacts, so the question arises of how does wind-farm technology affect the landscape.

Landscape and Visual Impact Assessment (LVIA) is a standard process used to examine the landscape and visual impacts of a specific development. Through this process, LVIA identifies the preferred siting and design option for a development. It is therefore important that care continues to be taken to ensure that further wind farms are sited and designed so that adverse effects on landscape and visual amenities are minimized. In addition, development sites which are highly valued for their landscapes and scenery are given due protection balancing different environmental issues as well as functional, technical and economic requirements [15]. In the case of wind energy developments, LVIA is an important means to document the values of a development site and its surroundings and ensure that wind-farm developments are responsive to potential impacts on these values.

Impact assessments typically present a combination of facts and values. Environmental Impact Assessment (EIA) literature tends to refer to landscape in terms of its visual and aesthetic qualities. As a consequence, LVIA may be presented as a separate report or form one part of EIA of any development when there are likely to be negative effects on the landscape. However, LVIA is technically complex and should be conducted only by qualified landscape architects, so that negative landscape effects are avoided, reduced or offset [15, 17, 18].

A. Zone of Theoretical Visibility (ZTV)

When looking at the potential LVIA of wind-farm developments, it will be necessary to look at the visual characteristics of the area in which the farm will occur, and also the visual characteristics of the areas from which the farm will be observed. Areas that are particularly sensitive to aesthetic impacts include areas of exceptional scenic quality, areas that have some distinct or unique visual or cultural attributes, areas of recognized natural value where cultural elements are out of place, or areas where a particular historic period has been preserved [4].

The assessment of visual effects addresses the effects of change and development on the views available to people and their visual amenity. The concern here is with assessing how the surroundings of individuals or groups of people may be specifically affected by changes in the content and character of views as a result of the loss of existing elements of the landscape or introduction of new elements.

Some of the techniques commonly used to inform the LVIA are as follows: a) zone of theoretical visibility (ZTV) maps, b) photographs to record the baseline visual resource, c) diagrams to provide a technical information (scale, shape and position), and d) photomontages or video-montages [16, 19]. As a result, we can see the starting point of any landscape

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and visual impact assessment is ZTV, which represents the extent of the area within which views of the proposed wind-farm may be obtained. Visual impact decreases with the distance as detailed in the following [16, 20].

- *Zone I (Visually dominating).* The movement of blades is obvious. The immediate landscape is altered, and the turbines appear large in the overall view. The distance is up to 2 km.
- *Zone II (Visually intrusive).* The turbines are important elements on the landscape and are clearly perceived. Blade movement is clearly visible and eye-catching. The turbines are not necessarily dominant points in the view. The distance is between 1 and 4.5 km in good visibility conditions.
- *Zone III (Noticeable).* The turbines are clearly visible but not intrusive. The wind farm is noticeable as an element in the landscape. The movement of blades is visible in good visibility conditions, but the turbines appear small in the overall view. The distance is between 2 and 8 km depending on weather conditions.
- *Zone IV (Element within distant landscape).* The apparent size of the turbines is very small. Turbines are as any other element in the landscape. The movement of blades is generally indiscernible. The distance is over 7 km.

The landscape team identifies sensitive locations and receptors within the ZTV and seeks to agree on these locations in consultation with the local planning authorities [10]. Though visual impact is very specific to the ZTV, physical characteristics in the design and siting of wind farms have been identified that change their potential visual impact on landscapes.

B. Methodology for Landscape and Visual Impact Assessment (LVIA)

There is a fundamental divergence of opinion over the question of whether landscapes have objective beauty that is measurable or comparable or whether scenic beauty is a value that can only be subjectively attributed to a specific landscape [21]. Indeed, landscapes comprise a combination of facts and values. Facts in this sense refer to the objective reality of the landscape that comprises the landscape as an object, whereas values in this sense refer to the subjective realm of the landscape. Therefore, it is important that any approach to assessing landscapes be considered from these combinations [17]. As a result, there are two principal methodological schools of thought in the landscape impact assessment: the expert-based and the perception-based approaches (Fig. 1).

