American Journal of Environmental Science and Engineering
2025, Vol. 9, No. 2, pp. 76-85
https://doi.org/10.11648/j.ajese.20250902.15

Review Article

Preventing and Mitigating the Consequences of Inevitable Climate Change

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Abstract

This article discusses the urgent adaptation of mankind to an inevitable changing climate and this is more important than unrealistic and super-expensive "fight against global warming" (such as removing billions of tons of CO_2 from the Earth's atmosphere.) The environment will never be able to return to the previous composition and temperature of both the atmosphere and the World Ocean. Consequently, humanity will in the future have to live with more frequent and more destructive hurricanes, floods, wildfires, droughts, etc. Simply replacing fossil fuels with clean energy is insufficient for survival in the face of globally altered climate condition. Consequently, humankind urgently requires the implementation of modern technologies to prevention and mitigate the impacts of the global climate change. Regrettably, humanity is ill-prepared for this "new climate reality" and lacks carefully considered scientific and technical adaptation plans. The author for the first time substantiated and analyzed suitability of some various innovation technologies for human adaptation to a changing climate, and this is the novelty of the article. The main idea of this article is well expressed in the Charles Darwin's quote written 165 years ago: *"It is not the strongest and smartest who survive but the one who adjusts best to the changing environment."*

Keywords

Climate Change, Natural Disasters, Preventing and Mitigating, Urgent Adaptation, Mankind Survival

1. Introduction

It is already clear that climate change on the Earth has led to a sharp increase in hurricanes, floods, wildfires, droughts and other natural disasters and to a huge increase in financial damage to federal and local budgets [1, 2] – see Figure 1 and Figure 2. It is interesting that as Figure 1 shows, the number of natural disasters increasing markedly around 1960-1970 exactly when the intensive consumption of fossil fuels by industry and transport began. However, the most important (and most alarming) conclusion for scientists was not the fact of climate change itself but the fact that the Earth's climate is capable of changing much faster and more radically than we thought before, and humanity doesn't have much time to adapt to these climate changes either technologically, or evolutionary. In addition, many of the changes that have already occurred (an increasing concentration of CO_2 in the Earth's atmosphere, acidification of the World Ocean with excess CO_2, melting of Arctic/Antarctic ice) are just irreversible. *The purpose of this review is to justify how modern technologies can REALLY help humanity to prevent or mitigate the consequences of climate change.*

The recipe for solving all the previous problems of mankind was the transition to a higher technological stage: from a

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Received: 27 January 2025; **Accepted:** 11 April 2025; **Published:** 19 June 2025

raw food diet to making a fire, from picking berries and nuts to settled agriculture, from the Stone Age to the Iron Age, and from a horse to a "Ford". The problems caused by climate change must be solved in the same way.

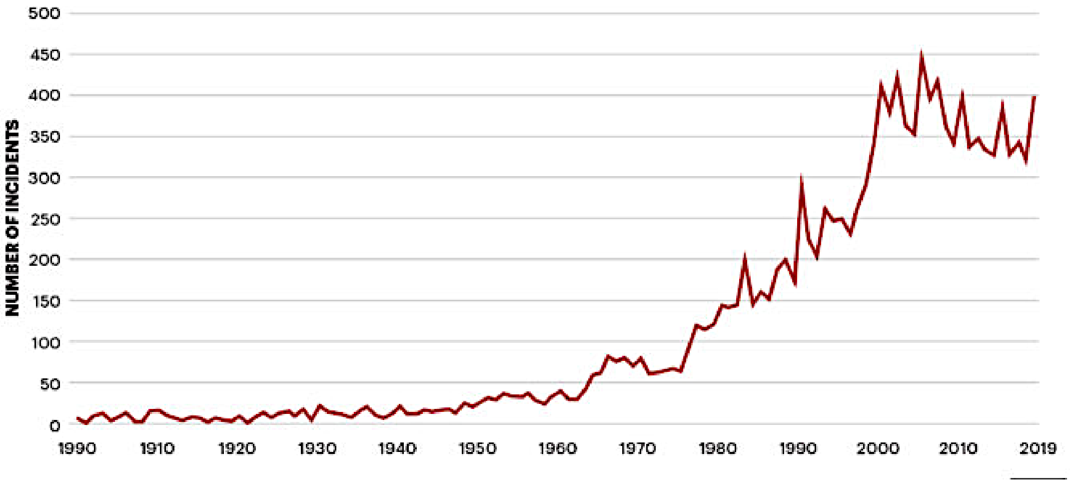


Figure 1. Trend in the number of natural disasters, 1900-2020 [1].

