

Article

Energy Saving and Carbon Neutrality in the Funeral Industry

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Abstract: As a result of the global population growth since World War II, and the major impact of the COVID-19 pandemic on the increase in the number of deaths, carbon emissions resulting from cremations in the funeral industry have increased by more than initially expected. In order to achieve the goal of the Kyoto Protocol and the Paris Agreement, to reach net-zero carbon neutrality by 2050, in this study, we comprehensively examined the literature on the differences in burial methods in terms of carbon emissions, and undertook stepwise analysis of the solution's sequence from 1990 to 2050 using the recurrence relations in the trend changes using 5-year intervals. By collecting the annual number of global deaths and calculating the average carbon emissions per death to be 245 kg, we analyzed and compared these data with the annual carbon dioxide amount and global population until 2050. In addition, the results for cremation and Cryomation were analyzed and compared to construct a model of comparative advantage. The results of this study show that Cryomation is more energy efficient and has a greater impact on carbon emission reduction than cremation because it does not require carbon emission elements such as embalming or coffins. Thus, Cryomation can effectively reduce damage to the environment. Taking appropriate strategies for the funeral industry to promote Cryomation can achieve the goals of environmental protection and sustainable development.



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1. Introduction

As of 11 January 2022, coronavirus disease 2019 (COVID-19) has caused 307 million confirmed cases (5.49 million confirmed deaths) globally [1,2]. Among these, the number of confirmed COVID-19 cases in the United States is about 61.5 million (about 830,000 deaths), and the number of confirmed COVID-19 deaths in India is 484,000. When an epidemic occurs, catastrophic deaths can also occur, and confirmed deaths must be properly handled within a short period. In addition to facing the global wave of energy conservation and carbon reduction, the funeral industry still needs to face the challenge of dealing with the deaths confirmed under the epidemic [3]. The funeral industry generally handles the arrangements in response to a confirmed death. The body is transported to the designated cremation site by the funeral vehicle, and the cremation is arranged after the mortuary is completed and the coffin is sealed. In recent years, the Paris City Government, which has vigorously promoted environmental protection and energy conservation, conducted an important study of the carbon footprint impact on the planet in the aftermath of a person's death. The funeral service unit of the Paris Municipal Government pointed out in 2017 that the total greenhouse gas emissions of standard burial coffins and tombstones are equivalent to the carbon footprint of a car traveling more than 4000 km. In addition, cremation, which is considered to be more environmentally friendly, also consumes a large amount of energy, which is equivalent to the carbon footprint of a car traveling 1124 km; it also produces pollutants such as dioxin and mercury [4]. To leverage the Intergovernmental Panel on Climate Change (IPCC) report, all human beings must significantly reduce carbon emissions by 2030 [5]. Global warming and the greenhouse effect have caused abnormal weather

conditions, and man-made deforestation and mass burial activities have caused serious damage to the environment and ecology [6]. Natural disasters are gradually occurring, and are already threatening people's lives, property, and activities. Land resources are being rapidly consumed due to population growth, industrialization, and modernization, and there is an urgent need to save and protect land [7]. The survival rights of future generations must be safeguarded by ensuring the sustainable use and development of land resources. The implementation of environmental protection and natural burial policies can be used to address the problem of land resource utilization. As a result of the aging society worldwide, the estimated death toll reached 55,987,200 in 2021 [8], and the main challenge of this problem is the lack of land available for funeral facilities. Experts suggest that as baby boomers age and begin to decline in number, and the population ages substantially, environmentally friendly funeral arrangements will become a common occurrence.

There are many synonyms for environmentally friendly funerals, such as green funerals, natural funerals, and ecological funerals. A "green funeral" does not use preservatives, expensive hardwood coffins, stainless steel or copper coffin ornaments, or cement burial chambers, does not involve high-temperature incineration, does not spray various pesticides or chemical fertilizers, and does not reduce cuttings in the management of cemeteries. The use of grass machines allows the deceased to naturally complete their final farewell, reducing the pollution of soil, water, and air resources [4,9]. According to statistics, the United States uses 82,000 tons of steel, 2500 tons of copper and 1.4 million tons of cement each year to build burial chambers. A large amount of formaldehyde is used in the antiseptic process, which is a threat to the health of funeral and interment practitioners. Burials pollute the environment because the mercury, arsenic, and formaldehyde in the antiseptic solution pollute groundwater sources [10]. The coffin itself is another known source of pollution [6,11]. If the body contains radioisotopes that entered the human body during radiotherapy before death or burial, the decay of the body may also cause environmental pollution [12]. In addition, the burial will take up a large amount of land space, which is the main reason why cremation funerals continue to be popular. However, an increasing number of studies have noted that the cremation process of the human body and coffin produces a large quantity of toxic waste gas, which has a very significant impact on the environment [3,10,13,14]. The main emissions from crematoriums during the cremation of human bodies and coffins are nitrogen oxides, carbon monoxide, sulfur dioxide, particulate matter, mercury, other heavy metals, and persistent organic pollutants (POPs), which cause serious harm to humans and the environment [10].

The green funeral emphasizes the use of ordinary cloth or even recycled paper to wrap the body. The coffin is also made of a simple combination of wood chips, bamboo, wicker, etc., so that it can be decomposed soon after being put into the soil. Not only do green cemeteries preserve the original local ecological environment and promote local biodiversity, they also save funeral expenses [11,15]. Those who advocate green cemeteries believe that, for cemetery operators, this method is more profitable than cremation; thus, it is beneficial to everyone and the environment. In recent years, the public's acceptance of cremation of remains has reached 90%, and the government has encouraged the use of environmental protection methods for burials to save land resources [16–18]. Green burial methods that do not retain ashes, such as "tree burial", "sea burial", or planting of ashes, have become a new funeral culture [6,19,20]. Additionally, in contrast to what may initially be expected, green funerals or eco-friendly funerals are cheaper than traditional funerals. Due to their efficiency and eco-green awareness, these burial methods are now gaining in popularity [11]. The Green Burial Council (GBC) was established in 2005 to set up standards for this growing movement. The GBC clarifies green burial as: "Green, or natural, burial is a way of caring for the dead with the minimal environmental impact that aids in the conservation of natural resources, reduction in carbon emissions [10], protection of worker health, and the restoration and/or preservation of habitat. Green funerals require the use of non-toxic and biodegradable materials such as coffins, shrouds and urns." [20].

