APOCALYPSE MANIFESTO

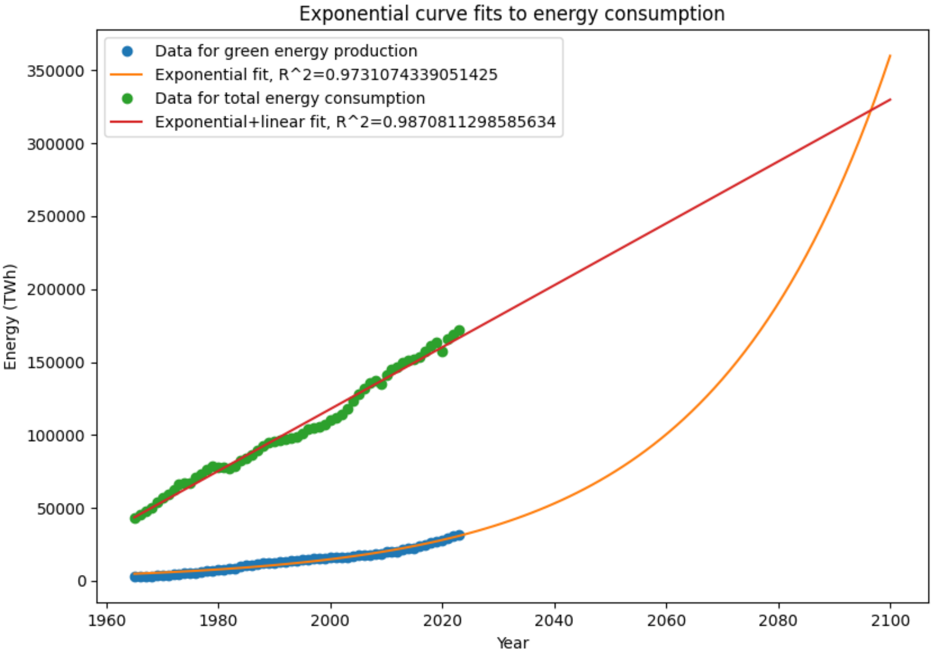

Figure 1: In the likely scenario that energy consumption steadily increases, the current exponential growth of green energy (renewables and nuclear) would catch up at the end of the century. Image source: I made this in Python with data from the Energy Institute.

APOCALYPSE MANIFESTO

How the world will not end

or

The plan for not all starving to death

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ABSTRACT: Do not panic!—and slow down. Circa 2,500,000,000 years ago the first plant breathed in carbon dioxide and mostly this was released back into the air, but every time some form of life got buried underground some carbon left the air and the climate cooled a little. Eventually a lot was buried making Earth liveable for life as we know it. Then man sucked hell empty and set its demons free: by burning fossil fuels the CO_2 concentration has increased by half over the past 200 years—notice the difference in scale. Now, temperatures have risen +1.5K and without action they will rise for centuries. We are crossing a threshold of melting ice and receding forest, which reinforce global warming, once crossed we are locked-in for +10K. Besides, now plastic pollution causes miscarriages, and globally reef ecosystems collapse, and within decades civilisation ends in hunger, and this century the last human may choke. As humanity copes with the beginning of global warming, it shows that we must do everything to stay below cataclysmic levels of heating. Severe technological intervention at an unparalleled scale and deep cultural and political reformation are required if mankind is to live.

This book wants to ignite the inner activist in everyone and can be of interest to anyone living in the Earth's ecosystem. It was also written for those technically capable or gifted with good scientific understanding, so that they may develop a clear picture of the problem and apply themselves accordingly. These are problems bigger than any one mind can comprehend let alone solve, we will need all of the greatest minds working on this. Beyond that, for the world to not end, there is a crucial role to be played by influencers of every type—from mothers to presidents—because all have to change their ways, so too the delusional and the disassociated. Yet there is hope. All these problems have solutions, which are feasible provided the vast amounts of labour to be done. If the Egyptians could build the Pyramids then humanity as a whole can save the planet. Do not go gentle into this dark night.

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In short, our world needs climate action on all fronts—everything, everywhere, all at once.

— António Guterres,
Secretary-General of the United Nations

Introduction

Hail Mary, full of grace, the Lord is with you. [538]

When activists painted Stonehenge orange I was saddened that they had not simply blown up the entirety of it. For Stonehenge to be irreparably damaged, for it to be forever lost to the world, would have been such a statement! No man to ever see these stacked rocks again, that is what is at stake. Their destruction would have been a statement that would have forced anyone to contemplate the darkest futures: societal collapse and human extinction. It is no small feat to get these images into the minds of the delusional and the dissociated, yet it is so important. I wrote this book because I do not want to die from hunger.

The obvious starting point of this book would be an argument that convinces you of climate change. More precisely, a discussion of whether climate change is happening, whether this is caused by humans and whether it is a problem. I will do no such thing. Firstly because I believe anyone can see the answers to these questions themselves. Secondly because if you have not yet been convinced of the reality of climate change, then there is nothing, not a single reason or fact, that will make you change your mind. If you are sceptical of climate change a rational argument will not convince you because you are not a rational agent. Besides, this book targets the intelligent who may have a great impact, and if you do not believe in climate change you are not part of the target audience. Because brevity is preferred many other topics will be cut short, left underexplained or be omitted. I do not expect you to agree with everything in this book completely, even I rarely do so with my own thoughts. God willing, things will be of interest.

Perhaps it would be wise to make some statements about the urgency of addressing climate change. We live in an unbalanced world: wrapped in a blanket of greenhouse gases, energy is accumulating in the Earth system [190]. Under the present geopolitical approach, this energy imbalance will force temperatures beyond +1.5K in the 2020s and +2K in the 2050s, and if business continues as usual the rise will continue until around +10K, where a new balance is found [249]. The truth is that nobody knows for sure how much time is left until the planet supports us not. What is certain is that haste must be made. (For the current state of global warming: earth.org)

As long as I live the world has been ending and as long as I live nothing has changed very much. Now time is running out. The people that are alive right now are up against the most formidable opponent of any time yet: their own ways of living. Change, on an individual level, is the hardest thing. Change, on a global level, may seem like an impossible task. In this book I will break down the thirty headed hydra into sub-problems and discuss them all briefly. Apocalypse manifesto is not the first roadmap towards a liveable future and there have been more that are of larger scope; more complete visions of potential technological effort. (A better technological roadmap is found at: drawdown.org) This booklet attempts to be of additional value by incorporating philosophy, I think that beyond technological intervention there are two more tasks: firstly that everyone must be made aware of their part in the whole purpose—which is the survival of life—and secondly that consumption must be limited.

Feel free to skip any part of this book that you feel is not for you. There are many things to be done by many people, and still more things to be done by a select few. I hope that you, the reader, will find one specific subject that you can see yourself working on. If you can help solve a (part of a) single one of the problems outlined in the book you have done so indescribably much for the human race. I hope you will find the book to be short, for there is but little time left. An apology is required for the tone, it is not an easy read. I am sorry I was not more kind, forgiving or hopeful but I simply am not. Lastly, I hope you will not collapse under the weight of so much heavy knowledge: do not get depressed. Perhaps cry for some time and then turn that grief into anger, so it may fuel your endeavours. We need you.

There is no way out. You are either: part of the problem AND part of the solution, or you are just part of the problem. All of mankind has a role in the solution of our problem, whether it be great or small. I hold that it is a moral imperative, a duty and just the right thing for everyone to take upon them as large a responsibility as they can carry. In the final hour of man, each soul will know what it has brought along. If you do not know what is your use, I strongly urge you to read this book. There is plenty of work to be done and surely you will find something you can do.

May peace be with you,

Max Flow, M.C.
Delft, Netherlands

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Part I

Book of Wood
Mankind & Planet Earth

Chapter 1

Apocalypse Now

God is truth: pious are those who seek it—this I believe. What follows is more of that which I have found to be true:

Since the species that wields fire came into being Earth has been in crisis. Its global spread brought the extinction of most large animals and countless birds [412, 52, 121]. Things have begun accelerating when the technological animal harnessed the invention of fire in machines. The steam engine was developed in the 18th century and powered by industrialisation, growth became a constant of capitalism in the 19th century which was exacerbated by the technological developments made during the world wars. Now, man is become supernatural, destroyer of worlds. So immense is the impact of humans on the environment that many speak of a new geological epoch: the Holocene has ended, enter the Anthropocene [127]. At present, thousands of species are going extinct [297], with half of all remaining species at risk [143]. As more and more ecosystems collapse, the functioning of the entire ecosphere—meaning: the whole of life—comes under threat. We are living through the sixth great extinction event and it is caused by man [350]. The myth of this spacefaring species is that it is a separate entity from the world around it and that mankind and nature are not mutually dependent. The truth for the technological animal is that we are cooking ourselves and in danger—and that damage done is damage received. All come from dust, and to dust all return [580]; all exist within one ecosphere which we will never leave.

Life means to perpetuate in cycles; to pump resources through the circles of ecology in perpetuity; to persist, that is what living is about. The linearity of the industrial mining-to-product-to-trash economy is not such a perpetuating cycle, and this is why it ends so many of the cycles of nature. It is very important to realise that life has acquired, in technology, the capacity to annihilate itself. This fact makes the question 'where are the aliens?' such a scary question: we too can go extinct.

Chapter 2

Slow, Then All at Once

Death will come slow, slow, then all at once. There are signs now, such as melting ice caps [567], increases in heatwaves, floods and wildfires [99], rising temperatures [192]. There may be cherry picked graphs such as the monetary damage or deaths from ecological disasters over the last twenty years, which do not show increase. That we can currently cope is no indication we will be able to continue doing so. Personally I have felt the shift in energy of the weather, especially over the last five years as permafrost started to melt, but I understand that my feelings are not an argument.

There will be fearful things and great signs from the sky [396]. The majority of experts is convinced we will not reach the Paris climate goals but instead trigger a feedback loop that will launch Earth to +3K and beyond [511]. There will be more and more frequent and extreme floods, droughts and extinctions as the amount of energy in the planetary system continues to increase [286]. Harvests will fail more often until agriculture can no longer sustain the population [316]. There will likely be a complete societal collapse within decades [66]. At that point it will all be far too late, as the planet would be well on its course towards a new equilibrium, unsustainable for mankind's civilisations and perhaps for life itself.

A ball in a hole will, when rolled up on some hillside, roll back to the lowest point [447]. When ice is added to boiling water eventually all has the same temperature [414]. Systems relax into their equilibrium [53]. Nature, when examined over shorter periods like centuries and millennia, can be viewed as constant struggle of species that compete for survival [131]. Soon an equilibrium between the species is reached: life is a plurality of cycles, the study of which is ecology [459]. Unbalanced growth causes calamities: the late Ordovician extinction happened because plants moved to land before animals did, disturbing the carbon cycle and causing a catastrophic ice age, and the late Devonian extinction was again an ice age after the arrival of trees [507].

