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FROM MY PERSPECTIVE

Harnessing rivers of wind: A technology and policy assessment of high altitude wind power in the U.S.

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ABSTRACT

This paper provides an assessment of the commercialization potential for high altitude wind power (HWP). Several technological and policy barriers are identified that may affect the development and deployment of the technology in the US. Technical barriers include electrical transmission from high altitudes and the development of viable methods of energy storage to address intermittency. Non-technical barriers include the lack of a carbon price in the US, which provides an advantage to embedded technologies and widens the 'valley of death.' A variety of stakeholders are analyzed in order to understand potential impacts upon the development of HWP. Many fossil fuel producers and utility companies have been leveraging political authority to lobby against a carbon tax, which could be crucial for broad deployment of renewable energy technologies. The combination of technical and non-technical barriers indicates that commercialization of HWP is unlikely in the short term. Commercialization would require major policy shifts at the federal level and advances in S&T. Recommendations are provided to increase federal investment in applied research through additional funding for the Advanced Research Projects Agency—Energy (ARPA-E). It is also recommended that ARPA-E create a matching fund to assist in the commercialization of renewable energy technologies.

1. Overview and methodology

This assessment aims to explore the prospects for the commercialization of high altitude wind power by examining the technologies, policies, and stakeholders that are affecting the development of this emerging area. Section 2 provides a brief history of the technology along with current approaches to capturing wind energy at both high altitudes and at ground level. The section concludes with an analysis and discussion of some of the socio-technical barriers facing the technology. Section 3 identifies the relevant stakeholders who are affecting the development of high altitude wind power and how these stakeholders can influence US energy policy. Section 4 identifies federal policies that may impact high altitude wind power and identifies policy gaps. The paper concludes with recommendations for federal policymakers and a feasibility analysis.

2. History and introduction to high altitude wind power

Recent studies have shown that jet streams or high altitude, high-velocity wind reservoirs hold enough energy to power the planet. Generally speaking, wind velocity increases as altitude is increased [1]. Throughout the globe, there are several jet streams at around 35,000 ft that can reach speeds greater than 275 mph [2]. This represents a vast repository of untapped energy, but poses a complex and unprecedented engineering challenge. That is, how can engineers capture, convert, store, and distribute electricity generated by the winds aloft? To address this challenge, a variety of designs have been proposed such as high altitude kites, tethered rotorcrafts, or dirigible based generators to capture High Altitude Wind Power (HWP).

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2.1. History of HWP

The concept for a high altitude wind generator is not a novel idea. A patent search has indicated that there was at least one patented design for a high altitude system as early as 1943. This particular apparatus was intended to be used as a wartime light bomber/glider, capable of silent battery powered operation that would use wind power to charge its batteries and provide propulsion. The mechanism of action is similar to a ground-based turbine, as the planes' propeller would simply turn with the wind while gliding and charge a battery [3].

By 1976, a system was proposed that utilized a lighter-than-air balloon tethered to a ground station with the express purpose of generating electricity [4]. Along the length of this tether were several fixed rotors that would turn both the tether and drive-shaft in a uniform direction to convert the mechanical energy into electricity. From the late 1970s through much of the early 1980s, several additional patents for high altitude wind energy were filed, including for kite-based systems. One design filed in 1981, proposed using a balloon to raise the apparatus to the desired height, which would be maintained by lift generated by a kite at the end of the tether [5].

Overall, it seems that there was a flurry of patents in the emerging field of HWP during the latter part of the 1970s and early 1980s. This may be related to the energy crises of the time, which caused gasoline prices to increase dramatically and even quadruple in 1980 [6]. It was during this same time period, that the US government would dramatically increase its investments into energy R&D, although by the early 1980s, the price of gasoline would fall and R&D funding decreased as well [7,8]. However, over the past decade, HWP has made something of a resurgence, with dozens of new patents being issued and the technology has gained significant attention from the media [9].

Several designs have been proposed to capture HWP. What follows is a brief description and illustration of three leading approaches, which are at varying stages of development.

HAKs are intended to operate at an altitude of 1000 m while remaining tethered to a rotating, ground-based carousel [11]. The kites are able to capture the wind currents and exert an aggregate torque on a carousel, which generates electricity. HAKs are distinct from the other proposed designs as the sight for power generation is ground-based whereas the other systems must generate electricity aloft and transmit the power over considerable distances [12] (Fig. 1).

A TRC consist of four rotors mounted to a light-weight airframe, which is connected to a power station via cable. Initially, electricity would be expended in order to position the TRC at the proper altitude (10,000 m) and would then rely on the jet stream for operation. Once the TRC has reached the jet stream, the rotor rotation provides both lift and electricity, which is then transmitted via cable to the ground-based station [14]. A prototype system has been constructed and tested by the Sky WindPower corporation [15] (Fig. 2).

DBR prototypes utilize lighter-than-air gases to float a free-rotating dirigible to altitudes between 400 and 1000 ft [17]. The apparatus contains a series of folds along a cylindrical body which capture passing wind currents and result in rotation around a fixed axis. As the system rotates, this torque is converted to electricity by adjacent generators, which transmit power along a tether to a ground station (Fig. 3).

2.2. Ground-based wind turbines

In October 2009, renewable energy accounted for roughly 10.4% of total energy production in the US [18]. Within the renewable energy sector (biomass, hydroelectric, geothermal, solar and wind), ground-based wind turbines accounted for 7% of energy production in 2008 [19]. While wind turbines make up a relatively diminutive portion of the US energy portfolio, it is important to note that from 1998–2008, total wind energy production increased from 31 trillion BTUs per year to 514 BTUs [20]. Demand for both onshore and offshore wind energy has been steadily increasing in the US, despite a variety of limitations of the technology as well as a myriad of non-technical barriers that may threaten future construction. One of the major challenges with ground-based wind (GBW) power is connecting rural areas (low electricity demand) that may be rich in wind energy with urban

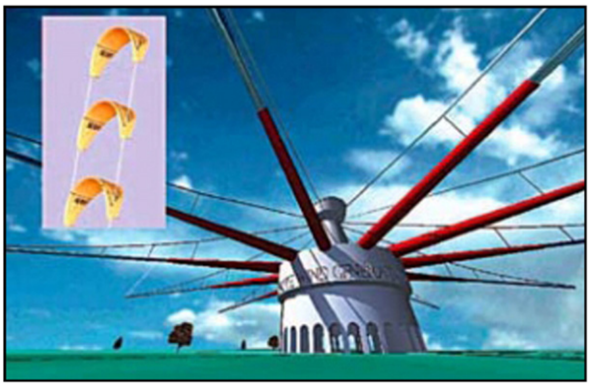

Fig. 1. High altitude kites (HAK) [10].