In light of this, the purpose of this study was to forecast the differential impact of various burial methods on carbon emissions, and to further explore the promotion and implementation of green funerals under government regulations and laws. The remainder of this paper is organized into five sections. Section 2 introduces the relevant literature on the funeral industry, encompassing inhumation, cremation, and Cryomation. In Section 3, we present our analytical model, and Section 4 contains analysis of the differential impact of Cryomation on carbon emissions and a discussion of the results. Section 5 presents the conclusion.

2. Literature Review

This section presents the recent literature on the funeral industry. It discusses burial, cremation, and cryopreservation. It also focuses on the various methods by which the funeral industry arranges the postmortem treatment of the human body according to religious and family wishes. Consideration of the environment may also have an impact.

2.1. Inhumation and Cemetery

As stated in the Soil Conservation Thematic Strategy (EC2006), the soil is a finite and non-renewable resource through which the European Union (EU) has defined its European Soil Conservation Action Plan [21]. Graveyards refer to the long-term occupation of high-quality soil and are an important natural resource, but due to the exponential increase in population, the need for environmental sustainability research has begun to arise [13]. As the number of people living on the Earth increases, the need for land, by both the living and the dead, also increases [7]. As land use is a serious contemporary issue, the contributors to land use cannot be ignored [22,23]. In a study of cemeteries in Belgium, Denmark, France, Spain, Netherlands, Germany, Norway, Slovakia, Slovenia, Sweden, and Italy [18], a total of 78 cemeteries were found to be established in the central landscape of the city as an important site in each country [16]. This suggests that cemeteries continue to appear in people's lives as they form an important part of the surrounding landscape [9,24].

The world's first human composting facility was expected to open in Seattle in 2021. With a high temperature of 55 degrees Celsius, soft tissues will turn into fertile soil within 30 days; if the remains are to be decomposed, they need to be added [25]; decomposition then takes two months [26]. This environmentally friendly burial method, including ceremony, costs USD 5500. Other approaches are used to minimize the subsequent carbon footprint [10], e.g., the natural cemetery in Niort, France [17]. In this woodland, which was opened in 2014, 136 people are currently lying harmoniously in the embrace of nature. Cement and granite tombstones are forbidden in the park. Coffins must not be painted, and are preferably made of untreated wood or cardboard; the columbarium must be biodegradable, and the remains should be protected from anti-corrosion treatment [26,27].

In the Greek and Roman world, funerals were primarily a family affair, but were also subject to changing circumstances [23,28]. To honor the deceased in an appropriate and respectful manner, there are family beliefs about the deceased that can be applied to the practice of burial and cremation [28]. Although there are some implicit social ambiguities [29], natural cemeteries provide vivid physical testimony of the immaterial memory of the dead because these cemeteries are suggested to be more comforting and inspiring than ordinary graves, and represent being part of the wheel of life on Earth [30]. In addition, they represent further investment and a programmatic multi-purpose land space.

2.2. Cremation

After a person dies, the body tissue begins to decompose and undergo a process of decay in the air. This decay phenomenon is mainly caused by the action of air and countless enzymes and bacteria, resulting in the transformation of human tissues into gases, liquids, and salts [4]. The decomposition process of human remains buried in the ground can last for months or even years, depending on conditions such as temperature, humidity, and soil

type [10]. Coffins are also a major source of chemical pollutants, due to their paint and wood preservatives, and their metal parts, which release lead, zinc, nickel, iron, and toxic gases. Burial bodies that can decompose quickly and safely require high-quality functional soils, thus competing with agricultural, commercial, and construction land. Cultural customs and habits, including those relating to burial, differ by country. For example, the custom in India is the water burial [31]. In Taiwan, after death, people are mainly buried in the earth, which provides the greatest consolation. The impact of burial on the environment is mainly due to space constraints. Taiwan is narrow and densely populated, and has decreasing capital that can be used to bury people after death. Therefore, after the corpse has decomposed, it has to be buried a second time. The main impact of the body is due to its occupation of space, even if it is moved to the Nagu Tower. The decay of the body during the burial will also have an impact on the environment; for example, the land next to the cemetery will be unusable. Although cremation does not require much land, its high carbon emissions and air pollution are unacceptable to certain environmental and religious groups [12,16,32].

A cemetery is a place where memories of the dead are preserved by lasting, moving monuments. Cremation is another means of disposing of corpses as a burial substitute [17]. Cremation is the burning of a body in a crematorium. The Netherlands uses two types of ovens: hot-start ovens (70% of the total) and cold-start ovens (30%), where the former are preheated to 800 °C and the latter to 400 °C [11]. In Dutch crematoriums, both types are heated with natural gas. Because hot-start ovens make up the majority, research has focused on the thermal system and its effects [18,33]. The oven is mainly composed of stainless steel and electronic components and has an average lifespan of about 25,000 cycles. To make funerals more environmentally friendly, Tameside City Council in Greater Manchester, UK, plans to retrofit incinerators to convert the heat produced by cremating bodies into heat [25,34]. The city council designed the heating system to allow the heat from the city's crematorium to be passed through [19]. The original heating and cooling furnace can be reused after absorbing most of the hot air. In addition, after connecting the heat exchanger to the boiler system, the thermal energy can be generated by a turbine.