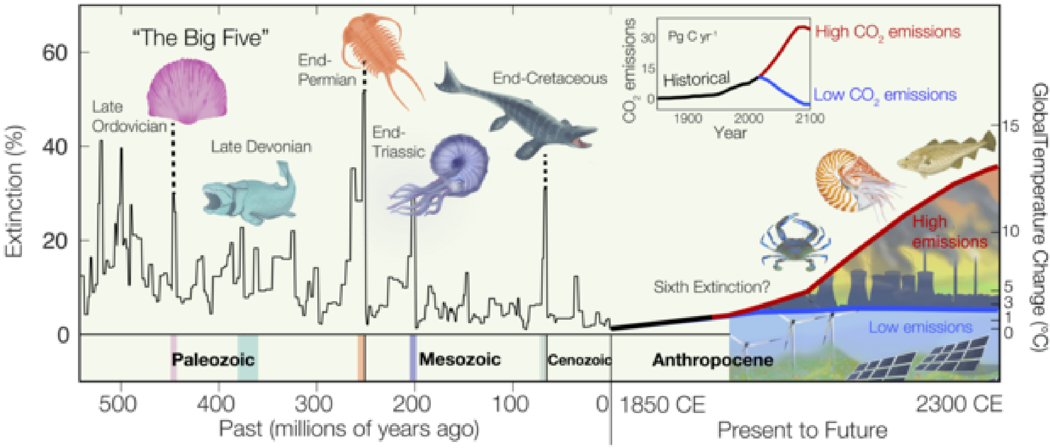


Figure 2.1: There have been 5 great extinction events before. Image source: (Data) Justin Penn and Curtis Deutsch. (Illustrations) Yesenia Román.

If we roll a ball over a hill it will find a lowest point on the other side; a new equilibrium is found. So too are there events that shift the equilibria of ecosystems [50]. There are triggers, such as a spark, or a mutation—or the meteor impact that ended the Cretaceous period [16]. After a trigger a cascade of events may follow, lasting milliseconds to megayears before new equilibrium. A reoccurring theme in extinction events is ocean suffocation, where so much marine life dies that decomposition consumes all oxygen, making the ocean unbreathable and causing further death [318]. Thresholds that once crossed cause positive-feedback loops are known as tipping points. The end-Permian extinction was triggered by volcano activity after which runaway global warming effects heated the planet to +6K and 95% of species went extinct [51].

Once Earth is hot, wildfires that release carbon dioxide become more frequent [75]. When ice and snow melt they no longer reflect light, accelerating warming [645]. As perma-frost melts, the methane from rotting that occurred underneath is released [544]. As the oceans heat and acidify, first the reefs [275] and then the whole marine ecosystem will collapse—this dead material will enter the atmosphere too [144]. The risk of apocalypse increases from +1.5K onwards [26], when Earth's temperature rises beyond that border it will be entering annihilation territory.

Chapter 3

Being Connected

Unity of origin underlies everything even though each thing is different [367]. Do think about a tree, a whole of connected being—or better yet: a forest—even though the whole is invisible. Do pray, and do not think too long about how little agency exists in the world: every event has a cause, every event has an effect [583], and in most cases these are not within the individual. In life however, every act is done; everything is action. To be is to bear responsibility for your actions, but is all of ones doing their own fault? Emotions infect: I may get irritated or happy when a baby cries or laughs [252]. The good causes the good and the bad causes the bad, for in happy and irritated states I am more prone to right and wrong [101, 375]. Memes infect new hosts, persisting through generations [133]. History can be understood as karma perpetuating itself, and such an analysis would mostly be a tale of traumatised people causing trauma [130]—such is life.

> *In spring wind*
> *Peach blossoms*
> *Begin to come apart.*
> *Doubts do not grow*
> *Branches and leaves.* [149]

But really, what is life? What came from the origin, it remains a mystery [367]. The cells of nature are self-managing machines that, if energy is provided, can 'overcome' the second law of thermodynamics, which drives systems into chaos, so the cells not turn to dust [542]. Thus, life is a struggle for energy. All food once was life, the body is what it ate, and upon death it decomposes and seeps into soil until the root of a plant makes dust enter the food-chain once more. Plants breathe out oxygen, animals breathe in oxygen. Life is the cyclical movement of matter. All the living exists in a web of relations [98]. As all animal life is ultimately powered by energy from plants, no mammal is ever free from plants. As plants would be plagues without the animal, no plant is ever free from animals. No one is free—such is the interconnectedness of the living. Then there is Earth, mother of life: not once was there a cell in nature unconnected from its environment and able to persist without the grace of this mother, and in turn life shapes the planet. Thus there is interconnectedness of life and the elements in the Earth system.

The mystery is again a mystery [367]. From the cell arise new self-regulating phenomena at higher levels of organisation: bodies, ecosystems, societies [572]. The self-management of society is done by its people, who are each controlled by the other. Every behaviour is triggered [566], from within or without. The within is formed by socialisation; through identification we absorb the other [41]. No one ever made up their mind by themselves [643]. No man is an island, entire of itself; every man is a piece of the continent, a part of the main [146]. We are caused by others and we can be an outside cause onto others: this is the interconnectedness of humanity. Each human is made, formed and regulated not by itself but by the cosmos. No one is free from interdependence. Never can you disconnect, never can you leave, connection is never gone—it is only forgotten. This forgetting is the meaning of dissociation. The mystery is the door to all truth [367].

We human beings,
Squirming among
The flowers that bloom. [311]

If things just happen, with no one managing things, this begs the question: how will the world be saved if all are powerless? Some believe the world is doomed: bunkers have been made [209], which will only allow for dissociation and not survival as +10K implies that, if there is a recovery, it will take millions of years before Earth is habitable for a species like ours again [623]. Attempting to separate from the world will not save our species: the fate of all life on Earth is one. Meanwhile there is no one individual powerful enough to save us; the messiah is not coming. No indeed; I swear by the alternating stars that only collective change in behaviour is a true solution [5, 470, 565]. How will the world be saved? Behaviour is guided by norms [172]; man is controlled by the other, and behaviour is guided by emotions [605]; man is controlled by themselves. In both cases it is values and beliefs that determine what is normal [591], and it is norms that rule over behaviour [227]. Because man makes apocalypse—which is unethical towards all of life, now and forever—we can infer that the moral of man is misguided. To have the world not end the spread of a new normal is needed.

Make environmentalism great again [555]! Even when we see that we are part of a cosmic flux of cause and effect, we will come to the conclusion that we are no slaves either: despite everything, there is often the experience of choice, action is everywhere. We choose what we do, and we can act on others. Bring them into nature, which the city-dweller sees too rarely and has become dissociated from [579], so they may see its beauty and realise its value. The natural has no mouth and it must scream—so let us yell. Do not be afraid to make a fool out of yourself for in a flash—Days? Months? Years? Decennia?—you will be gone, while life will or will not continue for billions of years. The great enlightenment to be spread is interconnectedness, which means: nothing in life is independent. Interconnectedness is the idea that you do not control or depend on yourself wholly, for you are controlled by and dependent on the environment, and also, because your actions are causes elsewhere, that you control the world, just not by yourself alone.

We are all in the same boat: all men literally want one thing and it is world not end, and all men are helpless. As Buddhist enlightenment is a realisation of what was always true—namely that there is only empty existence; essence, self and all ideas are fabrications of the mind, which cause desires, which cause suffering—so is ecological enlightenment the realisation of something which was already so: your existence is one instant of a pattern which has continued for more time than fits in the mind. Strive not to be ecologically; you already are in the ecosystem. Truth must be lived, action is everything. Philosophy is worthless as mere thought—philosophy lead to French and later American revolutions. Just like a blossom, bright coloured but scentless: a well-spoken word is fruitless when not carried out [214]. You depend on nature therefore the agenda of nature is your agenda: strive to be environmentalist. As stewards of Earth we must ask how we will evolve our ecosystem away from destruction; what and whom can we change? If the planet is to be saved then those with the most impact must join the mission for lasting life [656]. Their recruitment is possible because everyone is connected to and controlled by the whole—meaning that unless the elite have already hidden in their bunkers there must be chains of influence from environmentalists onto them.

The cherry-blossoms having fallen,
The temple belongs
To the branches. [91]

How then will we reach ecological enlightenment? Hardly through thinking, for what is the weight of a thought? Hard through thinking, for the whole is invisible. The way that can be known is not the eternal way and the name that can be named is not its name [367]. If there is a forest you should visit it, you will see: all the living depends. The ancients sought refuge in nature to meditate in seclusion. Action is everything—the way is non-action. To establish connection it is not sufficient to know of existence, one must meet, feel and experience what is. The world is not theorised, it is there. The truth of the priceless gem is in the flower of the lotus and, alas, the truth of life is at the far end of the circle.

Chapter 4

Do Trees Grow Forever?

No indeed; I swear by the alternating stars [433], the thought that papa Elon or ChatGPT will save us with miracle inventions is simply delusion: we cannot think our way out of this. There is a mind-virus spreading stories that we can save the world by accelerating development and growth, and it is a fairytale [85]. The argument is that faster scientific and technological progress will cure society and make the transition happen—and all that before apocalypse is here!—which is false [455]. The argument treats the growing tumour that is overconsumption by encouraging its expansion. More critically, the idea of need for progress is misguided. We do not need more scientific knowledge and technological inventions necessary for a complete transition to sustainability already exist [81], what we lack is not innovation but the collective will, skilled labour and resources to implement these solutions at scale. The change will be slow [582], because the work is difficult [569]. Only when a green energy economy becomes cheaper and more accessible than fossil fuel will we witness rapid advancements [194], which is a chicken-and-egg paradox: green energy will establish itself once it has become so established that it outcompetes fossil. Let it be clear: techno-optimism is simply delusion.

I propose eco-realism; the belief that technology is the problem instead of the solution [326], that humanity depends on the limited resources that nature provides [423] and that there is limited damage the environment can sustain [520], and therefore that growth must stop [256]. In the 26 years of my life I have seen too little transitional progress to believe the next 26 will see enough. As the transition is slow, there remain two courses for a liveable planet. One is the existential gamble: carbon removal [364] later would theoretically allows us to raise CO_2 beyond safe levels now (while praying that removal technologies somehow industrialise faster than green energy). Two is degrowth [129]: we embrace the economic contraction that enables the stringent decrease of energy consumption necessary for staying under +1.5K

[285]. Slowing down is the answer and a smaller steady-state economy is the future [313]. Constant growth is simply self-destructive. Human consumption has exceeded the biosphere's production since the 1980s [644]. In due time we will see the results: when a species becomes a plague it consumes the environment at unsustainable rate, until there is no sustenance and large parts of the plague population starves.