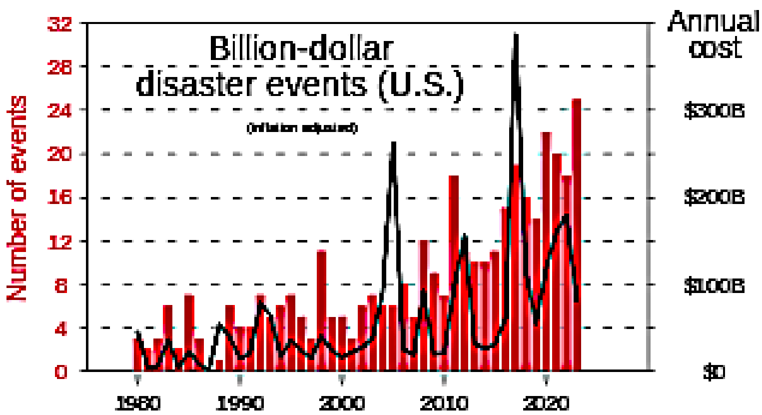


Figure 2. Growing damage from natural disasters in the US over 40 years (1980-2020) [2].

2. Discussion

2.1. Hurricanes and Flooding

Hurricanes, passing over the ocean surface, send powerful waves to the shore (the so-called "storm surge") which cause catastrophic flooding. Heavy and prolonged rainfall and rivers overflowing their banks can also cause flooding. Given the escalating frequency and intensity of floods worldwide, the construction of large-scale dams and effective drainage systems is paramount. Only in 2020-2021, strongest floods with destruction and casualties occurred in Brazil (Belo Horizonte), China (Henan), Germany (North Rhine), India (Maharashtra). In 2005, the monstrous Hurricane Katrina literally destroyed the US city of New Orleans: about 80% of the city's area was under water, 1,836 residents died, about 700 thousand people lost their homes, and economic losses reached $125 billion [3]. Although the initial investment may appear substantial, the long-term benefits in averting catastrophic damage and preserving lives far outweigh the costs. Japan, with its extensive coastline, exemplifies this approach with over 2,500 protective dams, including the formidable Tokuyama Dam [4]. Standing at 161 meters in height, with a length of 421 meters and a volume of 13.7 million cubic meters, this dam serves not only as a flood control measure but also supports a hydroelectric power plant generating 150 MW; its total cost is $500 million. Since its completion, the Tokuyama Dam has more than justified its cost by averting potential multiple floods in the protected region.

Tokyo's Drainage System (TDS) – Figure 3, one of the largest in the world, stands as an exemplary model [5]. Its main underground sealed hall, named the "Bath for Regulation Water Pressure," spans 178 by 77 meters with a height of

18 meters. Supported by 59 reinforced concrete columns, this giant "bath" has an emergency capacity of over 200,000 cubic meters of flood water. The TDS employs gas turbines to pump 185 cubic meters per second of rainwater to the Edogawa River through a large pipeline with a diameter of 9.5 meters. This system has significantly (9 times) reduced street-level flooding in Tokyo, underlining the pivotal role of comprehensive drainage solutions in flood-prone areas. Tokyo Drainage System was built during 8 years, project cost was 1,9 billion dollars. Many regions with high rainfall are in dire need of similarly comprehensive drainage systems.

Figure 3. *Tokyo underground drainage system - water pressure control bath (size 178x77x18 meters).*

2.2. Wildfires

2.2.1. Wildfires Are Catastrophic Event

The damage is staggering - hundreds of thousands of hectares of mature forest have been burned, thousands of homes reduce to ashes, damages soaring into hundreds of billions of USD, and especially tragically, the loss of numerous lives. Since 2000, in the US, between 5 and 9 million acres of forest have burned each year. The US administration reports that wildfires caused $81.6 billion in damage from 2017 to 2021 [6]. From 2013 to 2023, 376 people died in the United States due to wildfires [7]. Wildfire in Australia in 2019-2020 led to: 19 million hectares were burnt; 33 lives were lost; around 3,094 homes destroyed; 1.25 billion animals had been killed [8]. Moreover, each hectare of burnt forest releases approximately 10 tons of aerosol soot particles and a ton of toxic and greenhouse fire gases into the atmosphere. In addition, burnt an each hectare of mature forest could have absorbed 2-3 tons of excess CO_2 annually while emitting about 150-200 kg of life-sustaining oxygen [9].