In India and Nepal, more than 7 million deceased people need to be cremated each year. The cremation ceremony is deeply rooted in the core of the faith of the locals. They believe that this is a way for the souls of the deceased to leave their bodies, leading to the gods. Local Hindu outdoor cremation rituals require about 550 kg of firewood to be collected, mixed with cow dung, camphor, and mango bark, and burned for four to six hours. These firewood piles consume approximately 50 to 60 million trees each year. Researchers estimate that the aerosols emitted by cremation are equivalent to 23% and 10% of the annual emissions of aerosols from fossil fuels and biomass fuels, respectively, and 53 times those of households' daily activities [18]. Both cremation and normal burials in Brazil lack federal laws regulating the funeral system. In particular, crematoriums lack legislation to regulate their practices, making it difficult for them to be established by interested businessmen [10,32]. It is a traditional Brazilian custom that, after the death of a loved one, two sets of shrouds are prepared. One set is made of paper and is used for cremation, and the other is for the relatives of the deceased to wear. However, the common clothing worn by the deceased before their death is commonly made of nylon, plastic, and other materials. After cremation, not only is dioxin produced, but the residue also adheres to the bones of relatives, which is inappropriate and not environmentally friendly [35].

In the remains of patients who died of an acute respiratory disease, the lungs and other organs are still host to a live virus, and the virus has a chance to spread during an autopsy [10,36]. Therefore, the families of those dying from the new coronavirus disease must ensure that the deceased's funeral is handled by professionals [15]. Although the use of global transportation has decreased, especially via aircraft, the carbon emissions caused by COVID-19 due to the increase in the number of deaths, particularly in developing countries, had increased, e.g., in India, where cremation accounts for almost 100% of the dead bodies caused by COVID-19 [37].

2.3. Cryomation or Promession

Swedish biologist Susanne Wiigh-Mäsak invented the technology of freezing corpses in low-temperature liquid nitrogen at minus 200 degrees Celsius, and then breaking them into powder by vibration [38]. Crystalline bulk powder filters out heavy metals, such as mercury, which permits the powder to be buried in a biodegradable container. These organic residues are fully combined with the soil within a year, reducing carbon emissions and helping to reduce severe climate changes. In addition, Cryomation, a company based in Woodbridge, UK, studies the use of freeze-drying equipment to reduce carbon emissions. The human remains are first dried and sterilized in a vacuum. This technology is further used to freeze the corpse to -196°C using liquid nitrogen, and the frozen body becomes brittle, powdered, and free of any metal. The powder can be buried in biodegradable boxes or composted and spread as fertilizer [35,39]. Paul V. Stock and Mary Kate Dennis (2021) examined the death-care discourses of 20 elderly environmentalists to examine the 2014 debate by Rumble et al. on disposal and dispersal [31].

Burial at sea is the throwing of ground ashes (or in containers made of non-toxic and easily decomposable materials) into a certain sea area designated by the government. The cremated ashes need to be reprocessed to make them into small particles or fine powder. The currently used method involves wrapping them in double-layer environmental protection bags, to which multicolored stones are added to add weight [40]. After the blessings and prayers, the reusable bags and flowers are thrown into the sea, and the ashes sink into the sea under the silent prayer of the crowd [19,32,39]. Tree burial and flower burial refer to burial methods in which the ashes are buried in the soil in a cemetery, and then flowers are planted above them, or the ashes are buried around the roots of trees. The ashes for tree burial are ground into containers, and the container materials are easily decomposed and free of toxins. At present, decomposable urns are mostly made of corn starch.

According to research conducted by Washington State University Professor Carpenter Burgers, adding nutrient materials such as mixed wood chips in the final stage of the body's decomposition can make microorganisms more effective. The soil is finally heated to 55 degrees Celsius for disinfection and sterilization, and the decomposed soil can be used as compost [35,40,41]. In addition, according to the weekly report of "Science News", the founder of Recompose, Caterina Spade, specifically stated that, compared with cremation, the organic degradation of composting can reduce carbon emissions by 1.4 tons, and uses only one-eighth of the energy required for cremation [15,30]. Compared with burial, composting can greatly reduce the land-use space, avoid the use of the materials and the cost of the coffin for burial, and also reduce the carbon footprint and funeral expenses. Although composting is not as cheap as cremation, the price will tend to be lower when it is widely used.

The hydrolysis process is similar to traditional cremation, except that instead of using fire to destroy carbon-based organic matter, water, alkali, and heat are used to dissolve the body [13]. Both methods leave behind bones, which are crushed into a powder, known as ashes [15]. However, hydrolysis does not require combustion, so there is no air pollution [42]. A study by Bio-Response Solutions, an American company that produces hydrolysis units, shows that this technology saves 90% of the energy required for cremation, and its carbon emissions are only 10% of those of cremation [37,43].

Here, under the premise of the death of the human body, we have discussed a large number of funeral methods, particularly Cryomation, and previous research has discussed 'Resomation' [44]. Research by Recompose shows that natural biodegradable decomposition uses one-eighth the energy consumption of incineration and can reduce carbon emissions by one metric ton. If 10% of the American population chose to use biodegradable coffins, the carbon reduction would be equivalent to removing 61,339 passenger cars from the road for a year [31]. Resomation is a method of chemically treating the corpse, although its potential environmental impact is still under evaluation.

2.4. An Overview of Green Funerals

Birth, aging, illness, and death are unavoidable, and the provision of funeral services is an ancient industry. The needs of society and the increased population must be met, although there has been a sharp reduction in resources and a deterioration in the environment, which have triggered changes in the funeral industry. Green funerals are new options that enable carbon saving, reduce greenhouse gas emissions and environmental pollution, and achieve benefits for both the funeral industry and the protection of the ecological environment.

Dead bodies are a potential source of pollution. The bacteria and infectious diseases carried by remains will directly endanger people's health. The preservation and cremation of remains require large quantities of chemicals and fuels, causing soil, air, and water pollution. People who have died due to COVID-19 still have live viruses in their remains, not only in the lungs, but also in other organs, and at autopsy, the virus is still contagious. Cryomation is a feasible method that can be compared with cremation and burial.

