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Maximizing the Benefit of Desalination Brine: Guidance and Awareness for Transitioning from Waste to Valuable Resources

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Maximizing the Benefit of Desalination Brine: Guidance and Awareness for Transitioning from Waste to Valuable Resources

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Abstract: The competition for desalination is currently underway. A mere decade ago, nations within the Maghreb region and, rather unexpectedly, European countries, were fortunate enough to evade humanity's primary adversary: drought. However, the unpredictable nature of climate change has since altered this reality. Consequently, an increasing number of countries are contemplating the serious prospect of utilizing desalination to fulfill their potable water requirements from the seas and oceans bordering their coastlines. Regrettably, research and experience have indicated that highly saline water presents a significant threat to marine ecosystems. This scholarly investigation aims to contribute to the discovery of a solution that will enable the continuation of seawater desalination without inflicting harm on the marine flora and fauna, and this work can be considered as a prototype that need to be studied closely, because the results are here and undeniable, plus this is all what we going to need more and more in near future, namely water and energy.

Keywords: climate change; seawater desalination; marine ecosystems; drought; energy efficiency; high yield

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1. Introduction

The impending freshwater shortage is a serious issue that requires immediate attention. Scientific studies predict that this crisis is becoming increasingly likely, and its impacts would be far-reaching and devastating. Mass migrations towards the north [1], escalating conflicts between neighboring countries over scarce resources [2], and a sharp decline in the GDP of many nations [3], [4]are just some of the potential consequences.

To address this issue, several projects need to be explored urgently. One promising solution is the establishment of water highways connecting southern and northern countries [5], while also transmitting clean energy from the south to the north via cables. This would allow northern countries to tap into the abundant solar and wind resources available in the southern regions [6]. However, such ambitious projects come with a hefty price tag and require extensive feasibility studies and international cooperation.

To safeguard their water security and maintain control over their water supplies for drinking, agriculture, and certain industries, desalination of seawater is a viable, albeit costly, option [7]. The desalination process involves extracting seawater, desalinating it to the maximum extent possible, and then returning the remaining water to the sea. However, environmentalists have raised concerns about the impact of desalination on marine biodiversity [8], [9]. The discharged brine, which has a high salinity level, can harm marine ecosystems. This highly saline water, known as brine, is a crucial component of the proposed solution. Instead of being disposed of in the sea, it will be repurposed from an unwanted waste product into a valuable asset for this project.

This article targets two primary audiences: biologists concerned about the impact of underutilized marine waters on sea life, and institutions in countries currently or soon-to-be affected by rain scarcity due to global warming. The aim is to innovatively address this modern challenge by

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proposing a compromise or effective solution. To maximize the project's performance and generate more drinking water, electricity, and overall affordability, a comprehensive set of measures is required. Essentially, this work offers a ready-to-implement solution for interested parties, with only the scaling aspects left to be tailored by relevant stakeholders.

2. Shedding Light on the Matter: A Clear Exposition of the Problem

In order to promote this indispensable freshwater resource, this study should focus on the most advanced seawater desalination technologies. Currently, three types of desalination technologies exist, as summarized in the table below, highlighting the two factors most relevant to this study: energy consumption and brine-to-freshwater ratio.

Table 1. energy consumption and brine-to-freshwater ratio for each desalination technology.

Desalination technology	Energy consumption (kWh/m^3)	Brine to drinking water ratio (Average)
Multi-stage flash (MSF)	8 to 12	57%
Multi-effect distillation (MED)	4 to 8	67%
Reverse osmosis (RO)	3 to 6	50%

Reverse osmosis, with its outstanding brine-to-freshwater ratio and minimal energy consumption, stands as the most favorable technology [10], thus taking center stage in this study.

Irrespective of the desalination technology used, be it reverse osmosis or any other technique, the end objective is consistent: to generate drinkable water while disposing of the resulting brine in an environmentally responsible way. The central focus of this study is the acknowledgment that the primary hurdle is energy-related, particularly, securing ample energy for both the reverse osmosis process and the disposal of brine. This study offers a potential solution among others to tackle this challenge.