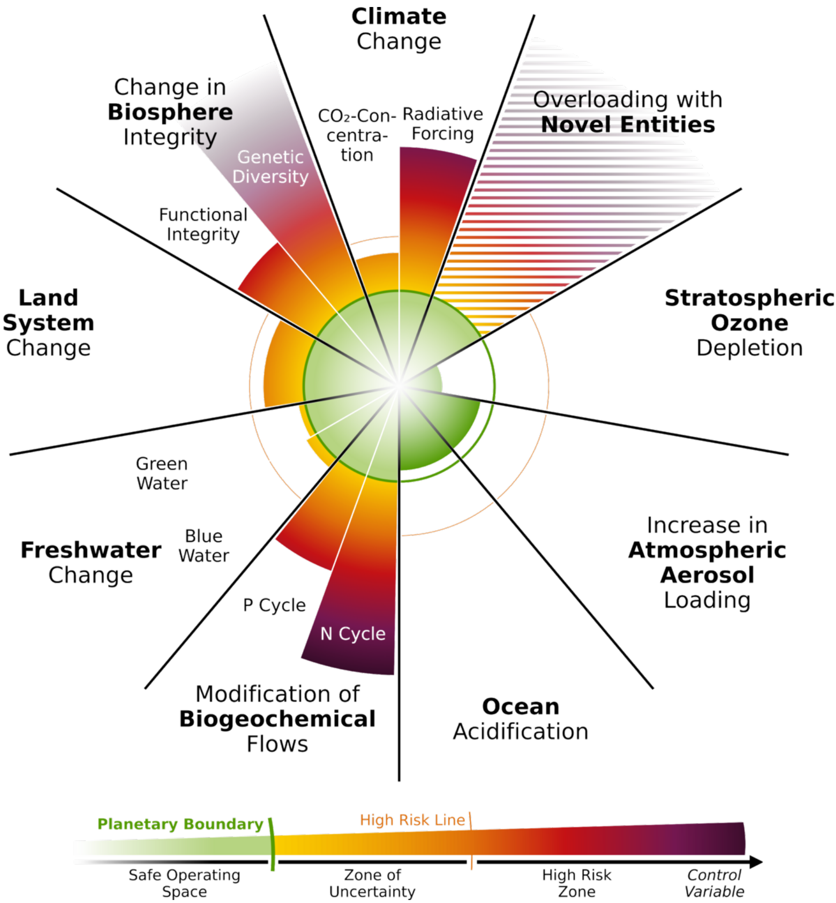


Figure 4.1: A 2023 update on the planetary boundaries, which are the limits to the damage Earth can sustain while remaining liveable. Image credit: Potsdam Institute for Climate Impact Research.

Picture this: the food-chain of money. Some consumer trades their money for goods or services provided by a company, which buys the labour of a worker, who again trades the money with a company. A big web-of-transactions, where money flows, that is how I want you to see the economy. If we drew the web-of-transaction, we would see a tree with roots, where primary capital is generated by raw material production, that merge upwards through the supply chains of trading companies, into a trunk, which is the monolith that owns all, and throughout the branches and twigs of sellers, to eventually reach the leaves that provide labour. At every stage that involves an owner who takes a cut, money flows to some roots where the wealth of the owning class accumulates [485]. Can a tree grow infinitely large? Not in nature.

It was written in the Edda: at apocalypse will the tree of the world end in fire and so too does the economic theory of entropy pessimism predicts that the world will end, although through a different mechanism [217]. We cannot take more from nature than there is, physical materials are a zero-sum game that will end [42]. After Earth is depleted, we may attempt to recycle, but anything less than %100 efficiency means eventual depletion. Hard is it on Earth, with mighty whoredom; axe-time, sword-time, shields are sundered [597]. It is unclear if we can defend against this fate. Even for sustainable energy the amount we can build is hard-coded into Earth by the amount of resources available; the amount of neodymium determines how many permanent magnets in wind mills we may have [14]. Although the energy consumption of the world can theoretically grow, we cannot build more than what is available in resources [257]. Even in a completely renewable energy economy there are boundaries to consumption and growth.

The serpent shall blow venom so that he shall sprinkle all the air and water [596]. Beyond the depletion of minerals there is the toxication problem [103]. Economies cannot keep polluting a finite environment and expect it to support the same amount of life [440]. As the destructive effects of raising CO_2 levels become apparent a new question arises: what about the rest of pollution? As humanity struggles for survival over one single type of pollutant, it pollutes oceans [244], air [405] and soil [343] further with different chemicals. One out of every six deaths is from pollution [366]. Waste and exhaust remain on their way to fill up all the spare reservoir of purity nature has, until Earth becomes too toxic for life [218, 562, 10]. Then the ash of the tree shall tremble, and nothing then shall be without fear in heaven or in earth [596].

Even through green growth we mankind may eventually end up consuming ourselves and leaving the planet uninhabitable [260]. Every individual of the global economy seeks a niche, and with continued growth all will be exhausted to completion. For the benefit of few, the nature that provides for all is degraded, and there is no technical solution [250]. Here the world falls, nor ever shall men each other spare [597]. It is a conflict of who is given the available space; ecosystem integrity diminishes as man takes more and more land [134]. Meanwhile we depend on nature [123]: without insect pollination no plant reproduction, without plants no humans. Truly, growth cannot continue forever for there are many borders beyond which the planet cannot sustain mankind. Save the bees [230].

A scary thought: that man tamed fire may end up his demise. As the dragon falls like an asteroid towards Earth, the distress of Earth becomes like that of sheep when a wolf falls upon it [23]. There is little you can do: become a green engineer, limit consumption. Over the last twenty years the amount of fossil fuel use grew steadily, despite gains on the front of building green energy, because consumption increased more [287]. Will hell be our punishment; a world that ends in flames? Fire melts the metal of righteousness, from the mountains it flows over this Earth like a river; all men will pass into that melted metal and become pure. [23]. All men will choose between difficult truths and comfortable lies [248]. Yet truth is never black and white: I attempt to be an eco-realist, meanwhile this book promotes techno-optimist ideas like carbon removal and planetary cooling too, for they are necessary. The essential nuance of eco-pragmatism is my thesis that technology cannot, will not and is not going to be the complete solution, because the prevention of apocalypse is only achieved by stopping fossil fuels. Technology is only able to address symptoms, not the underlying illness: overconsumption.

Now, humanity must speak truths more than ever, and not dwell in falsehoods. There is no other way to put it: mankind has gone collectively insane. Out of touch with the world that allows it to live, man fails to see the Earth as it is. The mental sphere is sick from ideas of closedness; that man is separate and that not all is but one great breathing interdependent whole. When one is righteous, then it seems as though he walks in warm milk, but when wicked, it seems to him in as if he walks continually in molten metal [23]. There is truth and there is lie and, in delusion, people have killed themselves—many such cases.

The tree is a weed that will destroy the mother that provides for it.

Then two fiends remain at large, the liar and the cosmos. The creator comes to the world and holds the holy cord in his hand. Defeated by the truth of the weave, the wicked spirit and the order of the cosmos become impotent, and by the passage which he rushed into the sky the liar runs back to gloom and darkness. The dragon burns the serpent in the molten metal, and the stench and pollution which were in hell are burned in that metal, and hell becomes quite pure. With the metal, the creator closes the passage into which the evil spirit fled. He brings the land of hell back for the enlargement of the world; the renovation arises in the universe by his will, and the world is immortal forever and everlasting. [23]

Chapter 5

Waves, Flowers & Chaos

Everything is connected: you are part of the ecological system that is planet Earth [98]. There is no way out: you are either part of the problem or part of the solution [422]—there are no other options. You are the effect of the environment and in parallel the environment is the effect of you and many other actors, be they trees, the pull of the moon which causes the tides, the clouds or your neighbours. It is impossible to think of man without it being home in an environment. Hence the modern idea of man as the created being, the perfectly seperated, the special monkey, it leaves us lonely and never home. Delusion is smashed by truth—dissociation is healed by coming home. The healing of the planet will happen in three phases: a new mental ecology, a new social ecology and a new physical ecology [237].

> *The old pond:*
> *A frog jumps in—*
> *The sound of the water.* [43]

The mental revolution is rare but it does happen. Few are completely dissociated or delusional [374]—few think the science through completely. Most remain dissociated to a degree [660], because full of angst is the truth and hard to face. Many bad ideas live like weeds in our gardens. Mind is a war-zone where all thoughts strife to be the truth. The idea of the interconnectedness; the idea of the interdependence of all the living; the idea that every single action everywhere will have a result somewhere—this idea too attempts to persist and does so by spreading across minds, like in you reading this book. Then, by awakening to the truth one may be spurred into climate action [611]. When a meme spreads to a sufficient percentage of people, then the entire fabric of society will be rewritten. No government has withstood a challenge of 3.5% of their population mobilized against it during a peak event [111]. Currently 80% of the world is convinced of the climate crisis [183] and a little less than 3% is vegetarian [304]. Once revolution has been established and climate action normalised, different physical results will follow [186].

What is climate action? An idea is a plant. A blooming flower spreads a scent that other buds pick up, and they soon unfold all across the forest. A tree blossoming in spring—such could be the spectacle life [176]. But make no mistake: the revolution is not a happy evolution that makes mankind loving and peaceful. The revolution is war; war against lies, war against the systems of destruction, war against the monolith [347]. The revolution is a completely serious affair, it is the struggle for survival and a last Hail Mary prayer in the hopes of not the end of the world [587]. The apocalypse has already begun, and it is up to us to prevent it becoming total annihilation, mitigate the damage of what we have done and adapt to the hell we have conjured on Earth. It all begins in the mind: the task of the ecosopher is to weed out the mental illnesses of closedness, techno-optimism and relativism [368].

What is relativism? Relativism is a more widespread mind-virus that claims everybody is entitled to their own truth [65], because some people like certain styles of painting and others do not get it. Free to be you and me? I disrespectfully disagree. All questions about matter existing in the world have a singular answer [57]: the world is, in exactly one way, which is no matter of opinion and you eating meat is bad for me. Although the appreciation of, for example, Hip-Hop music will vary through the lands, certain facts are true everywhere on Earth: the sun rises in the east, things fall downward, all of society will end in hunger if business continues as usual. Relativism leads to the perverse sentiment that even the views of the delusional are to be respected; that all belief is valid even if it is pertinently false [202]. Respectful relativism hinders the first and for now most important front of the war for life: the sphere of public opinion [379]. It must be conquered, the delusions must perish soon as possible.

> *The light of a candle*
> *Is transferred to another candle—*
> *Spring twilight.* [91]

All of the destiny of life on Earth is decided by the following question: which tipping point do we cross first? Will it be the one in society [539], or the one in the weather system [377]? It is entirely within the realm of possibility that mankind destroys its habitat to an extent it cannot repair before the general public wakes up to the necessity of living with instead of against nature [520]. Many are convinced something must happen, but because the problems are so large they return to the infantile state where big corporations or the government must do everything while they individually do exactly nothing [221]. The entire world is individuals! Although these people know a truth, they are still part of the problem. Which threshold will we cross first? There is but one thing that is certain: we will not know until we have crossed it.

It is said that the weather is so difficult to predict because one flap of a sea gull's wings could be enough to alter the course of the weather forever [262]. Earth is a very big system for a physical scientist to consider and there is a lot of chaos and missing data. Predicting the future becomes increasingly more impossible for a physicist as the system increases in complexity and the predicted future is further away [427]. Very small actions can have very big impacts.