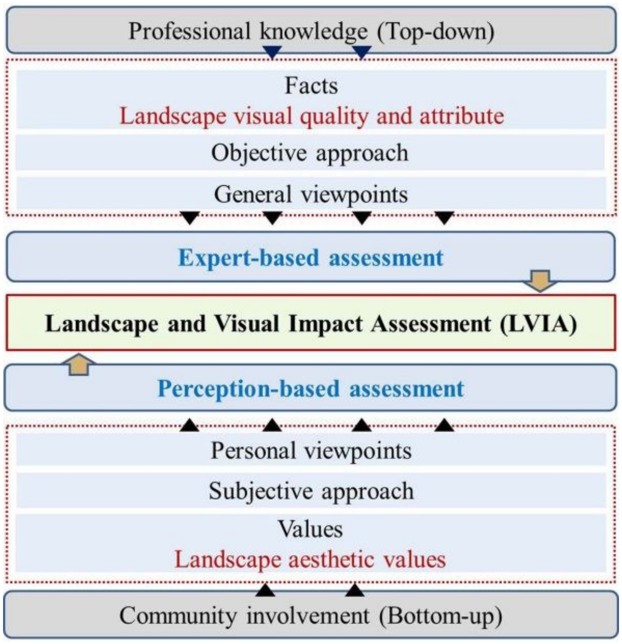

Fig. 1 Approaches for the LVIA

- *Expert-based assessment.* This method aims to define landscape scenery qualities and attributes with an objective approach, including attributes that define shape, height, structure and colour. These attributes are subsequently connected with properties such as variety, unity, uniqueness and distinctness. It is also necessary to recognize the

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morphology, vegetation and attributes of civilization related to the settlement and agricultural use of the landscape [18]. Expert-based assessment results in classification of landscape into three categories: landscape with low, medium and high aesthetic value [22]. However, assessments based on expert judgment sometimes are criticized as not being sufficiently representative of the perspectives of non-professional interest groups. As a result, communities are increasingly voicing their expectation that they should be consulted as to what is of significance to them. However, expert approaches have the potential to allow comparison between alternative sites and even arrangements of wind farms. Therefore, the professional groups could be requested to offer advice on different approaches in terms of scheme design or access servicing arrangements. The major advantage of expert-based assessment is its practical efficiency, in that it is less time-consuming and less expensive compared with the perception-based approach [17, 18]. According to Daniel [22], the weakness of the expert-based approach is the low resolution of different levels, as it is deeply dependent on the professional knowledge of the assessor.

- *Perception-based assessment*. In this approach, the community is considered as active participants in their landscapes as effective community involvement enabling the views of the broad community to be considered. Perception-based assessment is a subjective approach that focuses on individuals as the perceiving subject with their feelings, needs and imagination. The assessment is based on the assumption that landscapes may change over time and place and investigates community preferences by using choices, rankings or ratings provided by a sample of human respondents. Results are obtained using a range of methods by semi-structured interviews and questionnaires. The greatest advantage of this assessment is its high level of reliability even with a small sample of viewers (5-30). However, it is relatively expensive, time-consuming and difficult to organize on site. For this reason, photographs are usually used instead of the real landscape, and to assure reliability of the study, the researcher must follow certain rules when taking photos [17, 18]. In addition, computer-generated analyses can illustrate potential viewing areas. Simulated images provide a fairly accurate portrayal of how turbines will look. For each image, a realistic eye level, viewing direction, lens angle and distance are shown [4 11]. A further disadvantage is large divergences emerge when different groups of viewers obtained; the preferences of well-educated viewers will not be the same as the preferences of the rest of society [18].

Finally, the LVIA should assist decision makers, community members and other interested parties by providing a clear and common understanding of the predicted effects of wind farm proposals in an impartial and professional way. However, aesthetic valuation and LVIA are based on cultural background, and aesthetic values change in time. Consequently, LVIA can be judged on the basis of the facts of objective landscape attributes or according to the values of subjective opinions of viewers [15, 18]. In other words, the ideal tool for assessing impacts on landscape could be a combination of expert-based and perception-based assessment methodologies.

C. Public Perception and Acceptance of Wind-Farm Technologies

It is now generally accepted that some of the most limiting factors in the growth of wind-farm technology are socio-political factors, particularly, public acceptance of specific projects. The topic of public acceptance is becoming increasingly important; it plays an important role in the debate about which technologies to include in a future energy system. Consequently, public opinion and the portrayal of conflicts have become key areas of argumentation between regulator, developer and objector interests, each using different portrayals of wind energy and varied claims of public support to endorse their respective positions with community [23, 24]. Prominent opponents of classic wind-farms have confirmed that the noise can heard from 35 km away, whereas others talk about electricity from the turbines seeping into the soil and causing the deaths of hundreds of cattle and goats [25]. As a result, the search for new locations for wind farms is a challenge in which we must explore and weigh landscape and environmental aspects. However, new elements in the landscape often face misunderstanding and resistance. It is widely recognized that public acceptability often poses a barrier toward renewable energy development [3]. Without public support, using wind-farm technology to generate more green energy will not be possible. To integrate wind farms within landscape, involving administrators, councillors, energy producers, developers, investors, residents and civil society organizations is a fundamental approach.