3. Fundamental Principle Guiding the Promised Valorization Process

To address the environmentally responsible disposal of brine derived from seawater desalination, and given that soil injection is not a viable alternative [11], the most practical solution appears to be evaporation. One technique employs natural evaporation through solar radiation [12], a virtually cost-free approach, but unfortunately, it is rather slow, as even in the best-case scenario, only one-fifth of the daily brine production can be evaporated. The other equally evident method is assisted evaporation, which entails dedicating a certain amount of energy to accelerate the evaporation process. This study, however, aims to highlight another method that involves utilizing the water vapor destined to be lost to the atmosphere to generate electricity, which will then be reinjected to facilitate further brine evaporation. The figure n°1 below is dedicated to setting ideas and having a clear vision of the entire process implemented.

Table 2. Figure 1 legend.

	**Filtered water flow**
	**Unfiltered water flow**
	**Solid impurities, mainly sea salt**
	**Flow of electrical energy**
	**Steam flow**

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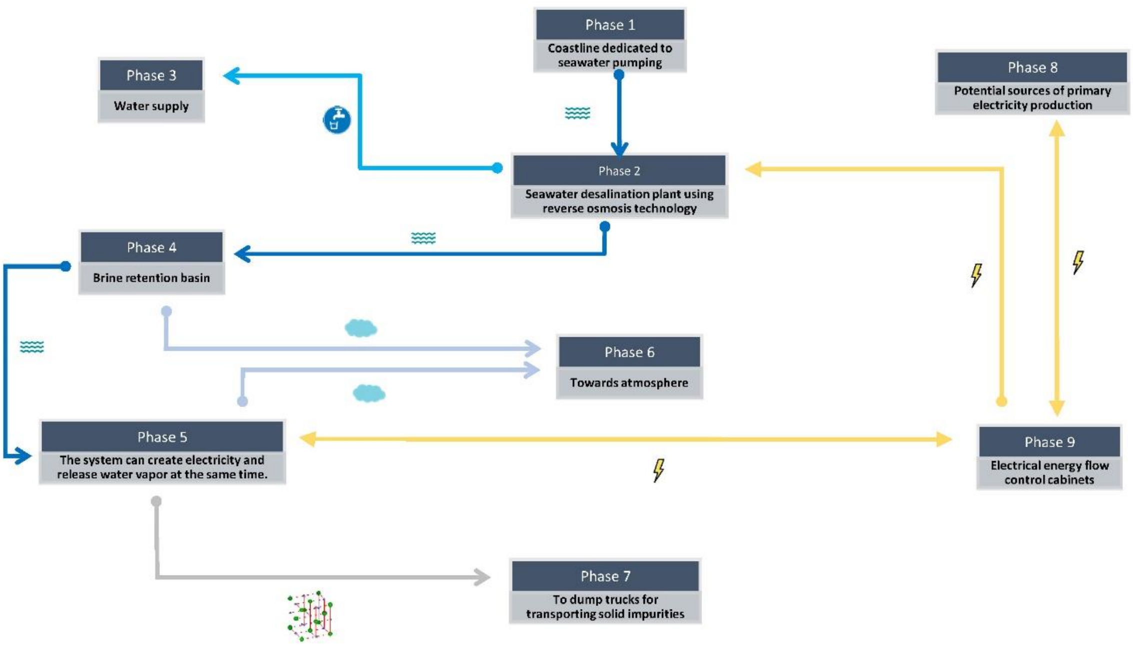

Figure 1. description of the entire process.

4. Situational Analysis and Identification of Paramount Challenges to Surmount

Notwithstanding the somewhat elevated expense of the infrastructure integral to this programme in its entirety, a cost that is nonetheless substantiated by the intricate and potentially precarious circumstances faced by numerous nations consequent to a sequence of arid years [13], another factor that could potentially impede the transition to seawater desalination, should penalties associated with the hazardous nature of brine discharge be imposed subsequently, is indubitably the expenditure incurred in the disposal of this very same highly saline water. The key environmental concern involves successfully recovering all the extracted water, both as filtered drinkable water and as a considerable quantity of solid sea salt, which holds value in various fields. Figure 2 below outlines the challenges that need to be tackled to advance the application of this method.

