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How to Build a Sustainable Grid: Solar Power and Saltwater Batteries

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ABSTRACT

Humanity worldwide is already dramatically impacted by the climate crisis, which will only worsen and further threaten civilization unless drastic changes are made to the foundations of human society. Primarily, our global energy system needs to be reconstructed in order to prevent the most dire calamities from a climate changed world. Specifically, the pairing of saltwater batteries and renewable energy sources, such as solar energy, offers an exceedingly promising future. Since the surge in popularity of batteries in the 1970's, lithium-ion batteries have been the most common batteries used in every appliance that requires stored energy. Unfortunately, lithium-ion battery use is unsustainable, as these batteries contain toxic and environmentally harmful substances that are becoming increasingly less abundant as battery demand increases. A more sustainable alternative solution lies in the potential of sodium-ion batteries (a.k.a saltwater batteries) whose chemistry is similar to lithium-ion batteries, but use sodium rather than lithium as the electrolyte. Although efforts are being made to improve the efficiency of saltwater batteries, specifically by increasing their energy density, sodium-ion batteries have several additional benefits including their eco-friendliness, the planet's relative abundance of sodium vs. lithium, the ethical supply of materials, zero known health and safety risks, and overall long-term economic efficiency.

Introduction

Humanity already feels the impact of the climate crisis through the increased risks of wildfires, rising sea levels, heat waves, and more. These effects will only worsen, become harsher, and exponentially more dangerous unless the global energy grid is transformed to become sustainable. As the Intergovernmental Panel on Climate Change (IPCC) wrote in their 2018 special report *Global Warming of 1.5ºC,* global warming harms human society on numerous fronts including crop production, the propagation of infectious diseases, freshwater supply, and sea level rise.[1] Therefore, the countless detrimental effects of the climate crisis have the potential to become catastrophic, and likely will, unless widespread steps are taken towards preventing the predicted 1.5-2.0º Celsius increase in temperature.[2] Global warming occurs through a process known as the greenhouse effect, which describes the trapping of heat in our atmosphere in the form of longwave UV radiation. Although this process ensures that the earth is a habitable planet, greenhouse gases (GHGs) emitted from human sectors intensify the heat trapping effect and lead to what is known as the *enhanced* greenhouse effect. Therefore, the simplest way

[1] Guilyardi, E., Lescarmontier, L., Matthews, R., Point, S., Rumjaun, A., Schlüpmann, J., & Wilgenbus, D. (2018, December). *IPCC Special Report: Global Warming of 1.5º C Summary for Teachers* (Rep.). Retrieved August 22, 2021, from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/03/ST1.5_final_310119.pdf

[2] Guilyardi, E., Lescarmontier, L., Matthews, R., Point, S., Rumjaun, A., Schlüpmann, J., & Wilgenbus, D. (2018, December). *IPCC Special Report: Global Warming of 1.5º C Summary for Teachers* (Rep.). Retrieved August 22, 2021, from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/03/ST1.5_final_310119.pdf

to slow global warming is to reduce carbon dioxide emissions along with other GHG emissions, which can be achieved by investing in renewable energy and creating a more resilient grid, as defined by an interconnected network transporting electricity from producers to consumers. Such a system can only be adopted by switching from fossil fuels to renewable sources, and by developing safe and eco-friendly energy storage technologies. Specifically, the combination of solar power and saltwater batteries has the potential to reconstruct the grid to become more sustainable by relying on renewable energy and eco-friendly storage techniques.