3. Analytical Model

This study used a literature approach to analyze the carbon emissions produced by cremation and Cryomation, and the associated environmental protection. This was based on the current causes of global warming and the increase in the proportion of global human deaths caused by COVID-19, which has contributed to the global emissions of carbon dioxide [45,46]. According to the IPCC, the United Nations Framework Convention on Climate Change (UNFCCC), and the WHO (World Health Organization) report, the growth in the global population within the coming decades will cause carbon dioxide emissions to increase [41–43]. The Kyoto Protocol and Paris Agreement indicate that neutrality in carbon emissions is necessary, and agree with the Global Carbon Project (GCP) and Conference of the Parties (COP) series of conferences that carbon dioxide should be tracked every 5 years. Therefore, we analyzed the reports, data, and information provided by the above-mentioned organizations using recurrence relation equations to simulate the effects of cremation and Cryomation. The impact of this paper was verified hypothetically as shown in Section 3.1, Equations (1) and (2). In Equation (1), we assume that the current quantity of global carbon emissions cannot be changed in the existing environment. However, quantitative variables can be used to verify how to adjust or reduce the amount of emissions over time. Equation (2) can be used to simulate achieving carbon neutrality in a smoother and straighter sequential manner without sudden implementation of Cryomation. Hence, in Equation (2), we impose a condition to limit the penetration of Cryomation to no more than 100%. Thus, it can be simulated by a certain percentage to emphasize the advantage of replacing cremation and environmental burials by Cryomation. By simulating the conversion of both cremation and environmental burials to Cryomation, the feasibility of the verification of the method studied in this paper was evaluated.

3.1. Equations

The following equations were used to produce the figures below. Via recurrence relations, the equations were used for monitoring the possibility of reducing the carbon emissions associated with funerals using Cryomation, according to the global penetration rate.

3.1.1. Cryomation Implementation Rate for Carbon Dioxide Reduction

The recurrence relations in Equations (1) and (2) are based on assumptions to simulate the Cryomation implementation rate for carbon dioxide reduction associated with the global number of deaths in the coming decades:

$$\begin{cases} a_1 = x \\ a_{n+1} = f(x) \end{cases} \quad (1)$$

$$\begin{aligned} f(x) &= (1 - 0.1_n) \times a_n \\ (10 \geq n \geq 1) \end{aligned} \quad (2)$$

“ x ” means carbon dioxide for the death toll for each decade.

“ $f(x)$ ” means carbon dioxide for the death toll after the equation result for the previous “ x ”.

“ a ” means the term of arithmetic sequence recursive of “ $f(x)$ ”.

“ n ” means the penetration rate for Cryomation per decade.

3.1.2. Carbon Dioxide Generated from Cremation

Equation (3) shows the carbon dioxide generated from cremation:

$$C = \frac{P \times \lambda Y}{1000} \quad (3)$$

“ C ” means carbon dioxide generated from cremation amount by tons.

“ P ” means global population per year.

“ λ ” means each death released carbon dioxide by cremation: 245 kg.

“ Y ” means death rate each year.

3.1.3. Calculation of Emission Factors of Harmful Air Pollutants from the Cremators

Xue et al. (2018) [12] calculated the emission factors of harmful air pollutants from cremators based on their emission concentrations, flue gas amount, and cremation time. The formulae are as follows:

$$E = \frac{C \times T \times S \times 60}{1000} \quad (4)$$

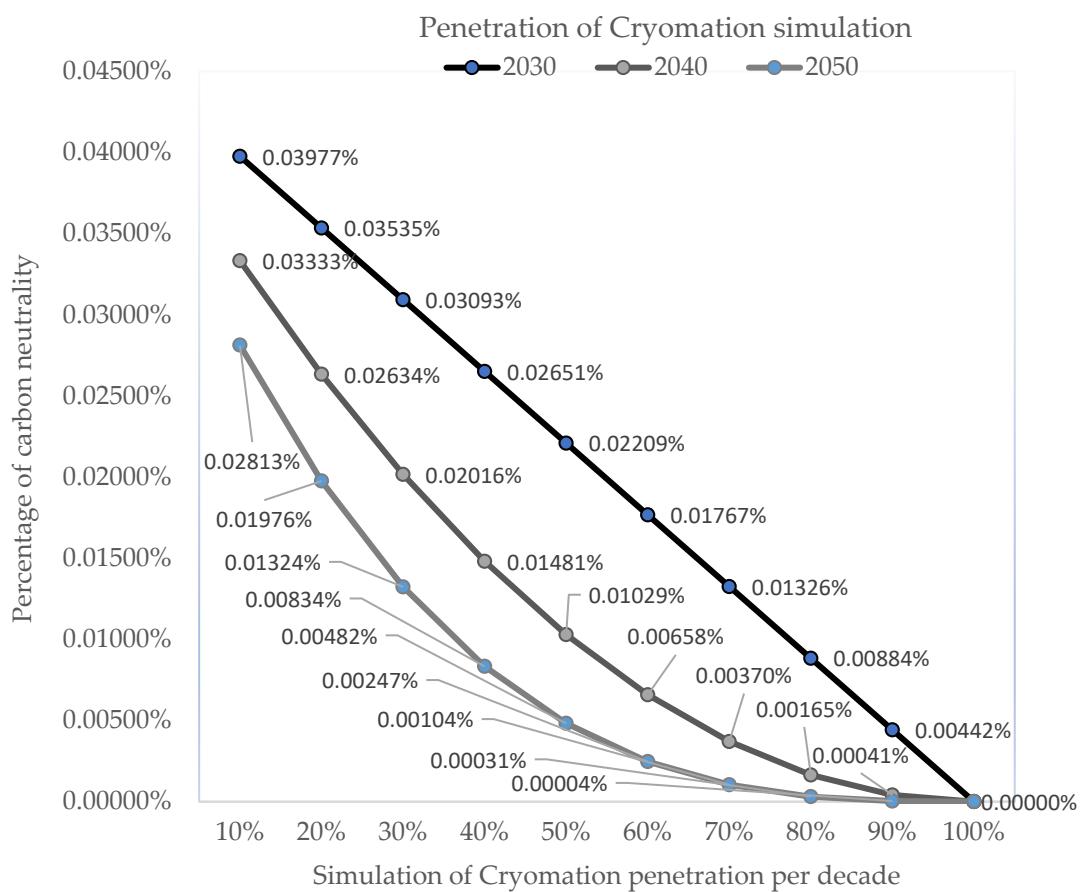
$$S = \frac{\lambda D^2}{4} \quad (5)$$

where E is the pollutant emission factor, g/body; C is the pollutant emission concentration, mg/m³; T is the cremation time, min; V is the flue gas flow speed, m/s; S is the cross-sectional area of the flue, m²; and D is the stack diameter, m.