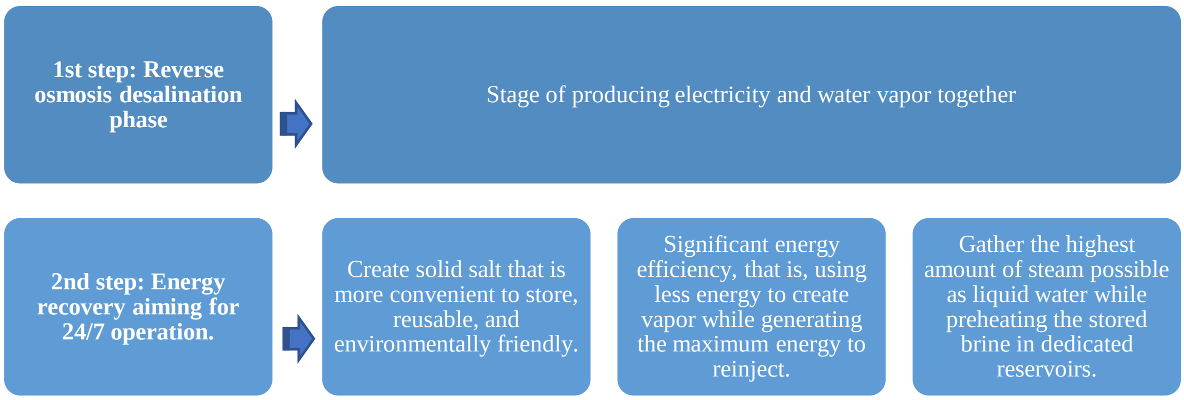

Figure 2: The two essential steps and their significant challenges.

5. Investigation of the Multifaceted Dimensions (Technical, Ecological, and Economic) Subsequent to the Deployment of Such a Solution for a Real-World Scenario

In this section, we will delve into the technical characteristics and features of this process, with the goal of illustrating its truly revolutionary nature and the significant impact it could have on two critical areas: the energy sector and the field of water stress management. By exploring these technical aspects in detail, we aim to highlight how this process stands to disrupt and innovate within these

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industries. Furthermore, other practices and approaches described within this same paragraph are designed to complement and augment this method, making it an even more attractive and impressive proposition in the eyes of potential future investors. By combining these additional practices with the core technical features, the overall appeal and potential of this process are substantially enhanced. With that in mind, here are some key points to consider:

- ✓ At 20°C and standard atmospheric pressure, it takes roughly 0.65 kWh of electricity to evaporate a liter of water.
- ✓ The energy demand to reach this temperature target could be substantially reduced if the project leverages deep geothermal energy. This approach would involve maintaining moderate temperatures and employing appropriate materials, as it requires managing water with a high salinity content.
- ✓ Alternatively, it is estimated that approximately 2 liters of water are required to produce 1 kWh of electricity using turbines specifically designed for this purpose [14].
- ✓ By employing well-designed heat exchangers that involve steam from the thermal power plant and brine from the desalination plant [15], it is possible to:
  - On the one hand, it is possible to significantly increase the treated water from 50% using reverse osmosis to theoretically more than 90% by recovering the steam at the turbine outlet.
  - In addition, by incorporating the heat exchangers into the system as suggested in the study, it is possible to produce water at a much higher temperature than the ambient temperature. In fact, depending on the efficiency of the exchangers, this water could reach temperatures close to 70°C, and as a result significantly decrease the energy required for its evaporation.
- ✓ Regarding the residual sea salt, it is used in various domains, including culinary, food preservation, cosmetics, health, industrial, agricultural, water treatment, and de-icing. It enhances the flavor of dishes, inhibits the growth of bacteria, exfoliates and softens the skin, improves circulation, and reduces inflammation. It is also used in the production of chemicals, textiles, and paper, as a natural fertilizer, and for water treatment and de-icing. This amount of salt is not insignificant, as it is 35 g/L.
- ✓ Beyond the undeniable advantages of such an approach in tackling the challenges faced by the agricultural sector, particularly those related to drought, these initiatives can also contribute to combating global warming in multiple ways. Firstly, by implementing extensive afforestation efforts, these projects can help absorb CO_2 from the atmosphere. Tree species such as Eucalyptus and Oaks are particularly effective carbon sinks, capable of storing up to 50 tons of carbon per hectare per year. Moreover, forests play a crucial role in mitigating the greenhouse effect, a phenomenon that has been extensively studied and documented by scientists. Forests emit significantly less infrared radiation compared to bare soil. In fact, implementing widespread afforestation can reduce infrared radiation emissions from 500 W/m² to a mere 200 W/m².