The Past: An Unsustainable History

Since the industrial revolution, human life has relied on fossil fuels as the primary source of energy, which have allowed economies to thrive, populations to expand, lifespans to grow, and the quality of life worldwide to improve drastically.[3] Fossil fuels result from ancient decomposition and photosynthesis which together produce organic molecules that emit energy in the form of combustion. Different types of fossil fuels include coal, oil, and natural gas, all of which are formed by the decomposition of a variety of materials in various environments. When society started burning fossil fuels on an industrial scale in the 1880s, environmental risk assessment was absent from the consideration of material use, especially with respect to climatic impacts. The climate crisis is a consequence of the continual release of GHGs into the atmosphere, which occurs whenever fossil fuels are burned. As more coal, oil, and natural gas is burned, the carbon dioxide and other GHGs emitted remain in our atmosphere and continue to trap more heat and release toxic particles that impact public health and longevity.[4] The current energy grid is unsustainable because it relies on sources of energy that are heating up our planet at an unnatural rate. Unless society begins to make serious changes to the entire energy system and way of life, planet earth will face catastrophic and heartbreaking consequences.

The Present: A Time of Change

All energy on Earth originally came from the sun. Even today's fossil fuels were formed when hundreds of millions of years of pressure and temperature led to the transformation of ancient plants which became stores of the sun's energy over long periods of time.[5] Unfortunately, the burning of fossil fuels has compromised every living organism, ecosystem, and biome on the planet, and has even altered the fundamental chemistry of the earth's atmosphere and oceans. However, instead of harnessing the sun's energy through the slow and time-consuming processes of plant and animal decomposition, solar energy can be harnessed to counter the dangerous warming of the planet. Solar power is the power provided by the constant supply of energy and light released from the sun. To harness this power, solar panels offer technology that is designed to absorb the sun's radiation and convert it into electricity to power any device or application that requires energy to function. The sun releases a magnificent amount of power at every moment: 173,000 terawatts, while the planet's current population uses 17.3 terawatts (only 1/10,000 of the amount provided by the sun).[6] Solar energy is completely

[3] Gross, S. (2021, June 16). Why are fossil fuels so hard to quit? Retrieved from https://www.brookings.edu/essay/why-are-fossil-fuels-so-hard-to-quit/

[4] Nunez, Christina. "Carbon Dioxide in the Atmosphere Is at a Record High. Here's What You Need to Know." *Environment*, National Geographic, 3 May 2021, www.nationalgeographic.com/environment/article/greenhouse-gases.

[5] Gross, S. (2021, June 16). Why are fossil fuels so hard to quit? Retrieved from https://www.brookings.edu/essay/why-are-fossil-fuels-so-hard-to-quit/

[6] Chandler, David L. "Shining Brightly." *MIT News | Massachusetts Institute of Technology*, MIT News, 26 Oct. 2011, news.mit.edu/2011/energy-scale-part3-1026.

renewable with minimal risk to the environment and will be available for billions of years, until the sun explodes. In fact, there is a theoretical limit to solar power, but one that does not apply to humanity at present or in the near future–as explained by MIT physics professor Washington Taylor, "It's finite, but we're talking billions of years."[7]

Solar power has the potential to provide energy to human civilization now and for the fathomable future. Additionally, solar power can address inequities that are exacerbated by the energy crisis by supplying energy to the 940 million people in under-resourced communities who lack access to electricity and therefore struggle to survive.[8] Energy-intensive resources that many citizens in the U.S. and other developed nations take for granted could easily be provided to the hundreds of millions of people who lack these resources and the energy supply needed to power them. When weighing the readily available supply of energy provided by the sun against fossil fuels, which can only be formed over million year stretches of time, the case is made that this rapidly decreasing energy supply could and should be supplemented with, and ultimately replaced by, solar power. Solar is an especially convenient source of power which can be accessed with or without connecting to the grid, as any individual or independent organization can install solar panels and have access to energy whenever needed.

Since 2010, the cost of solar power has decreased 82%,[9] and was predicted to drop another 25% by 2022.[10] As of May 2024, the average cost of solar in California is at most $2.86/Watt.[11] London's Carbon Tracker Initiative even revealed that the construction of new sun- and wind-power facilities is becoming cheaper than the operation of existing coal-fired power.[12] Solar power's cost-effectiveness is one of its most important features because of the historically high costs and limited resources currently allocated to clean energy. In 2021, when Bill Gates' book *How To Avoid A Climate Disaster: The Solutions We Have and the Breakthroughs We Need* was published, the price of solar panels was dropping 30 to 40% with every doubling of solar panel installation, and the cost-effectiveness has continued to improve since then.[13]