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IV. THE NEED FOR ALTERNATIVE WIND-FARM TECHNOLOGY

The idea of using winds at high altitudes to generate power was first suggested around four decades ago, but at that time, it was not technically possible. Now, with new materials and more advanced computers, electronics and sensors, and the development of unmanned aircraft, the concept may be practical. Unlike wind turbines mounted on towers, AWE systems can be automatically raised and lowered to the height of maximum wind speeds, thereby providing a more temporally consistent power production. Several industrial institutions and companies are investigating the best ways to tap into the resource to generate renewable wind energy [26, 27] and avoid visual impacts on landscape character and scenery.

The following section presents novel results related to an innovative AWE technology, a relatively new branch of renewable energy that utilizes airborne tethered devices to generate electricity from the wind. This technology captures the kinetic energy of the wind by reaching higher altitudes and transforms the kinetic energy into electricity with less negative visual impacts on landscape compared with ground-based technology.

A. Capturing the Wind using Flying-Based Technology

As a part of ongoing investigation of viable and sustainable solutions to generating alternative energy power, reducing negative visual impacts, flying concepts have emerged that involve relays on balloons and flexible kite concepts. Historically, the idea of harnessing HAWE using a tethered aircraft is not new [28]. However, only in the past few years have more intensive theoretical, technological, and experimental studies have been conducted. Whilst, there are still a number of engineering problems and regulatory challenges required to be investigated. The following will briefly cover the state-of-the-art ideas based on light materials, high-resistance cables, innovative designs and different mechanisms (Fig. 2).