Based on the same dataset and performing simple calculations, the efficacy of this device is clear and aligns with the intended objectives. Therefore, by combining established technologies and techniques, while still expecting some technical innovations, it is quite possible to meet the growing need for water [16] while respecting current environmental standards or potential future standards.

6. Boost the Prospects of Success for This Concept

To maximize the likelihood of success for such a project, whose objectives align with the priorities of many countries worldwide, an additional step could be undertaken, as illustrated in the figure 3 below.

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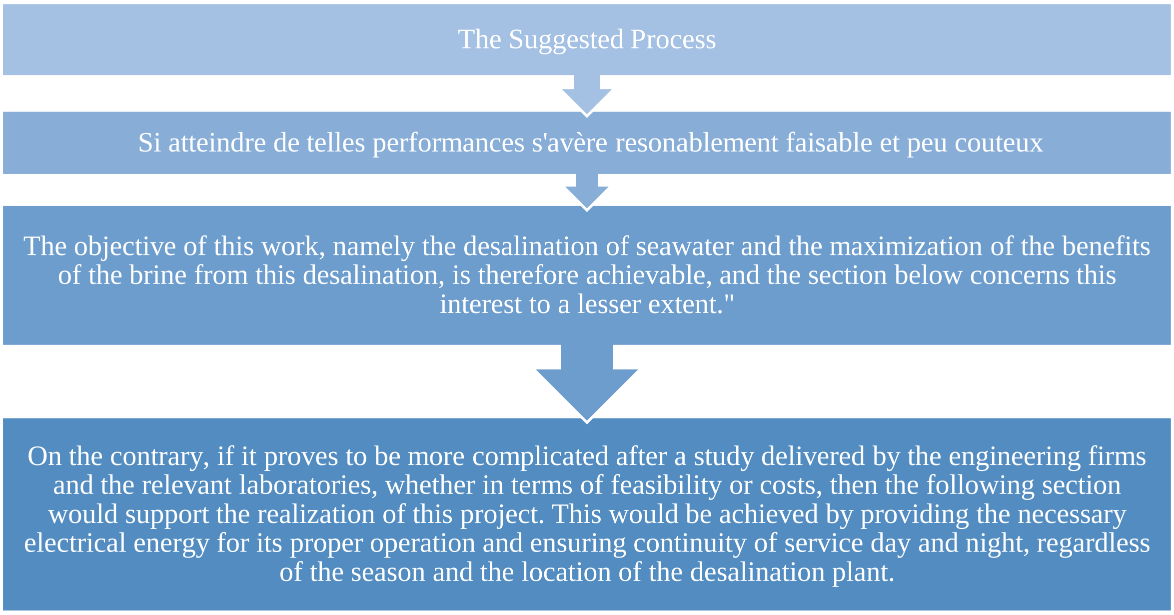
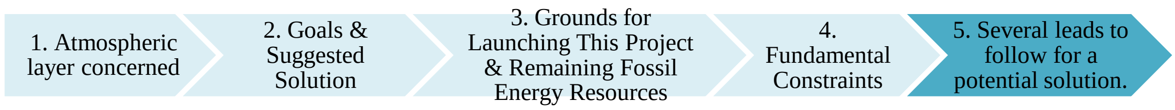


Figure 3. Justification for Introducing an Additional Step.

All the elements describing this additional method, which involves the evacuation of greenhouse gases into space, are presented in the following figure, namely Figure 4.