2.2.2. The Lockheed C-130 Hercules

Aircraft with a crew of six persons equipping and with a Modular Airborne Fire Fighting System (MAFFS) are now used to extinguish forest fires in the US (Figure 4). Hercules is capable of lifting 3,000 gallons (28,000 pound) of fire extinguishing agent. It is 140,000 pound aircraft over the fire, traveling at 130 knots (roughly 150 mph) and flying at least 150 feet above the ground. Then, they discharge the plane's full 28,000-pound load of slurry out through a tube near the left rear of the aircraft, all of it gone in under 5-10 seconds [10].

Figure 4. *Lockheed C-130 Hercules is doing firefighting [5].*

The problem is that the ALL area of the fire must be COMPLETELY and CONTINUOUSLY covered by fire extinguishing agents. To do this, it needs to have a big squadron of fire planes and helicopters, so that when the last plane/helicopter will drop the fire extinguishing agent on the flame, the first one would have time to recharge and to arrive at the fire [11]. *There needing a nonstop "aviation fire extinguishing carousel" over the wildfire!* Therefore, for example, California (and all other regions with high fire hazard) must have special airfield (or at least part of an existing airfield) where dozens of firefighting aircraft and helicopters would be concentrated, where huge stocks (hundreds of tons) of fire extinguishing powders and water.

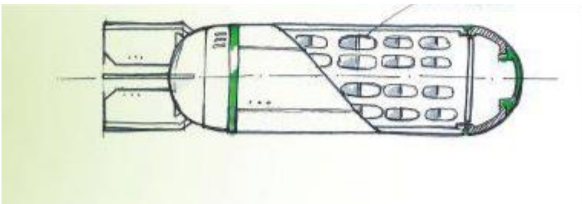
However, it is clear that it is impossible to extinguish a large forest fire from an airplane in a strong wind is useless and dangerous. But it is possible to significantly increase the efficiency of fire extinguishing by using "fire extinguishing bombs" because the fire extinguishing agent is delivered directly to the source of the fire - this is, in fact, a large, easily destructible vessel with a fire extinguishing agent and a small explosive charge inside. For example, there is Chinese a worldwide patent CN103100166A from 2013-05-15 "Satellite-guided Fire-extinguishing Bombs" (Figure 5.) Powder weight - 200 kg, range - about 3000 m, accuracy - about 10 m; effective fire extinguishing zone of one 200 kg bomb - 400 m^2. But these could also be other, simpler and cheaper "fire-extinguishing bombs" (powder and water bombs, at least 100 kg; their body is made of easily destructible non-rigid material) that could be dropped into the forest fire zone from specially adapted aircraft. This would significantly increase the effectiveness of extinguishing and reduce its dependence on wind strength.

(Source: Patent CN103100166A)

Figure 5. *"Satellite-guided fire-extinguishing bombs".*

Another the root of wildfires cause is the *poor forest management*. Many millions of acres of brush and tree as "fuels for next wildfires" have built up in the woodlands of all continents, increasing the risk of large and dangerous wildfires. For example, in California's forests flame can meet a dense wall of thigh-high dry grass that hadn't been mowed, grazed or burned for 20 years. Local communities in fire-prone areas are creating so-called "Prescribed-burn associations" which realize burning or micro-burning these brush and dried up trees under controlled conditions. But there are many legal, financial and organizational problems here [12].

It is interesting that the same "Lockheed Martin Corp." proposed creating new forests and restoring burned-out forests using *"seed bombs"* (Figure 6). It can be done using the same military airplanes C-130 Hercules for mass planting trees by bombing. The possibilities are amazing. They can fly on 1,000 ft at 120 knots, planting more than 3,000 capsules a minute across the landscape and each capsule contains a sapling. (The US government has committed to restore at least an additional.



(inside container are capsules with tree seeds)

Figure 6. *"Seed bomb" [13].*

200 million hectares of forests to plant an estimated 1.2 billion trees that will sequester 75 million metric tons of carbon) [13].

2.3. Building Codes

There is another major problem that needs to be solved to reduce the damage caused by hurricanes and wildfires, but it is not technical, but legislative. First, this concerns so-called WUI-zones (wildland-urban interface). The WUI is a zone where wildfires can cause significant damage to homes, critical infrastructure, and human lives. Building codes for residential and public buildings in any fire-prone areas must be tightened by the Building Code Council. Fire-resistant building materials are required there for the construction of any buildings. It should be the so-called refractory, or heat-resistant concrete, or fireclay. Look Figure 7: the wooden house burned down completely, but the fireproof brick and its chimney remained intact! If the whole this house had been built from fireproof materials, its frame would have been preserved – it would only have been necessary to restore the windows and roof and clean off the soot.