It is said that science is disturbingly difficult and never convincing, for even the best methods are by definition of the scientific method open to critique: science can only make an idea plausible, and the sceptic will always be its undefeatable opponent [490]. If the dust has settled after critique and discussion and now most, or all, scientists in a field agree on an idea, then this is as certain as man can make it. There is always doubt, nothing is ever more than a theory, yet smoking killed long before the definitive proof was found [263]. That scientific knowledge is not common knowledge is a part of the war for life on Earth that we are losing [450]. A major role is to be played by influencers of the online realm, because by remaining silent and not sharing your fears and thoughts about the crisis you express disbelief and enable dissociation. Indeed, we need the outcries, for screaming is the correct emotional response to the current situation. Share your feelings. Very small actions can have very big impacts. Even after millennia of truth seeking, most people still believe the average of what their social circles believe. Wake up, mankind!

It is known—by me—that ecophilosophy is notoriously difficult, with a schizophrenic undertone, and therefore completely inaccessible for the non-academic philosopher [438]. What is ecophilosophy? It concerns itself with the question that given the truth of science; a deeply complex system of trueisms without any ethical judgements, what moral compass one can derive from this truth [93]? It is very unsurprising that the philosophers who have attempted to find an answer by seeing and understanding the whole system of planet Earth, its ecology, its nature, its humans and their impacts and thoughts, have gone somewhat insane [136]. But it is a fundamental problem that there is no good guide towards the 'enlightened' state of action in accordance with interconnectedness and science. Soon everyone will be reached by the main message of environmentalism: stop oil. Yet how many will be connected?

> *Morning glory!*
> *The well bucket-entangled,*
> *I ask for water.* [113]

While everyone is perfectly able to realise that Earth is warming (80% gets this far) [183], not everyone can continue the line of reason to the conclusion that a new way of living is necessary (far less people realise this truly) [655, 222], and that your heroic actions are necessary for the survival of the species (almost everybody fails to realise this) [632]. We are sickly incapable of drawing conclusions: disconnected insanity is the average. Science has the power to lay bare all kinds of truth, but it will never tell good from evil [276]. A major role in saving the world is to be played by those who build bridges from belief in climate change, all the way across the abyss of doomerism, into action towards saving the world [484, 464]. Be warned, for it is much better to just "common sense" your way to climate action than to get lost in the intellectual masturbation that is finding your epistemically sound reason why causing climate change is bad. One who does attempt to enter this field of thought does well to realise the following: to entertain the schizoid thought is to enter the schizoaffective spectrum oneself, as certainly it becomes less clear what is self after seriously considering causation from a universal perspective. There is danger in reading these works fuelled by angst, it is not for the faint of heart or weak of mind.

Again, what is ecophilosophy? The school of thought that concerns itself with the house moreso than any of its inhabitants [439]. No wall is perfect and after they all crumble there remains just one single house: the Earth, our mother [394]. The ecosopher lets their mind not dwell on the individual, but rather on its relationships within the rest of the community [378]. No thing on Earth ever just is, always are things together. The uninitiated will enter a forest and see themselves as the hero to overcome and defeat any obstacle that nature puts in their way, the uninitiated will tell themselves a story of a seperate organism at war with the world—which is true; evolution is competition—which is false for all organisms are firstly members of the forest community [3]. The uninitiated who stare at themselves are blind for the given that they are at home in the forest, because they are together with the rest of all that lives long before any competition can happen. The ecosopher will enter a forest and see a forest: the entirety of trees and other residents in this community which the ecosopher belongs to as well.

Although the mental revolution has begun in schizoid ecophilosophers, the impact of most of these thinkers will be very minimal. Impact is maximised by an absurd leap over the question of ecophilosophy entirely towards the climate action endorsed by this herd of wise people that is science [471]. What is there to understand? Earth warms because of fossil fuels: just stop oil. The world will be saved by doers. Many small and great actions together can have unimaginable effects.

It has also been said that the climate activist underestimates their impact [610]. This is because of a cascading effect: suppose I convince two people to become vegan, and they each convince two people in turn, etc. then the reduction in greenhouse gas emissions achieved by the individual are unbounded [107]. The image of a photomultiplier tube springs to mind: where a single photon of light unleashes one electron on some first cathode layer of the detection device which accelerates and hits a second layer, a dynode, where upon impact multiple electrons are released, several dynodes later a single particle of light has cascaded into an avalanche of electrons, so that when the signal reaches the final layer, the anode, a spark may be visible to the human eye. A TikTok film of a storm may convince someone or some multitudes [481].

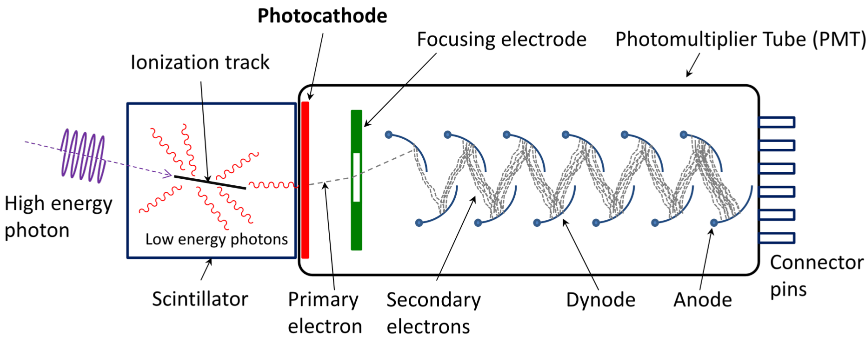


Figure 5.1: This is a schematic of a device which detects radiation; it describes the workings of a photomultiplier tube which amplifies the signal of a scintillator. Image source: TU Delft.

The scintillator can be understood as less than a metaphor: it illustrates the greenhouse effect. We can imagine all different kinds of light sensitive molecules. A scintillator absorbs high energy ultra-violet photons and emits low energy infra-red photons. The surface of Earth effectively acts as a scintillator, turning ultra-violet light received from the sun into infra-red which is emitted into space again. CO_2 and CH_4 are gases that do the opposite of a scintillator; ultra-violet can pass through, but infra-red cannot. This effectively puts a blanket around Earth, as the infra-red heat radiation cannot leave the system.

Who certainly cannot leave the system of Earth is you. You are entirely dependent on nature to live, and nature is entirely dependent on all living beings to exist [638]. The meaning of an organism in nature is to perpetuate the cycles it is a part of. The meaning of man, who is an ape beyond nature, is to decide arbitrarily why actions have use. On the greatest timescales all meaning is lost to man, but not to nature which will just steadily keep on repeating itself without ever having to question why it would want that. So natures meaning is superior [24]. If all this thinking does not help you and if doom, gloom and nihilism have taken hold of you then I offer a way out towards a childishly simple meaning. From now on you will know it to be true: regardless anything, a more epic meaning for your life will always be that you were meant to help save the planet; you were meant to be a hero.

Chapter 6

Control of Power

The struggle of the cell has always been a struggle for control over as big a part of the world as is achievable, so that it may be sure it will persist. Man's aggressive search for more niches to control has outcompeted most of nature. Meanwhile the quest for control is a meaningless pursuit as there is never a controller without dependence, but rather an infinite string of puppet masters being puppets to the next. It is also a suicidal pursuit as the increasing demand for control is what makes us energy addicts, vanquishers of nature and polluters of the planet.

> *A thicket of summer grass*
> *Is all that remains*
> *Of the dreams and ambitions*
> *Of ancient warriors.* [44]

There is a very simple answer to the question "who is to blame for the fact that we let climate change progress this far?" and that answer is: all members and ex-members of the Smoke and Fumes Committee. This committee which has known many names over the years, consisting of executives of leading oil companies involved with the American Petroleum Institute, has been involved in shaping public opinion on climate change by funding research [323]. Their main contribution has been a multi-billion dollar propaganda campaign dedicated to creating the illusion of discussion about whether there is such a thing as human-caused problematic climate change. Although the first theories about a greenhouse effect arising from pollutants stem from the beginning of the 19th century with the likes of no less than Fourier [195] and physicist-of-chemisitry Arrhenius [28], and although scientific consensus came about in the eighties, although there is by now a global consensus among all respectable scientists active in relevant fields, it has been by the effort of this committee that to this day there is still a public debate about the reality of climate change.(Further reading: smokeandfumes.org)

The first conclusion of having an answer to the question "who is to blame?" is that having a culprit does very little in solving the problem. It is too late to stop the people who have created this world on a path to annihilation and the people who will be involved in changing the course of mankind towards a path that has a future will be entirely different and unrelated people. The second conclusion is less trivial: not everyone is on the right side of the struggle for survival. Greed can indeed lead a man towards downright suicidal behaviour, and you would be surprised at just how many such cases there are. It is easy to downplay the risks of climate change, to believe that it will only be a problem in the far future and that the acts that work contrary to stopping it will have no big effect in the grand scheme of things; it is easy to believe that you may just as well cause destruction for personal profit. Whether it be politicians who deny climate science to appeal to their delusional voters, CEOs who do not reduce the emissions of their companies to squeeze out more profit or regular people who dissociate from the problem so that they can remain in their old ways without feeling guilt, there is a staggering amount of people who participate in the destruction of life on planet Earth.

The problem is essentially that of a regime change [215]. The power market varies globally from \$0.01 to \$0.50 per kWh for electricity and at times has been negative when a surplus was generated. In 2022 roughly 30 PWh (30 trillion kWh) of electricity was used and the market is only projected to grow [288]. Fossil fuel implies a centralised power structure: you cannot make gasoline everywhere. Renewable energy is decentralised: everywhere the sun shines and everywhere the wind blows is an untapped source that cannot run out. This leaves the current regime of the energy industry exposed to risk of losing a lot of control. As economies require energy, nations are subject to energy markets for their persistence. The monolith companies own, like everything, the majority of the energy institute and it is their most controlling tool. This is who we are fighting.

So from the Smoke and Fumes Committee to the many contemporary villains of this world, there are many answers to the question of who is causing climate change. The most general answer, which may not be a useful answer, would be: mankind as a whole. This answer is not useful because it makes abstract what is concrete and because it can get in the way of action. The most truthful answer would look somewhat similar to the Fortune 500 list; I believe that there is an aggregate of around 10,000 very powerful people who could cut emissions by a third by the end of this year should they all together decide that something needs to be done. The richest 80,000,000 could certainly do it, because the richest 1% emit as much planet-heating pollution as two-thirds of humanity [341]. I am very pessimistic about such scenarios becoming reality.

Getting back to the idea that climate change is caused by mankind as a whole, a constructive conclusion about who is to blame would be: you are. Now, do not panic. You are not (necessarily) evil. The fact that you are in part responsible for climate change is to be understood in the context of the idea that everyone is part of the problem, and that everyone can choose to be part of the solution.