Datas	Descriptions
Atmospheric layer concerned	▪ The troposphere is the atmospheric layer most directly affected by climate change, with significant consequences for climate patterns, meteorological phenomena, and terrestrial ecosystems. Other atmospheric layers are also influenced, but the impacts are less direct and not as well understood. The troposphere's sensitivity to rising temperatures leads to altered precipitation patterns, increased frequency and intensity of extreme weather events, and the melting of glaciers and ice caps. These changes have profound implications for global climate systems, agriculture, and ecosystem sustainability. ▪ The troposphere stretches from the Earth's surface to roughly 10 to 17 kilometers in altitude, varying with latitude and season. It is thickest at the equator (approximately 17 km) and thinnest at the poles (around 10 km).
Goals & Suggested Solution	▪ Assessment of the Viability of Venting Greenhouse Gases into Space: Technical, Economic, and Ecological Considerations, with a Focus on Extending Chimney Outlets to Altitudes That Prevent Environmental Harm.

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Grounds for Launching This Project & Remaining Fossil Energy Resources	▪ Indeed, such a project is, to say the least, monumental. However, unlike the endeavors of ancient Egypt, this project holds vital interests for the inhabitants of the entire current civilization. This implies that significant resources, whether for the feasibility study or during the implementation phase, must undoubtedly be committed. ▪ The proven reserves of fossil fuels encompass substantial quantities of oil, natural gas, and coal. According to the BP Statistical Review of World Energy, 2023, the proven reserves of oil are estimated to be approximately 1.73 trillion barrels. The same source reports that the proven reserves of natural gas amount to approximately 206 trillion cubic meters. Furthermore, the proven reserves of coal are estimated at approximately 1.07 trillion tons, as cited in the BP Statistical Review of World Energy, 2023. These reserves constitute a significant energy resource; however, their exploitation must be carefully balanced with environmental and sustainability considerations. ▪ With an efficiency of conversion of only 40% for all fossil fuel sources—a figure that, in my opinion, could significantly increase given the technological advancements in research and the construction of power plants—the total electricity production amounts to no less than 4906 trillion kWh. ▪ This figure may not immediately resonate, but given a global consumption rate of approximately 3,500 kWh per capita, such a reserve could independently sustain the world for no less than 170 years. This duration would provide ample time to reassess and confidently plan the future of energy. (without discussing fossil energy deposits that have not yet been discovered)
Fundamental Constraints	▪ It goes without saying that the primary constraint here is the significant distance that the chimney's exhaust must reach, which is in the range of 10 to 17 kilometers. ▪ Wind speeds of certain magnitudes present another challenge to overcome and must be taken into account, with peak speeds reaching 100 kph or even 200 kph.
Several leads to follow for a potential solution.	▪ To adjust the diameter of the chimneys by modifying the ventilation techniques used, thereby enhancing the circulation of the fluid, namely smoke, which is at a moderately high temperature. It is essential to consider cooling this smoke to provide a wider range of material options for the chimney.Diametre & masse des cheminées

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	▪ Selecting the most suitable materials for the chimney involves finding those that are lightweight, flexible, and robust. This task demands specialized laboratory studies to determine the ideal material, which will probably be synthetic, given that the lightest materials with the lowest surface density are usually produced in laboratories ▪ The techniques for suspending these chimneys can be either static or energy-consuming, or a hybrid combination of both possibilities. Regardless of the technique, the amount of energy involved is substantial.

Figure 4. Elements describing the proposed method, requiring further discussion and study.

❖ Proposed Mechanism by the Present Study in This Regard:

The mechanism that this study aims to highlight is the one meticulously described in Figure 5 below. This particular mechanism has been carefully designed and analyzed to address the specific objectives and findings of the study, offering a comprehensive understanding of its implications for this matter.

Harnessing space for energy or ecological purposes is likely the ultimate solution to address the critical situation that we currently face and that future generations will probably endure.

As for the present proposal put forth by this article, the use of fans at higher altitudes could be avoided if a subsequent fluid study is conducted, so that only low fans manage the fluid flow. Additionally, drones could be powered directly by wired methods from the ground, thus avoiding drone alternations.