3.2. Analysis

Many studies have used recurrence relations. A sequence is an ordered set of numbers that is particularly used in mathematical statistics, applied probability, operations research, and economic mathematics methods [47]. Using recurrence relations analysis, we simulated the penetration of implementing Cryomation in the three decades 2030, 2040, and 2050, as shown in Figure 1 and Table 1. We then obtained the results of the straight line and curve to achieve the perspective target of the different curves before 2050. Figure 1 and Table 1 also present the simulation result of different scenarios via recurrence relations analysis to realize the importance of implementing Cryomation.

First, we analyzed the global population and mortality rate over time, and we then recognized that the mortality rate is increasing based on COVID-19 in Table 2. The projected death rate is used to calculate the future deaths, assuming that people primarily use Cremation. Thus, we get the increase in global carbon dioxide caused by the increase in death, as shown in Figure 2 and Table 2. The proportion of carbon emissions from cremation was compared to hypothetical trend in the proportion of Cryomation. In the discussion of the next section, we also verify from the simulation results whether Cryomation will reduce global carbon emissions [45,46,48–51].

**Figure 1.** Cryomation penetration simulation.**Table 1.** Cryomation penetration simulation for the years 2030, 2040, and 2050.

Year of "f(x)"	10%	20%	30%	40%	50%
2030	0.03977%	0.03535%	0.03093%	0.02651%	0.02209%
2040	0.03333%	0.02634%	0.02016%	0.01481%	0.01029%
2050	0.02813%	0.01976%	0.01324%	0.00834%	0.00482%
Year of "f(x)"	60%	70%	80%	90%	100%
2030	0.01767%	0.01326%	0.00884%	0.00442%	0.00000%
2040	0.00658%	0.00370%	0.00165%	0.00041%	0.00000%
2050	0.00247%	0.00104%	0.00031%	0.00004%	0.00000%

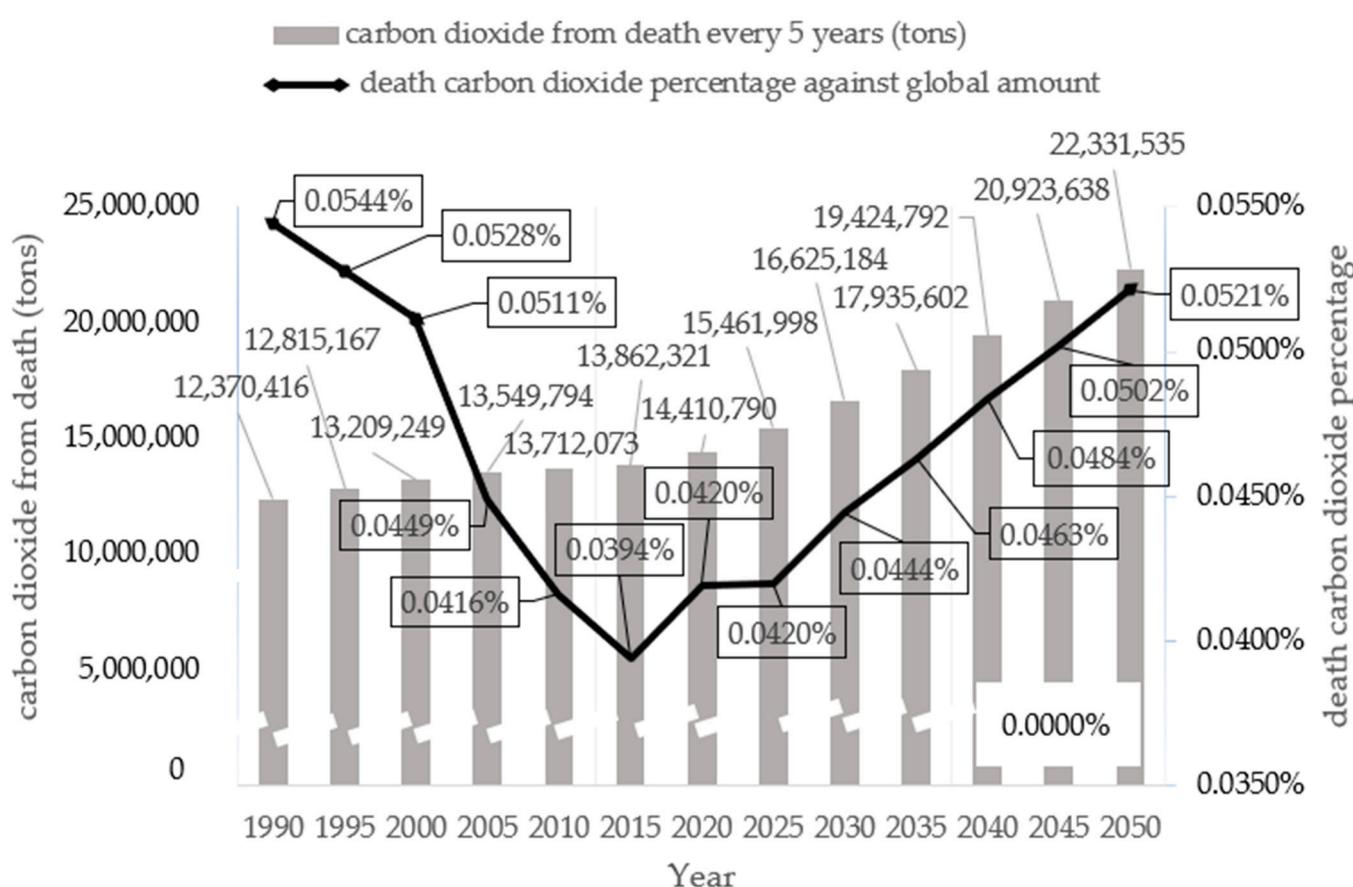
Table 2. Carbon dioxide generated by global deaths, relative to the global carbon dioxide, every five years.

