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Feasibility of a hidden renewable energy hydro power storage battery

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ABSTRACT

Global demand for clean renewable electricity is increasing. Although hydroelectricity is clean and renewable, storing excess energy during non-peak times in batteries usually causes negative impacts to the environment and may trigger legal or land use issues. Additionally, voltaic-based batteries are prohibitively expensive for storing the amount of electricity even for a small village. Actually it is a lot cheaper and cleaner to store electricity in water. This study explores how to do that. It features a unique pragmatic research ideology that included a literature review, comparative field research, data collection from the site, along with parametric statistical techniques. Relevant best-practices were cited from the literature and from comparative field research projects. A novel concept was the use of a land fault between lakes in a large park preserve. A scalable decision making model was developed for generating and storing clean renewable energy. The results should generalize widely to renewable energy storage practitioners, climate conservation activists, government policy makers and to other researchers around the world.

1. Introduction

The global concern for climate conservation and an increasing world-wide demand for electricity have driven many developed nations to implement 'green energy' creation alternatives including solar, wind, hydro and tidal systems [1–3]. Ironically, the energy generation potential of wind and solar powered systems surpass the world demand for electricity [4,5] as illustrated in Fig. 1.

However, paradoxically there is currently no feasible battery capable of storing these vast amounts of electricity to meet fluctuating demand when wind and solar systems cannot operate [6–8]. This problem occurs because wind and solar are unreliable due to atmospheric limitations and weather variations [8,9]. One high capacity 300 k Wh lead battery costs between $100,000–200,000 but can store only about the amount of electricity that a small-to-medium sized solar, wind or hydro system could generate in a day, and they have a much shorter lifespan [10–12]. Thus, with batteries being much more expensive and given the limitations of wind or solar systems for electricity storage, new alternatives are needed to meet the global stakeholder demands for more renewable green energy.

A water-based reservoir system is the storage technique used by 99% all electricity generation facilities over 150 Giga Watts (GW) around the world [13]. Hydro storage systems are simple, they produce clean energy, and they are renewable [3,14]. In a pumped hydro storage system water is moved into a reservoir or tank at a higher elevation using excess non-peak energy to be released later to generate electricity by spinning turbines to meet higher demand periods [10,15]. The problem with pumped hydro storage facilities is that they can be expensive to construct and the environment may be damaged in doing so [16,17]. Furthermore, there may be aesthetic concerns and legal issues associated with land use in order to acquire the reservoir and flood plains [7,18].

Several approaches have been proposed to reduce the cost and environmental damage associated with developing pumped hydro storage systems [11]. Novel designs include using compressed gas containers [19,20], weights [21], tall buildings [22], and underground caves [23]. The idea of using underground caves for storing electrical energy is the least expensive and the most environmentally friendly [23–25]. Nevertheless, the existing literature contains only theoretical proposals rather than a natural land fault type of hydro storage case study.

This is a case study of a novel hydro storage facility recently developed in New York, USA. Three attributes make this case study unique as compared to the existing literature. The area was rural, it was a subterranean pass-through hydro system located within a large protected natural preserve and an existing land fault between two lakes was leveraged. The preserve is large and diverse —at 6

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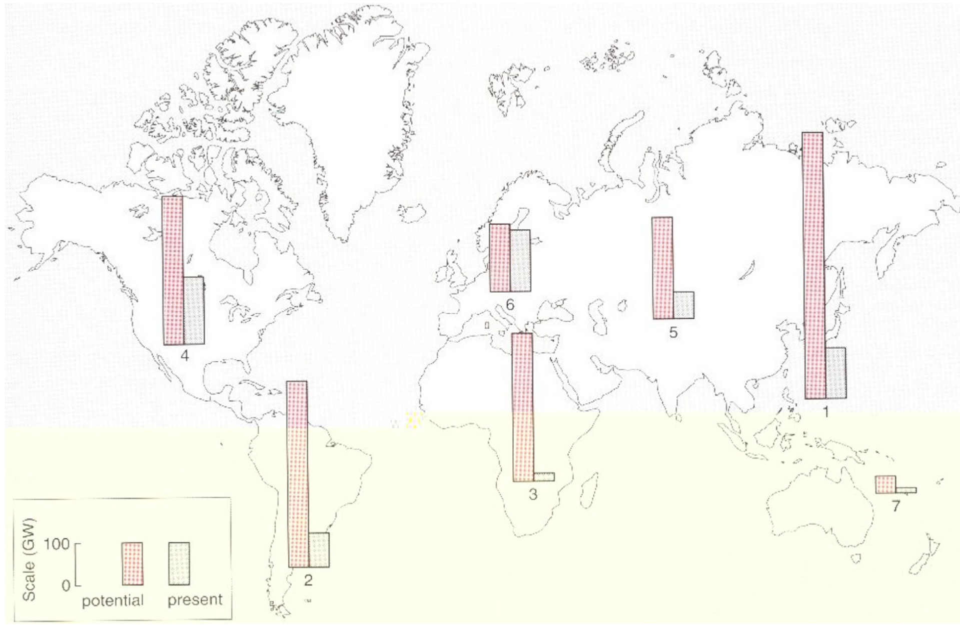