Figure 7. *The Pacific Palisades, a coastal neighborhood on the west side of Los Angeles, after fire.*

(Source: Washington Post, Jun. 7, 2024, by D. Hildebrand and J. Han)

The situation is similar in hurricane-prone areas - houses are built from easily destructible wooden elements that are poorly secured to the ground. But here there must be load-bearing columns made of monolithic reinforced concrete, which must be securely fixed in the ground (Figure 8) [14].

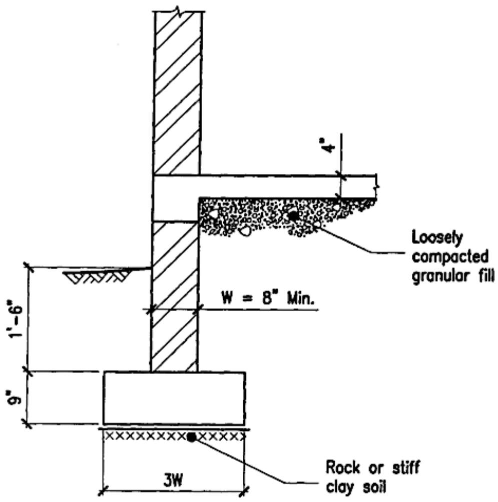


Figure 8. *Permissible arrangement of footing [14].*

Figure 9. *Winsun: Revolutionizing the Construction Industry with 3D Printing [15].*

In addition, if fire-resistant and hurricane-resistant cements are used, 1-3-story houses can be built many times faster if 3D technologies are used. So, Chinese 3D printing company, Yingchuang Building Technique (WinSun), started building houses with a giant 3D printer 10 years ago. Quoted from [16]: "Chinese Firm 3D Prints 10 Homes in 24 Hours"; "WinSun 3D Prints 5-Story Apartment Building and Villa"; "World's First Office Building 3D Printed in Dubai"; "Winsun completes world's first, 500 meters long, 3D printed river revetment wall."

Once again: now, in the US builds 1-2-3-storey residential and office buildings from combustible and fragile wooden elements that any fire can burn and any hurricane will destroy. The homebuilding industry argues that too much regulation drives up the cost of homes and could price out buyers. "The assault on safe, sane building codes is going on around the country," said Kim Wooten, an engineer on the North Carolina Building Code Council [17].

2.4. Cryogenic Underground Electrical Cables

As noted above, natural disasters like hurricanes, floods, and wildfires have become increasingly common in the 21st century, leaving vast areas without electricity for extended periods. Conventional high voltage power lines span many kilometers, consisting of hundreds of towering metal poles, each reaching heights of 30 to 50 meters. Within settlements, the lines are supported by poorly fixed wooden or concrete poles. These lines are especially vulnerable in mentioned hazardous regions. In contrast, cryogenic superconducting underground cables offer a highly efficient solution. These cables are comprised of a thin copper conductor housed within a narrow pipe, filled with liquid nitrogen, and insulated with a hydro-thermal layer. The benefits of utilizing cryogenic superconducting underground cables are significant (see Figure 10). First, the efficiency of power transmission over a superconducting cable is almost 100% (i.e. almost no losses; losses in conventional high-voltage networks - up to 10%). Second, a single superconducting cable for a 5 GW line will be ten times thinner than a normal copper cable. Third, a cryogenic cable can be laid underground with a "safety zone" of 5-10 m, while a conventional transmission line of the same power requires a right-of-way 100-200 m wide, and hundreds of metal poles 30-50 m wide. Fourth, I emphasize again that hurricanes, floods, and fires will not damage such an underground cable.