Year	1990	1995	2000	2005	2010	2015	2020
Population (K * persons)	5,327,231	5,744,213	6,143,494	6,541,907	6,956,824	7,379,797	7,794,799
Death rate	0.9478%	0.9106%	0.8776%	0.8454%	0.8045%	0.7667%	0.7546%
Death toll (K persons)	50,491	52,307	53,915	55,305	55,968	56,581	58,820
Carbon dioxide from death (tons)	12,370,416	12,815,167	13,209,249	13,549,794	13,712,073	13,862,321	14,410,790
Global carbon dioxide (K tons)	22,727,880	24,287,600	25,847,320	30,170,030	32,948,081	35,168,270	34,343,266
Death carbon dioxide percentage against global amount	0.0544%	0.0528%	0.0511%	0.0449%	0.0416%	0.0394%	0.0420%

Table 2. Cont.

Year	2025	2030	2035	2040	2045	2050
Population (K persons)	8,184,437	8,548,487	8,887,524	9,198,847	9,481,803	9,735,034
Death rate	0.7711%	0.7938%	0.8237%	0.8619%	0.9007%	0.9363%
Death toll (K persons)	63,110	67,858	73,207	79,285	85,403	91,149
Carbon dioxide from death (tons)	15,461,998	16,625,184	17,935,602	19,424,792	20,923,638	22,331,535
Global carbon dioxide (K tons)	36,797,442	37,413,673	38,735,717	40,172,179	41,690,374	42,839,421
Death carbon dioxide percentage against global amount	0.0420%	0.0444%	0.0463%	0.0484%	0.0502%	0.0521%

Remark: Emissions Database for Global Atmospheric Research (EDGAR) does not report the 1995 global carbon dioxide amount; we assume it to be the average amount between those of 1990 and 2000. * "K" in the figures and tables of this article means thousand, which is a numeric amount of measurement units.

**Figure 2.** Trend of carbon dioxide generated from deaths every 5 years.

4. Results and Discussion

4.1. Results

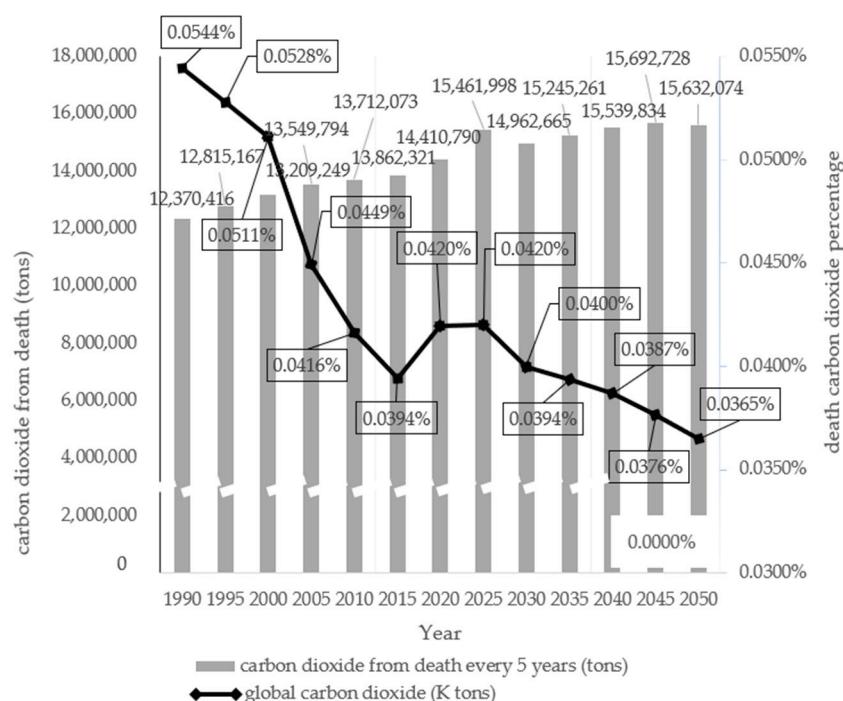
In 2020, the global death toll was 59 million people, as shown in Table 3. However, due to the impact of COVID-19, this increased by more than 1.9 million deaths, which accounted for 0.001370% of global carbon dioxide. Therefore, using the data discussed in this paper, variables were produced that, in turn, affect the accurate figures for carbon emissions [45,46,48–50]. We can then lengthen the time axis to compare every decade. This shows that, although the mortality rate is on a downward trend in the long term, this is because of the growth in the global population. The number of deaths continues to rise, and the death rate can be compared with the birth rate. Coupled with the fact that the human life span has been extended due to medical advancement, the carbon emissions caused by the death toll will continue to rise in the coming decades. Hence, in Table 3, we

compare the global carbon dioxide emissions caused by the death toll, assuming that each death generates 245 kg carbon dioxide [51].

Table 3. Worldwide deaths including COVID-19, and the resulting carbon dioxide versus global figures.