One misconception about the adoption of solar power is that solar panels occupy an excessive amount of space. However, the space required to power the world purely on solar energy is minimal compared to other energy sources, thereby further incentivizing the widespread adoption of solar panels. Powering the United States entirely with solar energy requires 21,250 square miles, which is only 0.5% of America's total land mass.[14] By comparison, 49,300 square miles of land in the US is used to grow corn purely for ethanol production.[15] In order to power the entire world on solar, 115,625 square miles are needed, or ~1/30 the size of

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[7] IBID

[8] Ritchie, Hannah, and Max Roser. "Access to Energy." *Our World in Data*, 28 Nov. 2020, ourworldindata.org/energy-access.

[9] Rollet, C. (2020, June 03). Solar costs have fallen 82% since 2010. Retrieved September 12, 2021, from https://www.pv-magazine.com/2020/06/03/solar-costs-have-fallen-82-since-2010/

[10] Ward, T. (2017, June 29). The Cost of Solar Will Drop Another 25% by 2022. Retrieved September 12, 2021, from https://futurism.com/the-cost-of-solar-will-drop-another-25-by-2022

[11] California Solar Panels: Pricing & Incentives for 2024. (n.d.). https://www.energybot.com/solarpanels/california/#:~:text=The%20average%20price%20for%20a%20home%20solar,will%20vary%20depending%20on%20the%20solar%20installation

[12] Mckibben, B. (2021, February 15). How Does Bill Gates Plan to Solve the Climate Crisis? Retrieved September 5, 2021, from https://www.nytimes.com/2021/02/15/books/review/bill-gates-how-to-avoid-a-climate-disaster.html

[13] IBID

[14] Nussey, B. (2021, June 20). How much solar would it take to power the U.S.? Retrieved September 5, 2021, from https://www.freeingenergy.com/how-much-solar-would-it-take-to-power-the-u-s/

[15] IBID

the Sahara Desert.[16] As such, the comparatively efficient space requirements for solar paneling are another compelling factor in transitioning from fossil fuels to solar energy.

The Present Continued: Challenges to a Solar-Powered Grid

Although effective methods to decarbonize the grid are readily available, challenges remain which sustain society's reliance on fossil fuels and impede the adoption of a sustainable grid. Fossil fuels are efficient and energy dense and have supported communities around the world throughout recent history. Additionally, fossil fuels have become cleaner over time, as energy industries transitioned from reliance on wood to charcoal to coal to oil to natural gas. Unfortunately, the high rate at which fossil fuels are currently burned threatens human health and longevity, as it accelerates the already deleterious accumulation of greenhouse gases in the atmosphere. However, global economies have become excessively reliant on fossil fuels, so transitioning entirely to renewable energy sources will be a challenge. Although solar power and other renewables are becoming more effective, efficient, and affordable every day, dismantling and rebuilding long-standing infrastructures will not be easy, and will require a global mindset that appreciates and values the long-term benefits of sustainability and planetary health rather than short-term convenience and stasis. An outsized concern is that many people and institutions involved in the fossil fuel industry will be financially disrupted by movement towards decarbonization, ignoring the multitude of jobs and financial opportunities that the renewable energy industry will generate.

Solar power offers many benefits to society but implementing it into the energy grid requires addressing some climate-related challenges as well. For example, in a cloudy city like Seattle, access to solar power isn't always in constant supply. In northern latitudes where sunlight is muted, or places where the sun is regularly obstructed by clouds, storage for solar power becomes crucial for providing energy from one day to the next. Major advances in battery technology provide compelling solutions to these challenges.

Batteries are containers consisting of cells that convert chemical energy to electricity which serve as sources of power and energy storage. Batteries work by transferring electrons from one material or electrode to another at the opposite end of the container. The flow of electrons produces a current and thus can be used to power an external device. The electrical energy in a battery can also be contained for later use, increasing its value in locations where the grid's power sources, e.g. wind and solar, can be unpredictable.