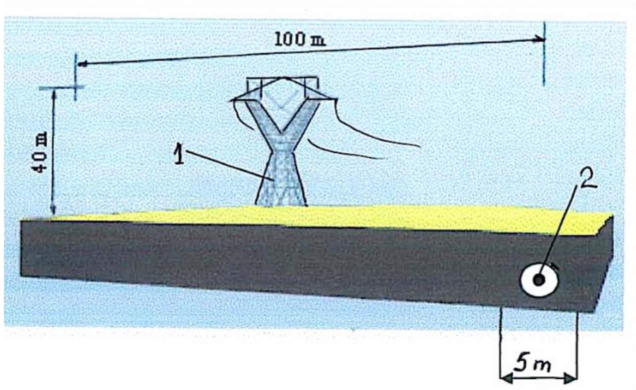


Figure 10. *High voltage line (1) and cryogenic superconducting cable (2) [18].*

2.5. Energy

2.5.1. Green (Clean) Energy

Energy has two aspects in relation to global warming: A) the transition to green (clean) energy in order to reduce CO_2 emissions; B) reducing the use of high-voltage power lines, since any natural disaster puts them out of action and de-energizes huge residential areas. In addition, clean energy benefits go far beyond "fighting global warming": clean, or green, energy such as solar and wind energy, unlike fossil fuel, does not need to be geological explored in the subsoil, or extracted, or enriching/refining (with the formation of thousands of tons of slag and sludge), does not need to be transported to a thermal power plant, does not need to be burned in boilers to generating steam - green energy can be supplied directly to consumers. These are huge, gigantic technological and financial advantages, but they are rarely mentioned.

The average flow of solar energy reaching the Earth's surface is 200-250 W/sq.m, while human economic activity requires only 15-20 W/sq. m. for highly industrialized countries and no more than 3 W/sq.m for poor countries [19]. That is, theoretically, it is enough to use up to 8-10% of solar energy to fully meet the energy needs of mankind without using of fossil fuels at all. Thus, the transition to green energy is a necessary step from the point of view of preventing and mitigating the consequences of climate change. However, while renewable energy sources accounted for about 30% of global electricity generation in 2021, hydropower provided half of that, wind power provided one third of that, and solar power only about 0.1 of that [20].

2.5.2. "Secondary" Solar Energy

The nature has created other grandiose thermal energy source for mankind - it is so-called "secondary" solar energy (i.e. utilization of heat of the upper layers of oceans, seas, rivers, and ground and the lower layer of the atmosphere). This "secondary" solar energy can be utilized with the help of so-called heat pumps which work on the reverse thermodynamic cycle Carnot (that is, the heat pump pumps, not generates energy). Additionally, the use of liquid ammonia as the heat carrier in heat pumps allows for heat extraction from the ground even in winter conditions (-5°C), making this technology viable across various latitudes and throughout all seasons (Figure 11).

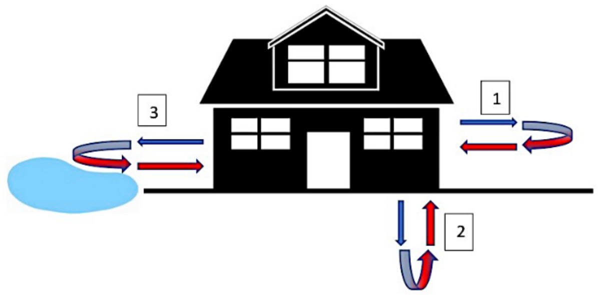
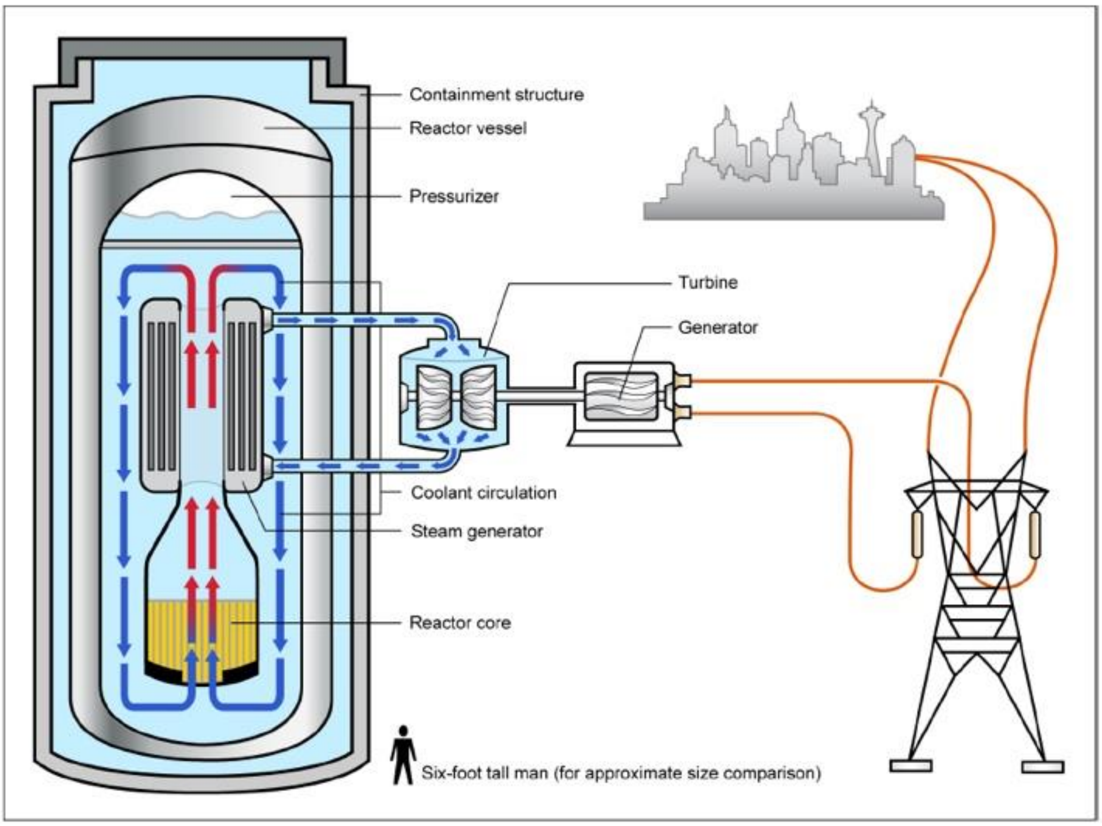