Year 2020	Death	Carbon Dioxide (Tons)	Worldwide (Tons)	Proportion
COVID-19	1,901,767	465,933		0.00136%
Worldwide	56,918,233	13,944,967	34,343,266	0.04060%
Total	58,820,000	14,410,900		0.04196%

Under the scenario of cremation being replaced by Cryomation, at the rates of 10%, 20%, and 30% every 5 years from 2030, we can estimate the reduction in carbon emissions. Deducting these from the hypothetical data shows the reduction in carbon emissions generated by human deaths, every 5 years, as shown in Figures 2 and 3 and Table 4. Assuming the penetration of Cryomation will increase over time, the carbon dioxide generated by cremation will be greatly reduced, as shown in the following simulations. The carbon emissions generated by other related industries have reached the goal of net-zero carbon emissions, and are not considered in this article [52].



2035, and $f(x)$ will change to 15,245,261 thousand tons compared to the 2030 figure, which is equal to a reduction to 0.0394% of global carbon dioxide. Compared with the original values in Table 2, the carbon emissions are reduced to 15,245,261 thousand tons from 17,935,602 thousand tons in 2035, which is equal to a reduction of 2,690,341 thousand tons, or a carbon reduction of 15%. Furthermore, we use the following sequential illustration: When $a_1 = x$, the 2030 figure is x . $f(x)$ is another figure from x , which is the 2035 figure, and the recurrence relations are used to transform $f(x)$ equal to $(1-10\%)$ times x . This can also be used to transform another % for coming years with the same simulation. However, if we forecast and analyze the penetration rate of Cryomation on a larger scale to achieve the goal of 100% net-zero emissions by 2050 in a stable manner, the forecast data are shown as Figure 4 and Table 5.

Table 4. The simulation of carbon dioxide generated from the death toll from 10% to 30% every 5 years between 2030 and 2050.

Year	1990	1995	2000	2005	2010	2015	2020
Carbon dioxide from death every 5 years (tons)	12,370,416	12,815,167	13,209,249	13,549,794	13,712,073	13,862,321	14,410,790
Global carbon dioxide (K tons)	0.0544%	0.0528%	0.0511%	0.0449%	0.0416%	0.0394%	0.0420%
Year (change to Cryomation 10% from 2030, 15% from 2035, 20% from 2040, 25% from 2045, 30% from 2050)		2025	2030	2035	2040	2045	2050
Carbon dioxide from death every 5 years (tons)		15,461,998	14,962,665	15,245,261	15,539,834	15,692,728	15,632,074
Global carbon dioxide (K tons)		0.0420%	0.0400%	0.0394%	0.0387%	0.0376%	0.0365%

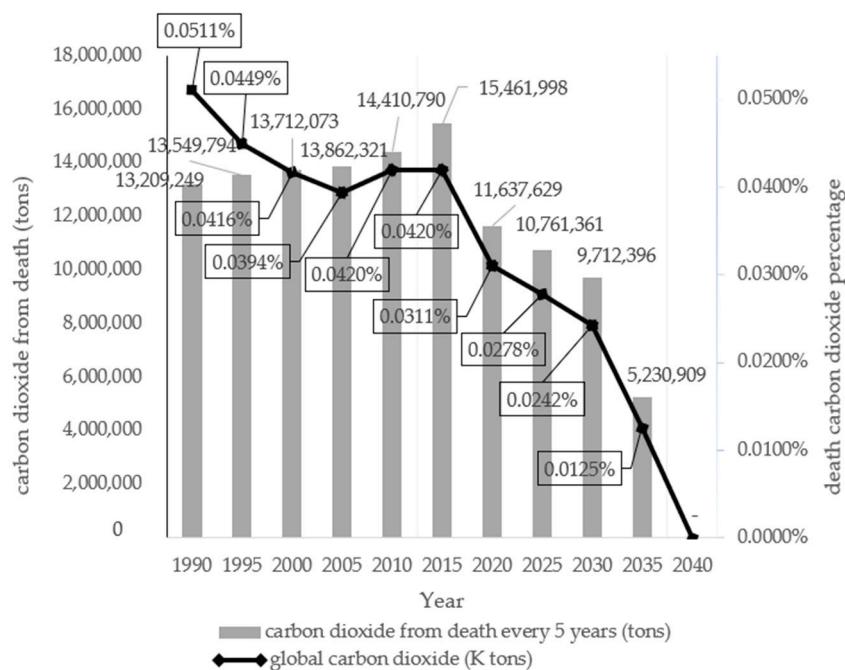


Figure 4. The simulation of carbon dioxide generated from the death toll from 30% to 100% every 5 years between 2030 and 2050.

4.2. Discussion

Environmentally friendly natural burial means that, when a person dies, the remains are burned into ashes by cremation, and no permanent facilities, ossuary towers, monuments, or tombs are built. This paper discusses the impact of cremation and environmental

burial on global carbon emissions. Although these emissions represent only 0.04%–0.03% of the total, if this proportion can be reduced to 0%, the destruction of the natural environment can also be reduced, in addition to the reduction in the global warming effect. Whether Cryomation can be accepted within human customs is not discussed here. The reduction in carbon emissions resulting from the promotion of Cryomation is the main issue discussed in this paper.

Table 5. The simulation of carbon dioxide generated from the death toll from 30% to 100% every 5 years between 2030 and 2050.

Year (Change to Cryomation 30% from 2030, 40% from 2035, 50% from 2040, 75% from 2045, 100% from 2050)	1990	1995	2000	2005	2010	2015	2020
Carbon dioxide from death every 5 years (tons)	12,370,416	12,815,167	13,209,249	13,549,794	13,712,073	13,862,321	14,410,790
Global carbon dioxide (K tons)	0.0544%	0.0528%	0.0511%	0.0449%	0.0416%	0.0394%	0.0420%
Year (change to Cryomation 30% from 2030, 40% from 2035, 50% from 2040, 75% from 2045, 100% from 2050)	2025	2030	2035	2040	2045	2050	
Carbon dioxide from death every 5 years (tons)	15,461,998	11,637,629	10,761,361	9,712,396	5,230,909	0	
Global carbon dioxide (K tons)	0.0637%	0.0450%	0.0357%	0.0295%	0.0149%	0.0000%	