To conclude this chapter: we are all by and large powerlessly trapped in a web of interdependent causation, we have struggled for control and now we are stuck in this competition for it. The emphasis is on 'stuck' because no-one can change one damned thing by themselves alone. However, after struggling for control for all these millennia, we will discover that there is but very little left of the world which is not controlled by someone. Ergo: united we could change anything we desire.

Chapter 7

Changing Systemically

Do think of a tree, as a living, growing and withering process. Do not try to grasp the structure of the tree, for it is ever changing. Ever evolving, but stuck the cycle of addiction: how will humanity get off oil if no single individual is responsible? Is it governments, corporations and the other abstract entities and structures that control us which are to blame? Stated differently: is it the global consumption machine which destroys the world or is the cogs of the machine, which is we. My objection to blaming the whole: there is no whole as being with a will, in actuality there is nothing but the cogs, so how will the machine ever stop when all cogs keep repeating to themselves that 'boy, this machine sure is evil, but I am just a cog so I cannot stop it.' This uttering implies nothing will happen until the machine collapses by the non-human intervention of climate catastrophes, which would be far too late.

> *The willow-tree*
> *Has forgotten its root*
> *In the young grasses.* [91]

For sure, the machine must be dismantled. Food must be produced sustainably, and the economy must become an ecology, and emissions must be stopped, meanwhile no one is free from the chains of codependency. It is hard to find a first cog willing to jumps out of the machine but one thing is certain: these cogs must be found, for all that is achieved by humans in this world starts with individuals. Indeed, often these individuals start collective movements, but every change in the world started from within just one person. I am curious what laws we can come up with to make the global sales-driven consumer economy less destructive, and how we will influence our way through lobbies and the politicians they have bought. It is important to realise that even when we may lack enough control to have someones mind become sensible, we certainly have enough control to make them act in accordance to sense.

(Further reading: systemschangelab.org)

The problem of mega-corporations is that they are controlled by a system in which everyone is part of some dependent chain: employee gets fired by boss if he does not continue the destruction, boss gets fired by shareholders if he does not continue and shareholders are seemingly just the villain. An obvious remark is that the employees can find different employment. As we remember the last chapter we again suppose that man is fundamentally a slave to his desire for control, which explains the desire for money. It is very possible that there are people driven by just this control hungry instinct as some amount of wisdom must be present for the fear of apocalypse to triumph over such impulses.

Tangled even further
in the wind
that dries them—
threads of green willow
wet with rain. [531]

A very close eye must be kept on the elite class of people that own substantial portions of the wealth, for they have the most control over the fate of Earth, yet they are also the most addicted to control and have the hardest time sacrificing this for the greater good, as admittedly their sacrifices will be greater. And indeed they do appear oblivious given the following statistic: the world's richest 10% produce half of carbon emissions while the poorest 3.5 billion account for just a tenth [228]. Hopefully they will be persuaded to cooperation, for if they are not willing to sacrifice then what can be sacrificed? As has been discussed, concessions must be made.

The machine must be dismantled and the only question is how. If you are a cog then I beg you: jump. Every action is performed by an individual, and realising interconnectedness we understand that every action matters in dismantling the machine.

Chapter 8

Slow Rebellion

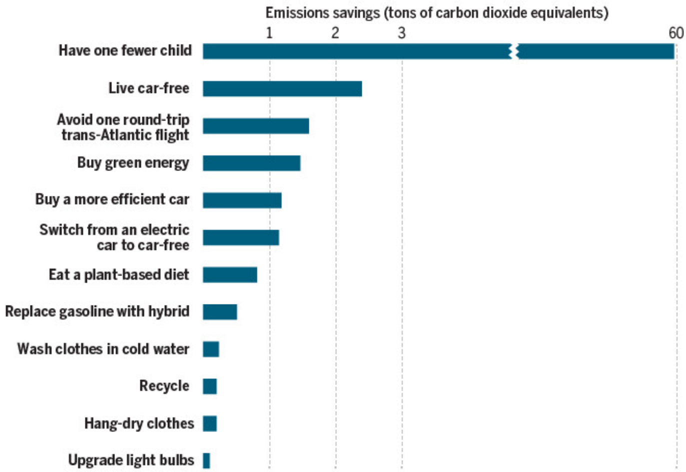


Figure 8.1: There are many easy and less easy ways to reduce your carbon footprint. Image source: (Graphics) J. You, Science; (Data) Wynes & Nicholas (2017), Environmental Research Letters.

What can one do? Consume less. While not everyone can do an equal amount to stop climate catastrophe everyone can do this one thing which directly results in lesser emissions. Everything we produce requires energy, energy to collect the resources, energy to ship the resources, energy to make the product, energy to ship the product and finally energy to process the product once it has become trash. In every act of consumption that is prevented, the apocalypse is delayed. The impact may seem small, but all of emissions are at the service of some consumption.We should all strive to have an acceptable carbon footprint if we want to have a liveable planet and the more you consume the more room for improvement there is. (Further reading: calculator.carbonfootprint.com)

Who can do the most? On the road to electrification of transport, Elon Musk has arguably done the most yet praise is not due the man as all his efforts can be neglected in the face of his greatest crime against the ecosystem: SpaceX. What everyone can do is this: ask yourself in what way you are destroying the planet and bringing about apocalypse, and taking steps to limit these behaviours.

A deranged lunatic may say that in taking man to Mars, Elon Musk is saving the species. Apart from the complete physical unfeasibility of the project, it also fails to see what we are trying to preserve: life—which is a rich and beautiful thing—and not just human existence, which can be insufferably empty. It also fails to see that trying to save society is a far more noble pursuit that increasing the survival chance of the human race by a marginal amount.

What can one do? Firstly: not dissociating. Choosing to be the solution! The horrors of apocalypse are truly great and it is far more comfortable to live as unawarely as possible. The first thing one can do is forgo the pleasure of forgetting that you are in danger and live in awareness. In awareness one will find terror and despair, certainly, but awareness will also lead one to the truest peace that remains available for rational agents, which is knowing that you are doing everything you can: slowing down. The essential answer to the problem is *less*.

How many people have chosen to just not bother? How many genius minds have decided to apply themselves to completely useless mathematical fields such a homotopy category theory, or worse yet, fields within theoretical physics that will never have a purpose, such as string theory, or worse even: how many of great intellect have chosen a path of finance often having a net-negative contribution to the ecosphere? How many great minds have in fact dissociated? This waste of intellectual capital is currently my greatest gripe of mankind and it keeps me up at night. All the aforementioned are clear examples of people who are brilliant and could have been doing something important, but chose not to.

So, what can one do? Secondly: not actively choosing apocalypse. This may seem surreal to many people but yes, they do exist, the actual enemies of mankind and all life on Earth. I mean those set on misinforming the dumb, propagating the myth that climate change is debated, of facilitating in the burning of ever more fossil fuel, all for a profit. Elon Musk may escape the apocalypse by rocketship, but I do not think the tickets will be for sale. It is very, very difficult, if not impossible, to buy your way to safety from the man-made apocalypse. Conventional amounts of wealth will not be sufficient. I estimate the bunkers you want to get into will cost billions at the minimum.

It is however better altogether, both morally and for self-preservation, to bet that mankind will prevail.

Sadly, the argument at the end of the previous paragraph will fall on deaf ears; psychopaths are unlikely to respond to pleas that address the goodness in their hearts. I believe that if you cannot actively work towards preventing apocalypse, the second best thing is to actively work against those who cause the destruction. Hold them accountable and make them famous. Bring back bullying and shame-culture. I applaud Just Stop Oil and The Extinction Rebellion and think they could go to far more extreme lengths to make their point, for there truly is that much urgency.

What can one do? I cannot answer this question for I do not know who is asking. What you can do for yourself is to take a look at the world and see what you can do and then proceed to do it.

Chapter 9

Decentralised Transition

Fuji's peak unseen,
Veiled in mist—yet fragrant
The plum blossoms bloom. -Buson

What the future looks like, we know not.

[Chapter going to be lit]

Part II

Book of Fire
Apocalypse of Man

Chapter 10

The Problem

God is life: pious are those who protect the creation—Satan schemes for its annihilation. The end of life on Earth is coming because of mankind and the way it exploits its environment until this environment supports man no longer. It has been a reoccurring theme in the falls of civilisations that these peoples find ways to extract more from nature than it produces, which inevitably leads to an exhaustion of natural resources: when the means of persistence have disappeared then so too the cultures that subside on them.

Current exploitation of the natural environment is done at a level not seen before ever in the existence of the planet. The core of our problem is to be understood as the global capitalist system which is too complicated, involves too much long distance shipping, and, through advertisement and mass media, is creating its own demand: the core of the problem is an economy that consumes too much in an unsustainable way. When this apparatus is left running unchecked it will soon overconsume to the point of its own complete demise. (Further reading: overshoot.footprintnetwork.org)

Put simply: we have to reduce destructive consumption. As an ex-smoker, I am very aware of how hard it is to break a habit. But mankind will have to kick it, through both replacement by sustainable alternatives and through a partial cessation of the economic machine that is global consumerist commerce. A recession, which is a natural part of the cycles of economy, is overdue and would come in the nick of time to slow down consumption and consequently emissions. Degrowth is a necessity for survival and is also necessary logically as the system of all natural resources on earth is a zero sum game: implying that infinite growth is impossible. Personally, as a minimalist, I think I will enjoy the simpler living. (Further reading: degrowth.net)

Chapter 11

Preventing Further Emission & Pollution

To save this divine creation is to just stop emission, destruction and pollution. Prevention means to stop the problem at the root. To prevent apocalypse the problems of fossil fuel, deforestation, livestock, organic waste, eutrophication, forever chemicals and air, water and soil pollution must all be addressed.

In the context of emission and global warming, prevention means an end to the emissions of carbon dioxide, methane, nitrous oxides and hydrofluorocarbons. In 2022 a total emission of greenhouse gasses equivalent to 53,800,000,000 tonnes of CO_2 was observed [287]. Of this gas, 75% was carbon dioxide, 20% was methane and 5% was nitrous oxide. The increase in atmospheric particles of CO_2 (carbon dioxide) has been caused by the human burning of fossil fuels and deforestation. The rise in CH_4 (methane) and N_2O (nitrous oxide) was driven by human agriculture, mainly in keeping animals, and the decomposition of organic waste.

In the context of pollution, prevention means to stop man-made waste from entering the environment. It can be the prevention of excessive release of agricultural fertilisers into the environment, because of which there are now some 300 hypoxic (dead) coastal zones. It can be preventing forever chemicals and plastics, which are—right now!—giving you cancer, from entering the food chain. It can be wastewater treatment and managing the trash. One in six deaths is from pollution.

11.1 Fossil Fuels

The combustion of fossil fuels is the primary driver of anthropogenic carbon dioxide emissions, significantly contributing to global warming [370]. Halting the rise in atmospheric CO_2 concentrations is essential to prevent further exacerbation of the climate crisis. Achieving this requires reaching net-zero emissions, where the amount of CO_2 released into the atmosphere is balanced by its removal.