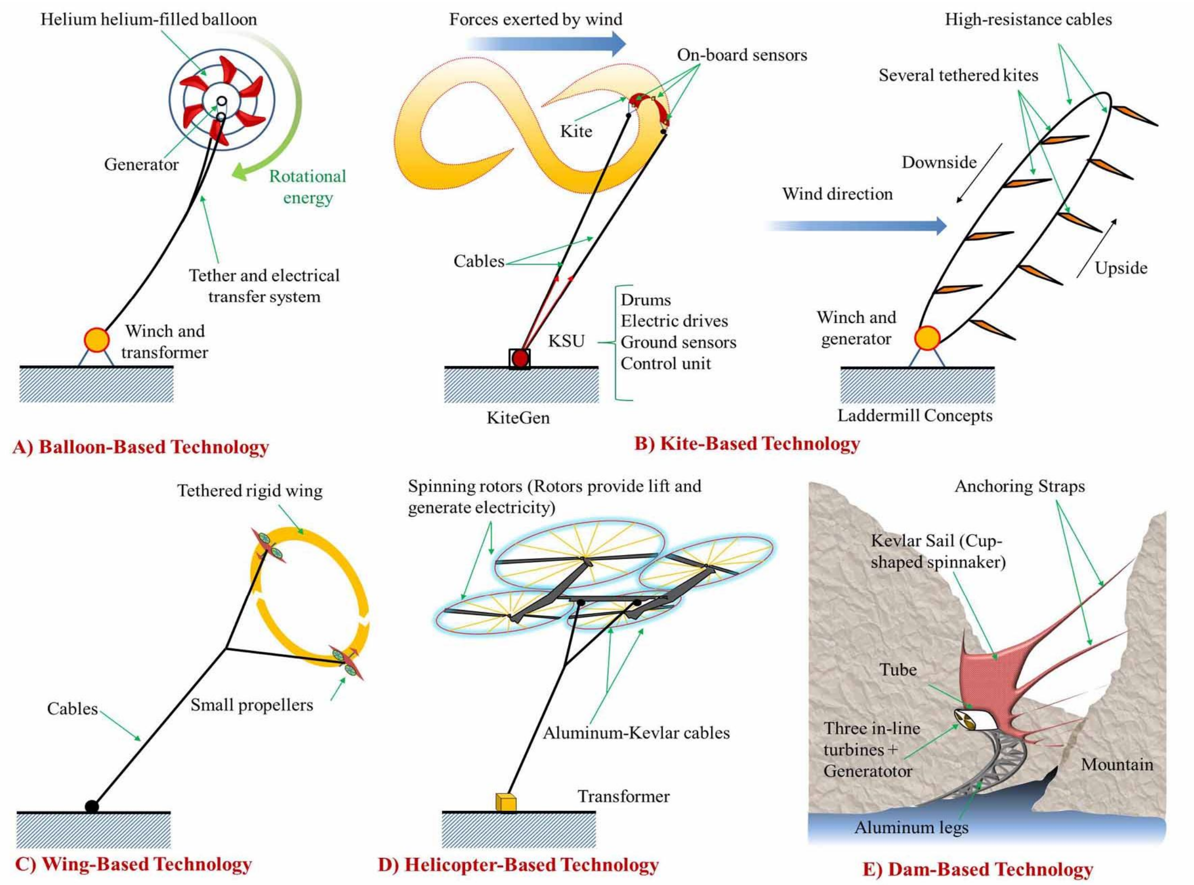

Fig. 2 State-of-the-art renewable energy technology that utilizes airborne tethered devices

- *Balloon-based technology.* One technology developed by Magenn Power Inc. is called the Magenn Air Rotor System (MARS) or inflated airborne wind generator. The concept depends on a helium-filled balloon stationary at a height between 200 m and 350 m that rotates around a horizontal axis in response to wind, generating electrical energy by a generator connected to its horizontal axis. The energy produced is then transmitted to the ground by a conductive tether [1] without having to build an expensive tower or the use of a crane to perform maintenance. MARS can be easily moved to different locations to correspond to changing wind patterns; this mobility is also useful in emergency deployment and disaster relief situations [29].
- *Kite-based technology.* Kites were used in China approximately 2,800 years ago. Apart from being children's toys, their early uses involved measuring distances, testing the wind, lifting men, signalling, and communication for military operations. After spreading throughout Asia, kites were brought to Europe by Marco Polo at the end of the 13th century. In the 18th and 19th centuries, researchers examined kites in their development of the airplane. At the beginning of the 20th century, interest in kites diminished following the invention of the airplane [1]. The first kite technology for energy utilities was proposed by Sequoia Automation from Italy. It is known as a kite wind converters or KitGen. This technology uses kites that spring from funnels on the end of giant poles when the wind blows. For each kite, winches release a pair of high-resistance cables to control direction and angle [30, 31]. Most kite-based technologies are based on the same basic idea, and the electric drives, drums, on-board sensors and all the hardware needed to control a single kite is denoted as the Kite Steering Unit (KSU), which is at the very core of the KiteGen technology [5, 8]. The concept of a kite-based system is to mechanically drive a ground-based electric generator using one or several tethered kites, particularly in Laddermill Concepts [1, 32]. This technology still has other innovative techniques concepts that will change the negative visual impacts of wind energy developments.
- *Wing-based technology.* Proposed by Makani Power in opposition to the kite-based approach, this technology involves a tethered rigid wing that travels in circles at altitudes of several hundred meters, mimicking the motion of a horizontal-axis turbine. Several small propellers are mounted on this wing, which generates power when the wind meets a minimum threshold and consumes power to maintain elevation in temporary lulls. Makani plans to develop mega-scale projects for onshore and offshore applications. The industrial company has already demonstrated full prototypes [33]. However, this concept has some technical complexities and a high cost with a significant risk related to its weight.
- *Helicopter-based technology.* Sky WindPower's helicopter generator relies on four spinning rotors to generate power while simultaneously keeping the craft and its tether aloft. The craft can thus ascend or descend from altitude as an elementary, tethered helicopter. This rather futuristic-looking design was proposed by Sky WindPower Co. and is commercially known as Flying Electric Generator (FEG) [34, 35]. However, the concept is innovative and still has negative impacts on birds, which may limit its development.
- *Dam-based technology*. Proposed by British architect Laurie Chetwood, this technology also aims to capture high-speed winds with a unique cup-shaped spinnaker similar to those used in yachting. The sail imitates the idea of a dam and does not let the wind escape, funnelling it through attached turbines to generate renewable energy. The conical shape of the sail directs air to three in-line turbines, which are enclosed in a tube [36]. Based on a computer model of the dam, the concept is expected to produce up to 120 megawatts per year, enough to power approximately 35 homes, but the design has drawn some criticism and far more than other renewable energy ideas involving kites. In particular, there has been criticism over the ability of the dam to stand up to catch wind from multiple directions, but the idea has the potential that can be developed [30, 31, 36]. In the future, this innovative idea could be solve one of the common complaints about wind turbines: that they disrupt the scenic landscapes and coastlines where, instead, they could be integrated. This technology would be ideal for mountain environments.