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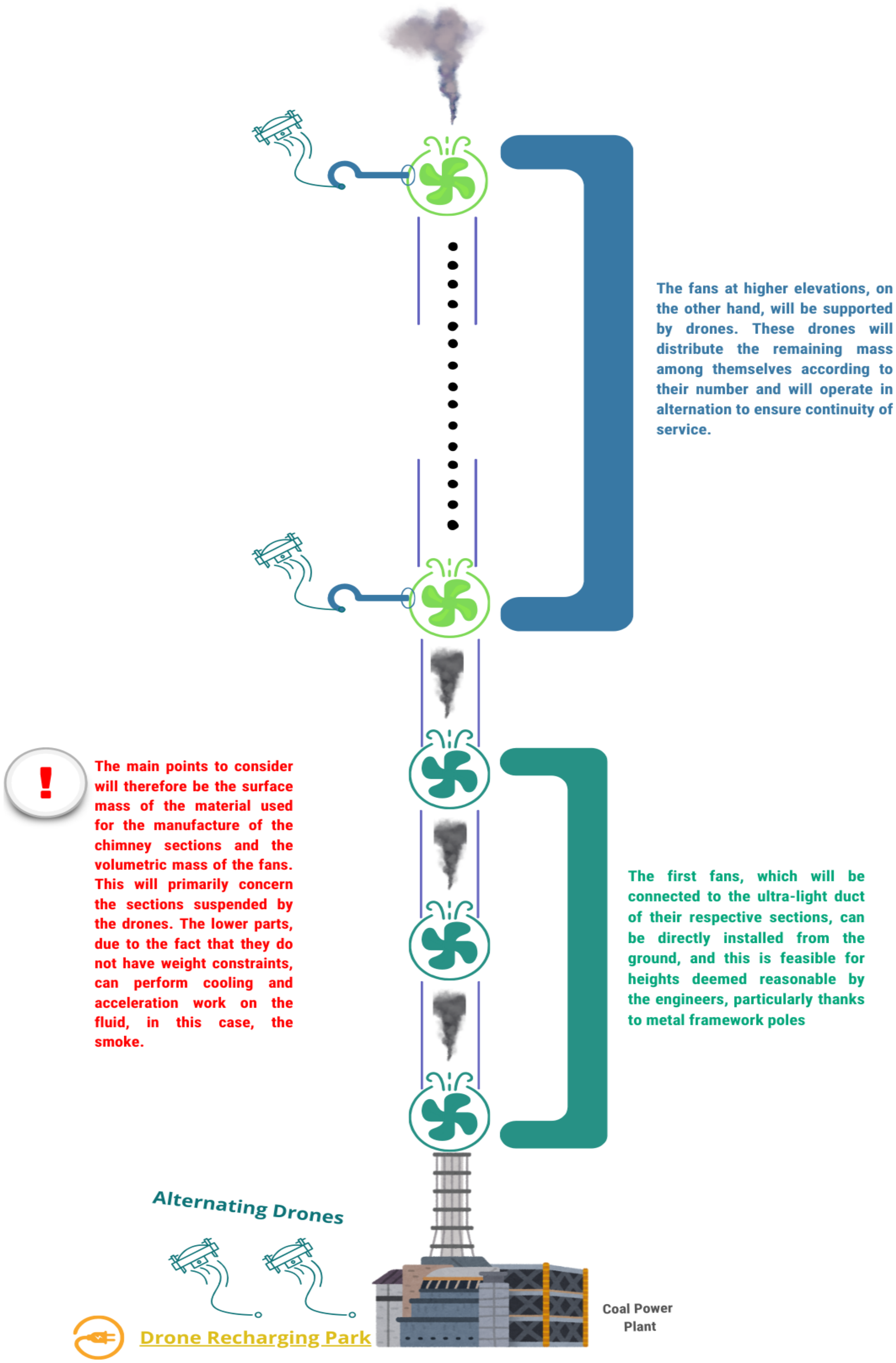

Figure 5. The mechanism that this study aims to highlight.

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7. Conclusions

The optimal outcome for this research would be for engineering consulting firms to adopt it and provide clarification on various points and technical aspects, transforming it from a purely theoretical study into a practical one. Energy and water are more crucial than ever before and will undoubtedly continue to be the cornerstones of human life on Earth. While it is true that the costs associated with such projects are enormous, gaining control over these two elements, water & energy, would enable us to approach the upcoming decades or even centuries with confidence. With that being said, if there are any areas that unquestionably merit investments from all parties, including private, state, or others, it is undoubtedly the aforementioned two elements. At the time this research was conducted, several major dams in Morocco, a country with a population of nearly 42 million people and whose economy heavily relies on water resources, were less than 10% full.

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