Net-zero is an interim target; the ultimate goal is net-negative emissions, which will necessitate the removal of historical carbon emissions to stabilize the climate and mitigate threats to civilization [524]. This transition demands a rapid shift from fossil fuels to renewable energy sources such as solar, wind, and hydropower. However, in "business as usual" scenarios, renewable energy growth is unlikely to match global energy demand quickly enough to prevent dangerous warming beyond 2°C, triggering critical tipping points [519].

To bridge this gap, complementary strategies are required, including energy efficiency improvements, electrification of industrial and transportation sectors, and investment in carbon capture and storage (CCS) technologies [21]. International cooperation and robust policy frameworks, such as carbon pricing and subsidies for renewables, will also play critical roles in expediting the transition away from fossil fuels [590].

11.2 Deforestation

Deforestation is a critical driver of climate change and biodiversity loss. Forests act as carbon sinks, absorbing significant amounts of CO_2 from the atmosphere, while providing essential ecosystem services such as water regulation and soil stabilization [477]. However, large-scale deforestation, driven by agriculture, logging, and urban expansion, contributes approximately 10-15% of global greenhouse gas emissions [33].

The loss of forests exacerbates climate change by releasing stored carbon, disrupting local weather patterns, and reducing the planet's ability to sequester future emissions [68]. Tropical rainforests, such as the Amazon, are particularly vital, as their degradation could push the global climate past critical tipping points [393]. Furthermore, deforestation threatens biodiversity, endangering countless species and destabilizing ecosystems.

Addressing deforestation requires immediate action like reforestation and afforestation: restoring degraded lands and planting new forests can enhance carbon sequestration and ecosystem resilience [45].Additionally, encouraging sustainable agriculture and logging practices, coupled with reducing demand for forest-derived products, can mitigate deforestation [220]. Essential is also policy and enforcement: strengthening laws that prevent illegal deforestation and stimulate forest conservation are vital [22]. Forest preservation is not only a cornerstone of climate mitigation but also essential for maintaining biodiversity and ecosystem stability.

11.3 Livestock

Methane is mostly emitted by the forgotten industry which must also be limited: the livestock industry. A lot can be achieved here very quickly: for an American to skip meat twice a week would have the same effect as if that American decided to never use a car again.

Methane emissions are estimated to have caused 30% of all global warming [289]. This is to be understood as a largely man-made problem created by the livestock industry. Maintaining this stock of life for man to exploit is utterly unsustainable ecologically. I will not go into the ethical discussion on animal suffering as plenty has been said: it is evil [564, 505, 139, 453, 197, 185, 351, 488, 135, 457]. Beyond unethical and a direct cause of global warming, ranching and the demand for cattle feed are a major driver of deforestation [446]. The amount of land needed to farm for meat is vast, because producing meat is an inefficient process: the calories of plant we feed animals are not converted into calories of animal product with an average loss of 93% [557]. Half of the world's agricultural land is used for livestock, either directly for grazing or indirectly for feed [513]. As the need for biofuels increase, and while we will always need forests, the problem of Earth's limited amount of habitable land becomes apparent—a problem that grows as populations rise and food-security diminishes. Eating less meat would solve many problems. In all societies of history but the one we live in now it would be frowned upon as decadency to eat meat everyday and it seems logical and necessary that we return to that normal.

11.4 Organic Waste

Organic waste, including food scraps, yard trimmings, and agricultural residues, represents a significant contributor to greenhouse gas emissions when improperly managed. Decomposing organic matter in landfills produces methane, a greenhouse gas with a warming potential much greater than carbon dioxide [629]. Globally, organic waste accounts for approximately 6-8% of total anthropogenic methane emissions [426].

Addressing organic waste offers a dual benefit: reducing emissions and recovering valuable resources. Transforming organic waste into compost reduces methane emissions and provides a nutrient-rich soil amendment that enhances soil health and carbon sequestration [82]. This process captures methane from organic waste and converts it into biogas, a renewable energy source, while producing digestate for use as fertilizer [270]. Preventing food waste through improved supply chains, better storage, and consumer awareness can significantly decrease the volume of organic waste generated [493]. Effective management of organic waste not only mitigates climate change but also supports sustainable agriculture and renewable energy production. Scaling these practices globally is essential for a more sustainable waste system.

11.5 Eutrophication by Phosphates and Nitrates

Eutrophication is a process where excessive nutrients, particularly phosphates and nitrates from agricultural run-off, wastewater, and industrial discharges, enter water bodies, causing overgrowth of algae [102]. This algal bloom depletes oxygen levels as the algae decay, creating hypoxic or anoxic zones, also known as ”dead zones,” that are inhospitable to most aquatic life [140].

The impacts of eutrophication are far-reaching. Fish and other aquatic organisms face habitat loss, water quality deteriorates, and ecosystems lose their balance, which affects biodiversity and fisheries [577]. Additionally, algal blooms can produce toxins harmful to humans and animals, contaminating drinking water supplies and increasing health risks [475].

There are several key actions in preventing eutrophication, such as reducing the use of fertilizers and adopting precision agriculture practices to minimize nutrient run-off [613], improving wastewater treatment to effectively remove nutrients before discharge into water bodies [365] and restoring wetlands which act as natural filters, trapping and recycling nutrients before they reach larger water systems [675]. Tackling eutrophication requires a combination of technological, agricultural, and ecological approaches to restore the health and productivity of affected ecosystems.

11.6 Plastic & Forever Chemicals

Plastic pollution and persistent chemicals, often referred to as ”forever chemicals,” pose severe environmental and health risks. Plastics are primarily derived from fossil fuels, contributing to greenhouse gas emissions during production, usage, and degradation [680]. Once discarded, plastics break into microplastics, which infiltrate ecosystems and enter the food chain, threatening marine life and human health [207].

Forever chemicals, such as per- and polyfluoroalkyl substances (PFAS), resist degradation in the environment and accumulate in living organisms. These chemicals are linked to adverse health outcomes, including cancers, hormonal disruptions, and immune system impairments [231]. Their widespread use in industrial processes and consumer goods makes them pervasive contaminants in water, soil, and air.

To prevent complete toxication of the Earth, mother of life, we need a transition to biodegradable materials and promotion of circular economy models to minimize plastic waste [518]. Beyond is need for regulating forever chemicals: need for strengthening legislation to limit PFAS production and mandating safer alternatives [125]. Investing in advanced filtration systems and chemical remediation techniques can help to remove plastics and PFAS from the environment [604, 356]. Mitigating the impact of plastics and forever chemicals is essential for safeguarding ecosystems, public health, and global sustainability.

11.7 Air Pollution

Air pollution is a major environmental and public health issue, caused by the release of harmful substances such as particulate matter (PM), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and volatile organic compounds (VOCs) into the atmosphere [663]. Sources include industrial activities, vehicle emissions, burning of fossil fuels, and agricultural practices.

The consequences of air pollution are profound. Fine particulate matter ($PM_{2.5}$) and ground-level ozone contribute to respiratory and cardiovascular diseases, leading to millions of premature deaths annually [376]. In addition, air pollution accelerates climate change through emissions of short-lived climate pollutants such as black carbon and methane [558]. Ecosystems also suffer, as pollutants can acidify soils, disrupt nutrient cycles, and harm wildlife [196]. Designing cities with better public transportation, green spaces, and reduced urban sprawl can improve air quality [410]. Deploying air filtration systems, real-time air quality monitoring, and pollution control technologies in industries can mitigate emissions [37]. Combating air pollution not only protects public health and ecosystems but also contributes to climate change mitigation and global sustainability.

11.8 Water Pollution

Water pollution is a critical global challenge, resulting from the contamination of water bodies by harmful substances such as industrial waste, agricultural runoff, and untreated sewage [665]. Key pollutants include heavy metals, pesticides, plastics, and pathogens, which disrupt aquatic ecosystems and pose significant health risks to humans and wildlife [546].

The consequences of water pollution are far-reaching. Contaminated water sources contribute to the spread of diseases like cholera and typhoid, particularly in regions lacking access to clean water [494]. Pollutants such as excess nutrients from fertilizers cause eutrophication, leading to harmful algal blooms and dead zones [140]. Additionally, chemical contaminants, including persistent organic pollutants (POPs), bioaccumulate in aquatic organisms, threatening biodiversity and food safety [598]. Advanced treatment technologies can reduce pollutants before they enter water bodies [606]. Precision farming, reduced fertilizer use, and buffer strips help minimize nutrient runoff [613]. Policies to limit plastic pollution and manage industrial chemicals are crucial for maintaining water quality [206]. Combating water pollution is vital for protecting public health, sustaining ecosystems, and ensuring the availability of clean water for future generations.

11.9 Trash

The global generation of trash, or solid waste, poses a significant environmental challenge. An estimated 2.01 billion tonnes of municipal solid waste (MSW) are generated annually, with a large portion inadequately managed, leading to pollution of land, waterways, and oceans [331]. Improperly disposed trash contributes to greenhouse gas emissions, soil contamination, and harm to wildlife.

Plastic waste is particularly problematic, persisting in the environment for centuries and breaking into microplastics that infiltrate ecosystems [518]. Additionally, electronic waste (e-waste), which contains toxic heavy metals like lead and mercury, poses risks to human health and the environment if not properly recycled [191].

Addressing the trash crisis requires a combination of strategies:

- **Waste Reduction:** Reducing waste at the source, through measures such as banning single-use plastics and promoting reusable products, is critical [219].

- **Circular Economy:** Emphasizing reuse, recycling, and resource recovery can minimize landfill waste and reduce the demand for virgin materials [193].

- **Improved Waste Management:** Investing in advanced waste collection, sorting, and treatment technologies can mitigate environmental harm [492].

A systemic shift towards sustainable waste practices is essential to address the growing trash problem and mitigate its impacts on ecosystems and human health.

Chapter 12

Mitigating Damage

As of now the temperature on Earth has risen and is rising which means that more energy is accumulating in the system. The rate of either energy loss or energy accumulation is determined largely by the constituents of the atmosphere. The amount of greenhouse gases present play a major role and this amount is rising. Sadly, even the amount by which this amount is rising, is rising. So each year Earth gets more hotter faster. It seems a matter of fact that we will face the new problems caused by substantial climate change. Climate change mitigation is a term that was invented for all work that is done to reduce how harmful global warming will be. (Further reading: climate.mit.edu)

12.1 Recyclables

Recycling reduces waste, conserves resources, and minimizes the energy required to produce new materials. Proper management of recyclables such as plastics, metals, and paper can significantly cut down greenhouse gas emissions associated with production and waste management [219]. Expanding infrastructure for recycling and promoting consumer awareness are crucial to achieving a circular economy.

Innovative recycling technologies, such as chemical recycling for plastics, offer promising solutions for hard-to-recycle materials [271]. However, current recycling rates remain low for many materials due to economic and logistical barriers. Moreover, recycling alone is insufficient; it must be paired with efforts to reduce material consumption through strategies like product redesign, reuse, and sustainable manufacturing [193].