Fig. 1. Potential of alternative energy generation potential has surpassed world demand.

million acres it is the largest park in the contiguous USA, with mountains over 4000 feet high (1,220 m), containing more than 2800 lakes and 1500 miles (938 KM) of rivers fed by over 30,000 miles (18,750 KM) of streams [26].

In this paper the design for a flexible hydro storage facility is discussed and a feasibility model is developed in an easy-to-use Google Calc spreadsheet. The model includes variables for uncertainty estimates to facilitate risk management and decision making. American imperial measurements are converted to metric units for dissemination to global practitioners. The results of this study should generalize to domestic and international stakeholders in the climate reality movement as well as to the clean renewable energy community of practice. This would include scientists, engineers, investors, project managers, and practitioners in anywhere electricity storage is needed to meet variable future demand.

2. Background material and literature review

2.1. Macroenvironment factors in electricity generation

The increasing global demand for electricity and climate conservation are two forces which have pushed many countries towards evaluating novel concepts for electricity generation and storage [4,14,27]. Electricity generation is not necessarily the problem because solar and wind are adequate except they are not available everywhere or anytime [28,29]. Very few locations have consistently strong enough wind [13,30] and only approximately 66% of the world population resides in feasible solar zones with direct angle sunlight [31,32].

Another global concern concerning electricity generation is the efficiency associated with the generation and customer servicing [33]. As discussed earlier, USA trails the developed nations in terms of the efficiency that the country produces renewable climate-friendly electricity. Germany, Japan, Italy, France, United Kingdom, China and Spain were the most energy efficient countries ahead of the USA [1]. This is interesting to see that China ranks higher than USA in efficient clean energy production since that is contrary to the public perception in America. One reason that China outranks USA is due to its lower demand and communist government that is capable of controlling the social as well as economic factors. Another reason that China ranks high despite its reliance on importing coal from Australia and using it for traditional fossil fuel electricity plants is that they have high numbers of renewable hydro plants [2]. Perhaps a limitation with the ACEEE statistics is their measurement methodology to rank renewable energy generation does not address cultural differences for environmental standards (e.g., flooded land due to dams) and quality of living conditions (building and appliance codes). Nonetheless the work of ACEEE illustrates what is possible for effective clean energy production in countries much smaller than USA, with less favorable land resources, and all nations in the top ranks had lower GDP levels as compared to USA.

Americans often forget that we are a small population on the planet and our traditional ways of using fossil fuel to generate electricity are not universally practiced. Biomass has become a popular renewable source of materials used to generate electricity in fossil fuel type plants [34]. Biomass is a natural product of solar energy consisting of wood shrub and grass. In tropical and subtropical regions, common biomass products are the chilauney tree, laber, katus, utis, mawa, panisas, malata, marich, bamboo and palmetto bushes [35]. Biomass products are burned to produce heat which is converted into electricity so these are not exactly clean energy methods because smoke pollution is created but the output is considered less hazardous for the ozone as compared with coal or oil [35]. The attraction of biomass products is their abundance and renewability [35]. The problem for northern climates of USA is that land is controlled, most productive vegetation is used for agriculture, farming, or forestry and what is left is insufficient to meet the customer demands of a technology-driven generation. Additionally, social groups in USA are against any type of fuel burning method for electricity generation since the output is carbon dioxide (greenhouse gas).

2.2. Electricity generation and storage

Chhetri, Islam and Pokharel [36] raised an important consideration when thinking about green energy creation and storage. They suggested a major constraint was the dependency of most people on a scarce few utility companies or limited fuel