Lithium-ion batteries have been the most efficient and least costly batteries since they were invented in 1985, leading to their widespread use today, including in portable electronics such as iPhones, iPads, computers, and AirPods, as well as in technologies such as electric cars, pacemakers, infusion pumps, and more. Despite their benefits, lithium-ion batteries have numerous downsides. Lithium-ion batteries are explosive, flammable, and require rare earth metals such as lithium and cobalt, which are both dangerous and controversial metals to mine. These batteries also pose environmental risks, as they require safe disposal in order not to affect local ecosystems; however, regulations are often neglected due to lack of responsibility, care, or financial resources. For these reasons and more, new battery technologies are being developed which have a similar chemical makeup to lithium-ion batteries, and promise low cost, guaranteed safety, and minimal environmental impact.

[16] A. (2020, September 17). Powering The Entire World With Solar: Surface Area and Panel Requirements. Retrieved September 5, 2021, from https://www.axionpower.com/knowledge/power-world-with-solar/

The Future: A Sustainable Grid

Saltwater batteries are an innovative, eco-friendly, and up and coming alternative to lithium-ion batteries. A saltwater battery, also known as a sodium-ion battery, uses a sodium solution rather than lithium as its electrolyte. Sodium is the sixth most abundant element on the earth's crust, making it inexpensive and easy to access. In contrast, the global supply of lithium is waning as the demand for battery production soars. Lithium-ion batteries require cobalt mining, which raises ethical, social, and political issues. Cobalt mining is hazardous to human and animal health, due to high levels of radioactivity recorded in mining regions, the dangers of mining waste pollution in rivers and drinking water, and the respiratory problems caused by the dust from rock pulverization.[17] In addition to the health impacts of cobalt mining within communities most proximate to the mines, the environmental consequences are felt world-wide because cobalt mining increases CO2 and NO2 emissions, which contribute to the enhanced greenhouse effect and perpetuate global warming.[18]

Lithium-ion batteries also contain materials that are toxic to the environment when exposed through spills and other accidents. Lithium spills harm ecosystems and nearby neighborhoods and communities through soil degradation and air contamination. The solvents within lithium-ion batteries are highly flammable and the batteries themselves have the potential to be explosive. Although the chance of a lithium-ion battery exploding is slim (<1/1,000,000), over 900 million people around the world carry what could be ticking time-bombs in their personal electronics wherever they go. [19] For example, Nicholas Jones, a graduate student who needed a replacement battery for his laptop, decided to buy one from Amazon, which turned out to be a grave mistake. Out of nowhere, his laptop suddenly ignited and the battery cells started leaking acid. Jones later had to be treated for first degree fire and chemical burns and needed to purchase a new computer, a new couch, and finance the repair of his damaged floor.[20] Although the number of casualties from exploding lithium-ion batteries remains minimal, sodium-ion batteries offer a promising alternative technology with zero known health or safety risks.

In terms of their chemistry, saltwater and lithium-ion batteries are almost identical. On the periodic table, lithium is directly above sodium, and the two function similarly as alkali metals. The greatest difference between the two types of batteries is their energy density. Unfortunately, saltwater batteries are less energy dense than lithium-ion batteries. As such, for a sodium-ion battery to store the same amount of energy as a lithium-ion battery, the size of the battery must increase, requiring more materials, and hence, an increase in cost. While size inevitably affects applicability, and saltwater batteries are not able to fit in mobile devices just yet, sodium-ion batteries are becoming optimal for storing energy along the grid that comes from renewable sources. Another important component of a battery's chemistry is its C-rate, which is the rate at which a battery discharges. Sodium-ion batteries have a lower C-rate than lithium-ion batteries as they require a longer period

[17] Frankel, T. C., Mucha, L., & Sadof, K. D. (2020, October 01). Perspective | The hidden costs of cobalt mining. Retrieved September 5, 2021, from https://www.washingtonpost.com/news/in-sight/wp/2018/02/28/the-cost-of-cobalt/