Transitioning to a more sustainable waste management system requires a combination of technological innovation, public engagement, and supportive policies. By integrating recycling with broader waste reduction strategies, societies can mitigate environmental damage while conserving finite resources.

12.2 Replacing Fossil Fuel

The industrialization of society has locked humanity into a fossil-fuel-based system, where participation is often necessary for survival. However, to mitigate the climate crisis, energy systems must transition to sustainable sources. Fossil fuel consumption must be replaced with low-carbon alternatives, and the approximately 400 exajoules (EJ) of global energy demand must increasingly be met through green energy sources [294].

Scaling down global energy consumption through more efficient technologies and reduced economic activity could lessen the burden of transition. However, without ambitious and immediate action, renewable energy growth may not keep pace with rising energy demands, increasing the risk of surpassing critical climate thresholds, such as a 2°C rise in global temperatures [300].

The distinction between green and renewable energy is significant. Renewable energy excludes technologies like nuclear power, which is often contentious. However, given the urgency of reducing emissions, nuclear energy remains a viable and necessary component of the energy mix due to its low-carbon footprint and reliability [201].

Comprehensive strategies for replacing fossil fuels include:

- **Expanding Renewable Energy:** Rapid investment in solar, wind, and hydropower to meet a significant portion of energy demand [295].
- **Enhancing Energy Efficiency:** Adoption of efficient appliances, buildings, and transportation systems to reduce overall consumption [473].
- **Integrating Nuclear Power:** Utilizing advanced nuclear technologies to provide consistent, low-carbon energy as a complement to variable renewables [317].

The energy transition is not only necessary but inevitable. It must be accelerated through innovation, policy reform, and global cooperation to achieve sustainable energy systems and a stable climate.

12.3 Reversing Climate Conditions

Reversing climate change goes beyond merely reducing emissions; it requires actively removing greenhouse gases from the atmosphere. Carbon dioxide removal (CDR) technologies play a critical role in this effort. These include:

- **Direct Air Capture (DAC):** Capturing CO_2 directly from the atmosphere and storing it underground or using it in industrial applications [204].
- **Bioenergy with Carbon Capture and Storage (BECCS):** Utilizing biomass for energy while capturing and sequestering the resulting emissions [575].
- **Enhanced Weathering:** Accelerating natural geological processes to bind atmospheric CO_2 in stable mineral forms [49].

Natural climate solutions complement technological approaches. Afforestation and reforestation increase the planet's carbon absorption capacity, while soil carbon sequestration enhances agricultural sustainability and removes atmospheric CO_2 [236].

Achieving net-negative emissions is essential for stabilizing global temperatures and avoiding the worst impacts of climate change. However, these strategies must be implemented responsibly to avoid unintended consequences, such as competition for land use or adverse ecological impacts. Scaling these solutions requires significant investment, robust international policies, and societal acceptance to ensure they contribute to long-term climate stability.

12.4 Remediating the Environment

Environmental remediation seeks to restore ecosystems degraded by human activities, improving ecological health and sustainability. Contaminated land, polluted water bodies, and degraded air quality require targeted interventions. Key remediation techniques include:

- **Bioremediation:** Using microorganisms to break down pollutants in soil and water, effectively detoxifying contaminated environments [640].
- **Phytoremediation:** Employing plants to absorb, stabilize, or transform contaminants in soil and water [533].
- **Chemical and Physical Methods:** Techniques such as adsorption, advanced oxidation processes, and nanotechnology for removing heavy metals, plastics, and oil spills [523].

Cleaning up industrial waste, plastic pollution, and oil spills is critical for safeguarding biodiversity and human health. Remediation efforts must also prioritize environmental justice, ensuring that vulnerable communities disproportionately affected by pollution are directly supported [430]. Additionally, long-term monitoring and adaptive management are necessary to maintain ecosystem recovery.

Scaling remediation technologies and integrating them with broader conservation efforts will be essential to mitigate the impacts of historical and ongoing environmental harm while ensuring equity in their implementation.

12.5 Rewilding

Rewilding is the process of returning land to its natural state, allowing ecosystems to regenerate without significant human interference. This approach promotes biodiversity, enhances carbon sequestration, and improves ecosystem resilience to climate change [600]. By restoring natural processes and species interactions, rewilding can help rebuild ecological networks and reverse the effects of habitat degradation.

Key strategies in rewilding include:

- **Reintroducing Native Species:** Restoring populations of keystone species, such as wolves or large herbivores, can reinvigorate ecosystem dynamics and trophic cascades [510].

- **Establishing Ecological Corridors:** Connecting fragmented habitats allows for species migration and genetic diversity, crucial for adapting to changing environments [265].

- **Removing Invasive Species:** Controlling or eradicating non-native species that disrupt native ecosystems can prevent further ecological imbalance [563].

Successful rewilding requires a balance between ecological priorities and human land use. Community engagement and local stewardship are essential to ensure long-term sustainability and social acceptance [392]. While rewilding presents challenges, it offers a transformative pathway for restoring ecological health and mitigating the impacts of climate change.

Chapter 13

Adapting for Survival

If one thing should have become clear by now it is this: prevention and mitigation have largely failed. A lot needs to happen for the temperature to stop rising and for the planet to eventually cool again. Until then we best prepare for the worst. Because all of Earth is one interrelated system, when CO_2 levels rise this has a wider range of effects than just increasing temperatures. Several troubling matters have been predicted or are already taking place, and these problems will be discussed in the ensuing sections.

Be advised: this chapter is dark, very dark. The disasters that the carbon crisis will bring will put billions of lives at risk, and perhaps end society or human life. Yet even if every prediction here comes true not all is lost: as long as there is man there is hope it puts its house in order. Although wise men may decide the situation too dire and prefer a way out, I will not go gentle into that good night. God willing, there will be a sun and a cool breeze in the morning.

13.1 Drought & Hunger

As climate change intensifies, the prospect of widespread droughts and hunger becomes alarmingly plausible. Rising temperatures disrupt precipitation patterns, exacerbating water scarcity and rendering vast regions unfit for agriculture [300]. Crops fail under prolonged heatwaves and erratic rainfall, leading to food insecurity for millions [188]. This phenomenon, already observable in regions such as the Sahel and parts of South Asia, poses existential threats to global food systems. The impact extends beyond agriculture. Diminished water resources exacerbate competition among nations, heightening geopolitical tensions [224]. Scarcity-induced migration is likely to overwhelm urban centres and destabilize economies [336]. Without coordinated global efforts to address water management and develop resilient agricultural systems, the consequences may be catastrophic [519].

Long-term survival demands comprehensive strategies. These include investing in drought-resistant crops, improving irrigation technologies, and implementing policies for equitable water distribution [169]. Emergency preparedness should prioritize food stockpiles and equitable access over exclusive plans that benefit only the elite, as global resilience requires inclusivity [290]. Avoiding societal collapse depends on proactive measures addressing the intertwined crises of water and food scarcity.

13.2 Wildfires

Wildfires are becoming an increasingly frequent and severe consequence of climate change, with devastating ecological, economic, and social impacts. Rising global temperatures, prolonged droughts, and changes in vegetation patterns create ideal conditions for fires to ignite and spread [182]. Combined with human activities such as land clearing and poorly managed urban-wildland interfaces, the risk of catastrophic fires continues to escalate [74]. The effects of wildfires are far-reaching. In addition to the immediate destruction of forests, infrastructure, and homes, wildfires contribute significantly to greenhouse gas emissions, creating a feedback loop that exacerbates climate change [633]. Moreover, the loss of vegetation reduces the land's capacity to absorb CO_2, further intensifying the problem. Health impacts from smoke exposure, including respiratory and cardiovascular issues, add to the human toll [506].

Adapting to the increasing threat of wildfires requires a multifaceted approach. Practices such as controlled burns, forest thinning, and creating firebreaks can reduce fuel loads and lower the intensity of wildfires [6]. Establishing fire-resistant building codes, creating defensible spaces, and implementing early warning systems can help protect communities located in fire-prone areas [601]. Post-fire recovery strategies, such as reforestation and soil stabilization, are essential to prevent erosion, restore biodiversity, and reduce the risk of subsequent fires [333]. Advances in satellite monitoring, predictive modelling, and artificial intelligence offer new tools for fire detection and response, enabling quicker and more effective action [314]. Building resilience to wildfires is not only an ecological imperative but also a necessity for protecting human lives and livelihoods.

13.3 Floods & Hurricanes

Floods and hurricanes are among the most devastating natural disasters exacerbated by climate change. Rising global temperatures increase the atmosphere's capacity to hold moisture, leading to heavier rainfall and higher flood risks [619]. Simultaneously, rising sea levels amplify storm surges, causing catastrophic coastal flooding during hurricanes and cyclones [349]. Meanwhile, storms are becoming more intense and longer-lasting, driven by warmer ocean waters that provide the energy necessary for their formation [159]. The frequency of category 4 and 5 storms has notably increased, along with their capacity to deliver record-breaking precipitation [352].

There are many adaptation strategies that prepare for these disasters, such as strengthening levees, dams, and stormwater systems to withstand extreme weather events [449]. Natural solutions exist as well; restoring wetlands, mangroves, and coral reefs can create a buffer against storm surges and flooding [441]. Fast responses can be achieved by deploying advanced forecasting and communication networks to facilitate timely evacuations [247]. Water-aware urban planning can prevent some of the worst disasters for humans by relocating vulnerable communities and adopting flood-resilient building codes. Timely action is essential to reducing the catastrophic effects of floods and hurricanes on vulnerable populations and ecosystems.

13.4 Sea Level Rise

The melting of polar ice and thermal expansion of seawater due to rising temperatures are leading to a steady increase in sea levels [468]. This phenomenon threatens low-lying coastal areas worldwide, where billions of people reside. Additionally, more frequent and extreme storms exacerbate the risks, causing flooding and storm surges to penetrate further inland [266]. Significant portions of coastal cities and infrastructure are at risk of inundation. Regions such as South Asia, the Pacific Islands, and parts of the United States, including Florida, face particularly dire consequences [448]. However, engineering solutions to manage sea level rise have been developed and successfully implemented in countries like the Netherlands, where advanced dike systems and storm surge barriers protect against flooding [118].

Despite proven technologies, adapting to rising seas requires substantial investments and political will. Where dykes, dams and natural defences fail, a managed retreat may be necessary [132]. Coastal resilience will hinge on the combination of engineering ingenuity and coordinated global action.

13.5 Climate Migration

As climate change renders regions increasingly uninhabitable, migration is poised to become one of the most significant humanitarian challenges of the 21st century. Droughts, floods, and rising sea levels will force millions to abandon their homes, transforming them into climate refugees [436]. Prolonged environmental degradation disrupts local economies and societal stability, compelling entire communities to relocate [285]. While the specific patterns of migration are contingent on localized impacts, climate models have already identified vulnerable regions. Areas such as low-lying coastal zones, arid landscapes, and flood-prone deltas are at heightened risk [64]. Proactive negotiation and planning are paramount. Without adequate international frameworks, host nations may struggle to accommodate the influx of displaced populations, potentially exacerbating conflict and xenophobia [55].