Figure 11. *Environmental heat resources ("secondary solar energy") for heat pump operation: 1 – air heat source; 2 – ground heat source; 3 – water heat source.*

That is, the heat pumps use a little electric energy for moving a large amount of heat energy from the outside environment to heat the air inside a home. While approximately 190 million heat pump units were operational in buildings worldwide in 2021, this still only meets about 10% [21]. I.e., this practically inexhaustible source of energy is greatly underestimated by humanity.

2.5.3. Ecological Nuclear Power

Today's nuclear power is neither strictly renewable nor fully green (its reactors are reactors on slow or thermal neutrons). A huge problem of traditional nuclear power plants (NPP) is the problem of highly radioactive nuclear waste (spent nuclear fuel - SNF). To date, more than 300 thousand tons of SNF have accumulated in the world. Besides, natural uranium contains 99.3% 238U and only 0.7% 235U. However, only the 235U isotope is suitable as fuel for conventional nuclear reactors. Therefore, natural uranium has to be enriched. As a result of the operation of uranium enrichment plants, about 2 million tons of depleted uranium waste have also accumulated in the world. The main ways to "more green" future nuclear technologies are as follows:



(Source: https://en.wikipedia.org/wiki/Small_modular_reactor)

Figure 12. *The small modular reactor (SMR) scheme.*

a) Stop using enriched uranium-238 as fuel and switch to unenriched or depleted uranium. For that ix needing switch to fast neutron reactors (FNR) [22]. The advantage of FNRs is that they can use as fuel both spent nuclear fuel from traditional nuclear power plants (of which more than 300 million tons have accumulated worldwide) and waste from uranium enrichment plants (of which about 2 million tons have accumulated worldwide). In addition, fast (i.e. high-energy neutrons) transform (right in the reactor) the useless U-238 into the plutonium fuel Pu-239. That is, a fast neutron reactor produces additional fuel "inside itself" during its operation. That is why FNR is called a breeder reactor. As a result of using the NFR, not only will it be possible to save up to 25% of natural uranium reserves, but the average burnup of nuclear fuel will become several times greater. Additionally, the danger (i.e. radioactivity) of their spent nuclear fuel will decrease by thousands of times.
b) Switch to the production of small modular nuclear reactors (SMNRs) [23] with a capacity of up to 300 MW (Figure 12). Due to their modularity and small size, SMRs can be manufactured in a factory and assembled on-site, significantly reducing construction time and costs. They can also quickly meet local energy needs and do not require the construction of hundreds of kilometers of high-voltage transmission lines. SMNRs can use American TRISO fuel (TRISO is the most efficient and safest nuclear fuel in the world.)

2.6. Agriculture

Traditional low-efficient and anti-ecological agriculture must be replaced with modern cellular and hydroponic agriculture.