[18] Farjana, S. H., Huda, N., & Mahmud, M. P. (2019, March 06). Life cycle assessment of cobalt extraction process. Retrieved September 5, 2021, from https://www.sciencedirect.com/science/article/pii/S2300396018301836

[19] John, A. S. (2016, September 21). Why Lithium-Ion Batteries Still Explode, and What's Being Done to Fix the Problem. Retrieved September 12, 2021, from https://www.consumerreports.org/safety-recalls/why-lithium-ion-batteries-still-explode-and-whats-being-done-to-fix-the-problem/

[20] Semuels, A. (2019, April 30). When Your Amazon Purchase Explodes. Retrieved September 12, 2021, from https://www.theatlantic.com/technology/archive/2019/04/lithium-ion-batteries-amazon-are-exploding/587005/

of time to discharge completely, constraining the convenience of saltwater batteries when a large amount of energy needs to be accessed in a limited amount of time.

However, the benefits of saltwater batteries abound. Firstly, discharging sodium-ion batteries has no effect on them, unlike lithium-ion batteries which are increasingly degraded with every full discharge, which is why mobile phones are only supposed to charge up to 80% and discharge to 20%. Additionally, the lifespan of saltwater batteries (5,000 cycles) is 10x that of lithium-ion batteries (500 cycles) which can save material resources and potentially even out the cost of repurchases in the long run.[21]

Lastly, the most compelling case for the transition from lithium-ion to sodium-ion batteries is to protect the environment and support a sustainable future. Saltwater batteries do not require the extraction of rare earth metals which lead to public health impacts and ecological harm. Sodium-ion batteries are recyclable, and save financial and material resources. While lithium-ion batteries can be recycled, the process is taxing and toxic, resulting in their most common disposal directly into landfills around the world, including in Australia, for example, where only 2-3% of lithium-ion batteries end up at recycling facilities.[22] Lithium-ion batteries will undoubtably remain in use for many applications; however, the environmental benefits and social impact of sodium-ion batteries must not be overlooked as continued use of lithium-ion batteries will lead to more dire climate consequences for future generations. Although the future of sodium-ion batteries on the market is still being developed, their current potential combined with rapidly evolving technological innovation could provide exactly what society needs to establish a sustainable grid.

One present-day example of technological innovation in sodium-ion batteries is being developed by the Austrian engineering team at Blue Sky Energy. Founded in 2012, Blue Sky Energy describes themselves as an "energy storage solution provider and system integrator" building numerous safe and sustainable energy storage technologies. [23] The Blue Sky team is currently working on improving high temperature range, high power, and high cycle stability.[24] Although there are many challenges towards implementing saltwater batteries, including their relatively low energy density compared to other batteries, groups like Blue Sky Energy are doing the crucial work to overcome those challenges, which is key to keeping the future skies blue. Energy density and C-rate, the two largest roadblocks towards creating an efficient saltwater battery, can and will be solved by the research and innovation, that companies like Blue Sky Energy are tackling.

Conclusion: Building a Better Tomorrow

As daunting as the climate crisis may seem, human society has the ingenuity and resources to rethink and rebuild its systems in a way that safeguards the future against climate calamities. To achieve this restructuring, individuals need to be more mindful about the environmental impacts of their daily actions; however, the avoidance of the most catastrophic impacts of global warming will require a sweeping effort on behalf of every government and enterprise around the world to reduce their carbon footprint and adapt to a climate-changed future. The combination of solar power and sodium-ion batteries as a foundation for the global energy system is one example of large-scale adaptation and sustainable development that is salubrious, effective, and attainable. Many scientists and scholars believe that society has entered an era of anthropogenic existential risk, the most pressing example being extreme climate change and its cascading ecological and sociopolitical

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[23] Bluesky Energy. (2021, September 03). Retrieved September 12, 2021, from https://www.bluesky-energy.eu/
[24] IBID

challenges. While this may be true, the prevalence of these dangers and risks is also leading to an emboldened sense of innovation, imagination, and creative solutions.

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