Ecological burial is based on cremation. Relatively speaking, the various problems arising from cremation cannot be avoided [53]. First, the construction of a cremation site will permanently occupy a large amount of land and directly affect the area of arable land. Second, the cremation process consumes a large amount of electricity, diesel, or gas, and emits carbon dioxide, carbon monoxide, hydrocarbons, and nitrogen into the atmosphere [41,43]. A large number of harmful substances, such as oxygen compounds and sulfur-containing compounds, cause environmental and air pollution. Furthermore, the accumulation of a large amount of dust in the environment surrounding the cremation site will have a negative impact on the surrounding agricultural, forestry, economic, and social development. Regarding the green burial method, in addition to the freezing method discussed in this article, a burial method that results in greater carbon reduction is available in the UK. This method mainly uses an alkaline water-based solution heated to 150 °C, which can accelerate the decomposition of the corpse during the burial process [38]. This novel burial method can reduce the damage to the global environment caused by cremation and results in greater cost saving. The references indicate that Resomation can not only result in greater carbon reduction, but also reduce the associated costs of the burial ceremony. Although Resomation is not discussed in this paper or within the scope of the research, in terms of carbon reduction, sufficient relevant information is available to make this method worthy of discussion and in-depth study. As noted previously, whether the Resomation funeral method can be accepted within human and funeral customs is not in the scope of our discussion. However, its potential cultural shock cannot be ignored and should be discussed, as in the case of Cryomation, for which the data trends were observed in this paper. Cryomation has sufficient relevant literature and information relevant to the topic of carbon reduction. As a result, it was shown that Cryomation has sufficient effects and methods to enable carbon reduction. Nonetheless, in the face of cultural shock and humanistic customs, this cannot be predicted [54].

The traditional funeral culture emphasizes the preservation of the integrity of the remains, the deliberate suppression of various changes in the remains after death, and the preservation of the remains for the short or long term through ice preservation, embalming, or other scientific techniques, to maintain the appearance of the remains. This process allows family members to have a longer period to view the corpse before it is buried [53]. Green burial does not deliberately suppress the decomposition of the remains, and may

even deliberately accelerate decomposition. It mainly uses environmental protection technology to allow quick and natural recycling during decomposition. Promotion of Cryomation and Resomation burials as a sustainable option depends on the low-carbon policies of governmental departments, the improvement in the public literacy relating to green burial, and the associated costs of Cryomation and Resomation burial, such as the costs of the treatment processes and personnel expenses. These factors differ for the two methods. Within the scope of our discussion, green burial methods also include tree burials, flower burials, and sea burials [55]. However, these burial methods still require processing by cremation, thus only saving the cost associated with the spiritual ossuary. Therefore, in this study, we examined the green burial method based on Cryomation, and the carbon reduction data were compared every 5 years, based on the assumption that the goal of net-zero carbon emissions will be successfully achieved by 2050 [36]. It is hoped that governments can adopt more diversified methods in the future, such as investing in the green funeral industry, encouraging private participation, and providing subsidies in the form of tax expenditures.

5. Conclusions

Since the outbreak of COVID-19 in 2019, the number of global deaths has exceeded the originally expected number. For the remains of those who are confirmed to have died due to COVID-19, in order to avoid the spread of infection, medical and funeral home staff who perform the mortuary and funeral procedures use protective equipment and disinfection tools throughout the process. The remains are sealed in a non-permeable double body bag and cremated within 24 h, to avoid the body being discarded randomly or being opened by unknown persons.

In this study, we specifically examined the causes of cremation carbon emissions and their impact on global warming. According to the United Nations and World Health Organization surveys, carbon emissions caused by cremation are increasing. Thus, a relevant question is whether funeral methods other than cremation exist that can achieve the same effect, i.e., destruction of the virus.

Rapid freezing to -196 degrees Celsius creates an environment in which it is difficult for both bacteria and viruses to survive. Thus, the use of Cryomation to handle a large proportion of deaths caused by COVID-19, based on the current relevant literature, can significantly reduce global carbon emissions. Therefore, this paper specifically concludes that the Cryomation method should be used to achieve the goal of net-zero emissions by 2050, in conjunction with a global discussion of the popularization of the method, and an analysis and review of the data every 5 years using the model of diminishing regression. There are likely to be great opportunities to significantly reduce global carbon emissions in coming years.

The relationship between Cryomation and carbon emissions was demonstrated in this literature review, according to human living habits, the value assigned by governments to this approach, and the encouragement of people to accept it. This study was based on data from the United Nations, and surveys and statistics conducted by the World Health Organization are worthy of examination. Finally, new technologies for environmentally friendly corpse disposal are likely to be an important trend in the future development of the funeral industry. Research on the impact of these technologies on the environment is very important because limited research has been conducted on the reduction in carbon emissions using various corpse disposal technologies. In addition, it should be verified that the use of these new technologies, in combination with religious ceremonies, will also meet the practical needs of families to transport their deceased relatives to their final destination. A major finding in this paper is that Cryomation should be implemented as soon as possible. Thus, carbon emissions can be reduced by more than shown in the original prediction, which was simulated using the results of recurrence relations analysis.

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Data Availability Statement: Referring to references [45,46], we can get the global carbon dioxide from EIA (Energy Information Administration, USA) since 1990 till 2005, so we get the rest data including prediction from EDGAR (Emissions Database for Global Atmospheric Research, UN) till 2050. Due to there is no data reference in 1995, we have to use the average amount to calculate its amount between 1990 and 2000, please refer to the remark illustration in Table 2. For worldwide population, we collect the date from UN (United Nations) report, please refer to Section References [48–50]. We also calculate carbon dioxide generated from Cremation referring to Reference [44], one death unit can generate 245 kilograms accordingly. We also add the formula in detail illustration on Sections 3 and 4, literatures come from UN, WHO, IPCC, EIA and EDGAR, to use mathematical methods to analysis the raw data to be transferred to the validated results by Equations on Section 3.1, which we can get the results for Table 3, especial for COVID-19 amount from WHO, Reference [50].

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