2.6.1. Vertical Farms

Vertical farms (Figure 13) using hydroponic methods within specially designed multi-storey buildings and 10-shelf racks on each floor of the farm. Additionally, numerous suitable unused buildings can be repurposed for vertical farming. Vertical farms offer the following advantages [24]: automation of all processes; the ability to grow several crops per year; complete independence from natural conditions and natural disasters; reducing water consumption several times (world agriculture consumes about 70% of freshwater); the ability to be located within the city, which leads to a sharp reduction in transportation costs; the conditions of vertical farming eliminate the appearance of pests, making the use of pesticides unnecessary (and about three million tons/year are produced in the world); if a vertical farm is equipped with solar panels, mini-wind generators, and heat pumps, it will provide itself (partially or completely) with electricity and heat. In addition, agriculture in Europe and the United States is hopelessly unprofitable. So, American farmers, in 2018, received 140 billion US$ of subsidies [25]. Wouldn't it be better to use this 140 billion to finance vertical farms?

Figure 13. *Vertical farm with 10 hydroponic shelving for each farm floor [24].*

2.6.2. Cultivated (Cell-based) Meat

Raising livestock for meat production is one of the most inefficient and environmentally unfriendly production processes, especially for beef (there are about 1 billion cows in the world) – see Figure 14. In addition, 63 million hectares will be freed up, since there will be no need to sow them for feeding livestock and poultry. Therefore, a transition to cultivated (cell-based) meat is necessary. Cultivated (cell-grown) meat produce from cow, pig, or chicken stem cells extracted from their muscles (see Figure 15 [26]). Production of artificial meat requires five times less energy and 10 times less water than conventional beef production for the same quantity. It also reduces greenhouse gas emissions by 20 times compared to livestock farming. In sterile conditions, artificial meat eliminates the presence of parasitic worms, salmonella, and toxic metals often found in raw meat. An artificial "meat plant" occupies only 1% of the land compared to a conventional meat farm (the average size of livestock farms in Europe is 35 hectares with 50 cows.)

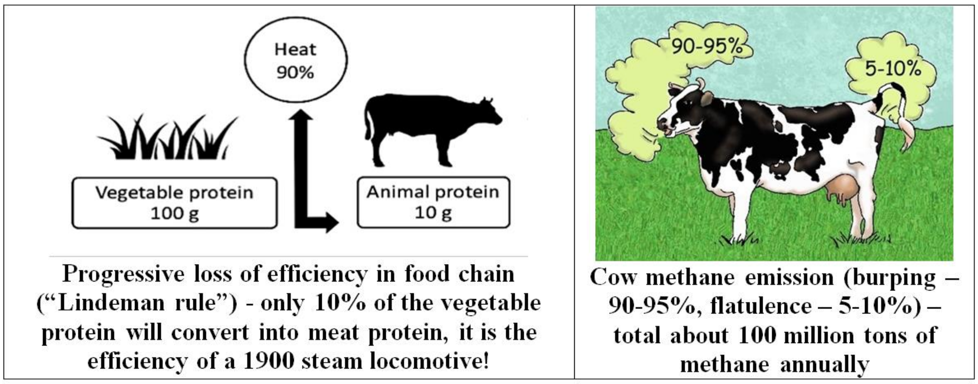


Figure 14. Low-efficiency and anti-ecological cow.

2.6.3. Minimizing Food Wastage

The United Nations World Food Program (UN WFP) reveals that approximately 14% of food produced is lost between harvest and retail due to transit, storage, or processing issues. Additionally, about 17% of food is wasted in households. In total, this amounts to a staggering 31% of global food loss and waste (review authors [27] believe 39% - see Figure 13 [25]. The transition to cellular and hydroponic agriculture will reduce food losses by three times up to 10% (in the sum of all stages) and save about one trillion USD.