V. THE FUTURE OF FLYING-BASED TECHNOLOGY ON LANDSCAPE ASSESSMENT

Landscape perception and visual impact are key environmental issues in determining the applications related to wind-farm development [16]. It is necessary to bear in mind that future generations will most likely have different aesthetic preferences. History confirms that aesthetic preferences and valuation as regarding landscapes change with the development of knowledge, philosophy, ideas and culture [18]. At the same time, the design of wind-farm technology has improved dramatically in the last decade [4]. As a consequence, a number of alternative flying-based technologies have been suggested to overcome the limitations of ground-based wind farms [35].

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Advanced societies should bear in mind that the relationship between man and landscape is mutual. To respect aesthetic values in landscape management, it is necessary to have a good understanding of them. Flying wind farms are also tall objects that are likely to have an influence on landscape and become major elements in landscape architecture. However, there is currently no formally agreed methodology for assessing the sensitivity of different landscapes to these innovative technologies. The study proposes a step for this assessment based on the comparison with other ground-based systems (Table 1) that can help in assessing the landscape impacts of flying-based technology.

TABLE I
POTENTIAL IMPACTS ASSOCIATED WITH FLYING-BASED TECHNOLOGY

Characteristic & Specific aspects			Impacts
Physical & Technical	Blades	-	No blades except FEG
	Colour	-	Varied
	Size	-	Smaller than classic wind-farm technology
	Height	-	High-altitude wind energy
	Shape	-	Innovative and more visually attractive
	Materials	-	Lighter materials, anti-reflection, high-resistance cables
	Towers	-	Supported in the air avoiding the expense of tower construction
	Wind generators	-	Flying-based wind generators
Economic	Cost	-	Lower installation cost
	Foot print area	-	Higher altitudes with less foot print
	Land use & Spacing requirements	-	Large by given multiple devices at multiple altitudes with multiple tether angles ascending and descending
	Maintenance	-	Low cost maintenance
	Energy	-	More reliable wind
	Scale of development	-	Varied
	Mobility	-	Easily moved to different locations related to changing wind patterns or maintenance requirements
Environmental	Noise	-	Quieter, the high-altitude devices would be too high to be heard
	Birds	-	Bird and bat friendly except FEG. Advanced radar system redirects the kites to avoid avian deaths
	Safety	-	Cables remain a serious problem, still have hazards associated with their operation
		-	More affected by worse weather conditions
	Type of environment	-	Varied

Finally, while ground-based systems require actually more land use, other flying wind farms consume more land area. Due to their flying devices landing and taking off, it is likely that no other economic uses would be allowable due to workers safety and insurance reasons. In addition, there is a host of technical and regulatory challenges that will face flying-based technologies, may be something similar to the regulations and laws governing airports and their surrounding areas. However, it's expected that human mind is always thinking out of the box to solve the expected challenges. Without major industrial research, some of the specific engineering challenges may be difficult to overcome. Indeed, let the future indicates that such innovative flying-based concepts will have real positive impacts or just look fancy ideas.

VI. CONCLUSIONS

Despite the scientific support for renewable wind technology, wind-farm developments are often met with local opposition and social debates. There is an established recognition nationally and internationally that ground-based wind farms can affect landscape values. As a consequence, several research groups are developing new generations of HAWE concepts, more specifically flying-based technology with flexible kites and balloons to harness the wind in the upper layers of the atmosphere.

Most landscape assessments are performed to evaluate ground-based technology, and there is a need for more studies that examine these futuristic HAWE technologies. However, there is no methodology that has been universally investigated from the landscape point of view. The effects of wind-farm technology on landscape and visual impact cannot be measured or calculated, and assessment measures are limited. As a consequence, this research is a step for assessing the landscape impacts of wind farms within flying concepts. This paper has gathered the recent accomplishments in this field of interest, presented and assessed their approaches. These technologies are still in their initial stages, including the simulation and small prototypes phases. However, the technologies are expected to reach the application phase soon, as a result of intensive work, interest and awareness of many research teams and sponsors.

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