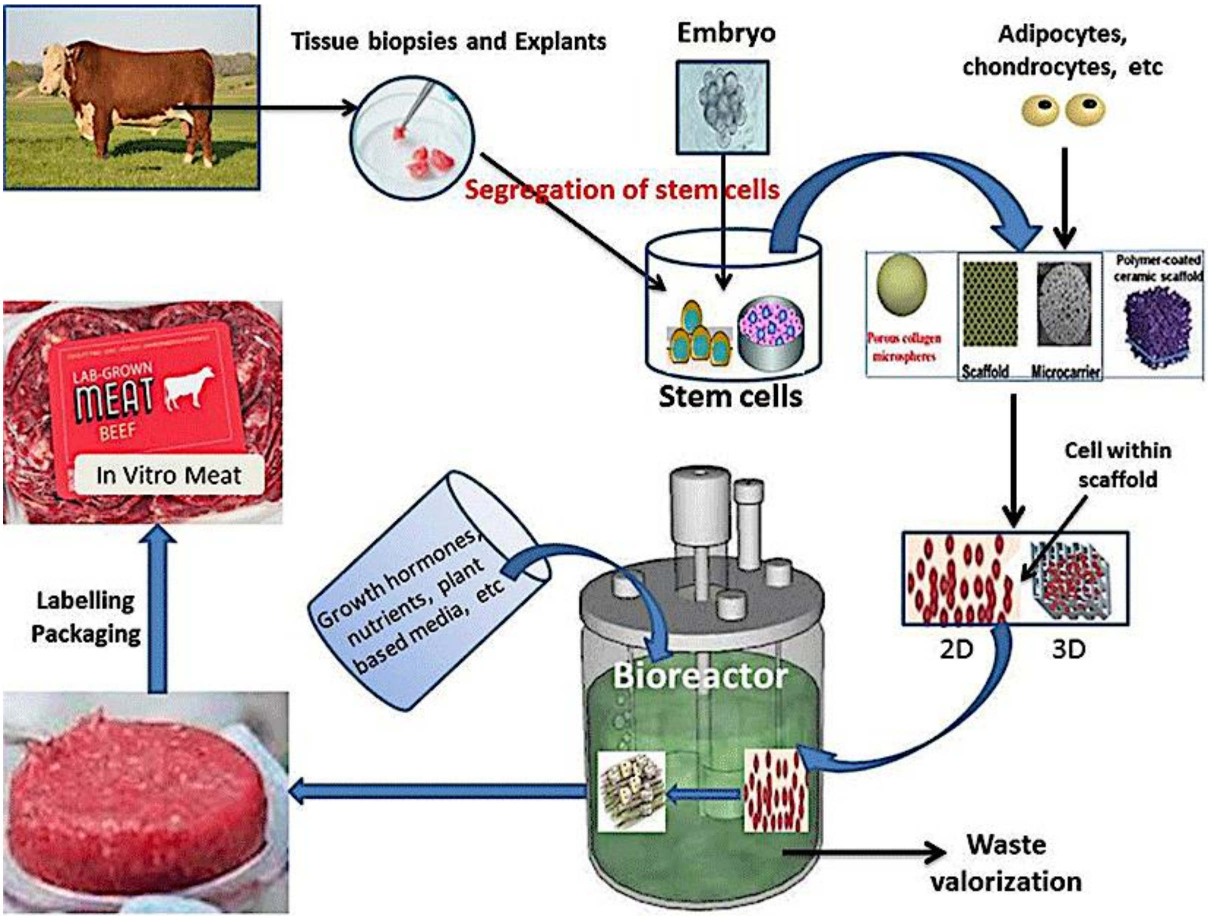


Figure 15. Scheme of a possible technology for the production of cell-grown meat [24].

Figure 16. *Where does food wastage and losses occur? [27]*

3. Conclusions

It is imperative that governments, international organizations, the business community, the scientific community, and environmental advocates recognize "Mankind's Adaptation to a Changed Climate" as a distinct and vital discipline within global science, economics, and politics. This recognition should prompt a redirection of at least half of their attention, financial resources, and intellectual endeavors towards the urgent task of adapting to an already significantly altered climate, one that is bound to further deteriorate. Merely striving for a "1.5°C" target is insufficient to ensure humanity's safety throughout the 21st century. Governments should start designing and building right now: powerful dams and drainage systems; hurricane-and-fire-resistant buildings; cryogenic power transmission systems; to form large units of firefighting and reforestation aviation; make greater use of solar and wind energy as well as heat pumps; etc. As the known proverb says, *"If the World Deluge is inevitable, one must spend the remaining time learning to live underwater."* After reading this article, any government official will say: "It's too much expensive!" Well, but 10-20 billion dollars damage every year - is it NOT expensive?...

Abbreviations

W, MW	Watt, Megawatt
CO_2	Carbon Dioxid
WUI	Wildland-urban Interface
m, sq.m.	Meter, Square Meter
FNR	Fast Neutron Reactors
SMNR	Small Modular Nuclear Reactor

Author Contributions

Mikhail Krasnyansky is the sole author. The author read and approved the final manuscript.

Funding

The author declare that no funds, grants, or other financial support were received during the creating of this manuscript.

Data Availability Statement

Data sharing is not applicable as no new data were generated or analyzed during this study.

Conflicts of Interest

The author declares no conflicts of interest.

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Biography

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