A just response necessitates early agreements on the legal recognition, rights, and resettlement of climate refugees [416]. Host countries must be supported in infrastructure development to integrate new arrivals, fostering cooperation rather than hostility. Climate-induced migration is a predictable outcome of environmental change, and addressing it with foresight ensures resilience and dignity for those affected.

13.6 Health Impacts

Climate change poses significant risks to public health, many of which are already observable. Rising temperatures are expected to increase the frequency and severity of heatwaves, leading to more cases of heat-related illnesses, including heatstroke and dehydration [648]. Vulnerable populations, such as the elderly and those with pre-existing health conditions, are particularly at risk [246]. Additionally, climate change is likely to expand the geographic range of vector-borne diseases, such as malaria and dengue fever, as warmer climates enable vectors like mosquitoes to thrive in regions previously unsuitable for their survival [480]. The mental health impacts of climate change are also profound: chronic stress and anxiety caused by climate-related disasters, as well as the broader psychological toll of witnessing environmental degradation, are expected to rise [116].

Adapting to these health challenges will require strengthening healthcare systems, developing early warning systems for heatwaves, and implementing community-based interventions to address mental health needs [151]. Although the impacts of soaring heat and disease spread may not be entirely avoidable, proactive measures can mitigate their severity and protect vulnerable populations.

13.7 Urban Heat Islands

Urban areas tend to experience higher temperatures compared to their surrounding rural regions, a phenomenon known as the Urban Heat Island (UHI) effect [465]. This effect arises from the concentration of heat-absorbing materials, such as asphalt and concrete, coupled with reduced vegetation and limited airflow due to dense building arrangements [642]. UHIs exacerbate the impacts of heatwaves, posing significant risks to public health, particularly for vulnerable populations such as the elderly and those with pre-existing health conditions [80].

To mitigate the UHI effect, cities must adopt strategies that enhance urban greenery. Increasing the presence of trees, green roofs, and parks not only cools the environment through shade and evapotranspiration but also improves air quality and biodiversity [73]. Moreover, using light-colored and reflective materials in urban design can reduce the amount of heat absorbed by buildings and pavements, contributing to cooler surroundings [8]. Urban planning initiatives should integrate UHI mitigation measures to enhance climate resilience. These interventions are particularly urgent in rapidly urbanizing regions, where the UHI effect is likely to intensify without proactive measures [515]. Designing cities with sustainability in mind ensures more livable environments and reduces the adverse impacts of rising global temperatures.

13.8 Acidification of the Oceans

Although carbon dioxide is a gas, it dissolves readily in water, forming carbonic acid. This reaction decreases the pH of seawater, a process known as ocean acidification [145]. The current levels of atmospheric CO2 have already led to a measurable decrease in ocean pH, severely impacting marine ecosystems. Coral reefs, often referred to as the "rainforests of the sea," are particularly vulnerable. Acidification inhibits the ability of corals to form calcium carbonate skeletons, leading to widespread reef degradation [268]. Similarly, certain plankton species, which form the foundation of marine food chains, may struggle to survive in increasingly acidic conditions, threatening ecosystem stability [166].

The broader implications of ocean acidification are profound. Fisheries that depend on healthy coral reefs and plankton populations face declining yields, jeopardizing food security for millions of people [76]. Furthermore, the cascading effects of disrupted food chains could lead to biodiversity loss and alter oceanic carbon cycling, amplifying climate change impacts [212].

The obvious steps include conserving vulnerable marine species and ecosystems before they are irreparably harmed. Restoring and protecting coral reefs is crucial, as they support a quarter of all marine life. Promising novel solutions, such as selective breeding of heat- and acidification-resistant coral species, have been proposed [70]. However, some of these approaches remain in developmental stages and must be carefully managed, particularly when they involve geoengineering, to avoid unintended consequences [212].

13.9 Ocean Current Disruption

The ocean currents play a critical role in regulating the Earth's climate by redistributing heat and maintaining the balance of regional temperatures [500]. However, the increasing energy in the Earth system, driven by anthropogenic climate change, threatens to destabilize these currents. Fluctuations in weather patterns are expected to intensify as disruptions to major currents, such as the Atlantic Meridional Overturning Circulation (AMOC), become more pronounced [92].

The collapse of ocean currents would have far-reaching consequences. For instance, a weakened or disrupted AMOC could result in significantly colder winters in Europe, intensified hurricanes along the Eastern United States, and severe droughts in parts of Africa [594]. Furthermore, disrupted currents can lead to ecological upheavals, with marine ecosystems struggling to adapt to changing temperatures and nutrient distributions [541]. This ecological redefinition will also affect terrestrial landscapes reliant on the stability of these currents.

Agriculture, in particular, faces severe risks. Shifting climate zones may render traditional crops unsustainable, necessitating adaptive strategies. Advanced climate modeling and predictive tools must guide the selection of resilient crops tailored to new conditions [108]. Proactive planning is essential to avoid widespread food shortages and ensure the survival of communities dependent on agriculture.

13.10 Biodiversity Loss

As a child, the loss of biodiversity was the problem that saddened me the most. The permanent disappearance of a species is an irreplaceable tragedy, marking the end of a unique evolutionary story. Beyond the emotional impact, biodiversity loss poses severe risks to the stability of ecosystems, which humanity depends upon for essential services such as pollination, water purification, and climate regulation [100].

Human activities, including deforestation, habitat fragmentation, pollution, and climate change, have driven extinction rates to levels comparable to previous mass extinction events [486]. The risk of ecosystem collapse increases as species disappear, disrupting the intricate networks of interactions that sustain life. For instance, the loss of pollinators like bees could severely impair agricultural productivity and plant reproduction [491].

A viable solution lies in returning land to nature. Establishing protected areas where ecosystems can recover without human interference is crucial. These reserves should ideally be connected through ecological corridors, allowing species to migrate and maintain genetic diversity [243]. Restoration efforts, including rewilding and assisted migration, can further enhance ecosystem resilience and mitigate the impacts of biodiversity loss [600].

While humanity has conquered nature in many respects, this domination comes with profound responsibilities. Proactive conservation strategies and global cooperation are essential to halt and reverse biodiversity decline. By preserving the natural world, we ensure the continuation of Earth's life-support systems and the legacy of the countless species that share our planet.

13.11 Permafrost Thawing

Permafrost thawing represents one of the most alarming feedback mechanisms associated with climate change. As global temperatures rise, permafrost—soil that has remained frozen for thousands of years—begins to melt, releasing significant quantities of greenhouse gases, including carbon dioxide and methane, into the atmosphere [545]. Methane, in particular, is a potent greenhouse gas with a warming potential approximately 28 times greater than carbon dioxide over a 100-year period [467].

The scale of this threat is daunting. Permafrost regions store an estimated 1,500 gigatons of organic carbon, nearly double the amount currently present in the atmosphere [274]. As permafrost thaws, microbial decomposition of this organic matter accelerates, amplifying global warming in a dangerous feedback loop [621]. The extent and rate of carbon release, however, remain uncertain, necessitating further research and refined climate models to predict these outcomes accurately.

Understanding the impact of permafrost carbon emissions is crucial for integrating them into global carbon budgets and emission reduction strategies. Future carbon removal technologies will need to address this additional source of greenhouse gases. Mitigation efforts must focus on limiting global warming to prevent the large-scale thawing of permafrost. Without decisive action, this process could significantly undermine global climate goals, intensifying the already severe consequences of climate change.

13.12 Oceanic Dead Zones

Oceanic dead zones, or hypoxic regions where oxygen concentrations drop below levels necessary to sustain most marine life, are expanding at an alarming rate [140]. These zones form when excessive nutrient runoff from agricultural fertilizers and sewage triggers algal blooms, which subsequently decompose and consume oxygen in the water [497]. Climate change exacerbates this process: warmer waters hold less dissolved oxygen, while increased stratification prevents oxygen-rich surface waters from mixing with deeper layers [79].

The proliferation of dead zones poses catastrophic risks to marine ecosystems and global food security. As oxygen-depleted areas expand, they create uninhabitable conditions for fish, crustaceans, and other marine organisms, forcing mass die-offs or migrations that disrupt fisheries and coastal economies [636]. The Baltic Sea, Gulf of Mexico, and East China Sea already host some of the world's largest dead zones, with hundreds more documented globally [141].

The implications extend beyond immediate ecological damage. Historical evidence suggests that oceanic anoxia—widespread oxygen depletion—played a critical role in several of Earth's mass extinction events, most notably the Permian-Triassic extinction that eliminated over 90% of marine species [482]. Current trajectories of warming and nutrient pollution could trigger similar conditions if left unchecked, potentially initiating cascading failures across marine food webs [334]. The release of hydrogen sulfide from anoxic waters, as occurred during past extinction events, could even poison coastal atmospheres and render regions uninhabitable [359].

Addressing dead zones requires coordinated action on multiple fronts. Reducing agricultural runoff through improved fertilizer management and buffer zones can limit nutrient inputs [120]. Restoring wetlands and implementing sustainable farming practices offer nature-based solutions that filter pollutants before they reach waterways [429]. On a broader scale, aggressive emission reductions remain essential to prevent the warming and stratification that amplify hypoxia. The stakes are existential: failure to act risks transforming our oceans into lifeless zones reminiscent of Earth's darkest chapters, and when the ocean rots and all its carbons enter the air—this would be where I believe it to be game over and will be checking out.

Part III

Book of Earth Political Solutions

Chapter 14

The Revolution

God is love: pious are those who spread it, those who care—do not let Satan freeze your heart. Earth is our vessel and we are its stewards, it is a ship with no one at the helm and it is heading straight for the cliffs. I cannot save the world, you cannot save the world, no single person can save the world, however, mankind might do it. The apocalypse will have been the creation of man and therefore it would appear that we can also choose to not create it. When I speak of revolution I mean the change in thought, speech and action that will put our vessel on a course where we may continue living.

The revolution will begin as a thought: interconnectedness. If a sufficient amount of people become infected by this way of seeing things; if enough people start to believe that every action matters as it is one that brings us either closer or further from apocalypse, then new social dynamics will arise which will be a tipping point. Only a fraction need be convinced for societal reformation to begin manifesting and when environmentalism has become mainstream it will become impossible for politics to ignore. After the revolution has transformed man into an ecologically conscious being, both in the singular and in the plural, then naturally this new society will push towards a different physical world which is no longer on a course to becoming uninhabitable. Such is the revolution that will prevent the end of the world.

If the revolution takes too long we all die. Luckily we live in the digital era, where ideas and sentiments can spread quicker than ever before in history. There are enemies of the revolution: the delusional, the dissociated and those who stand to lose their power. The enemy, who sadly appears to be ever more present as we ascend into the upper echelons of wealth and influence, must be dealt with. It is really quite plain and simple: this is the fight for survival. I mean each of those words as literal as can be.

Chapter 15

Citizens and Public Discourse

As 80% of people is convinced that action must be taken to prevent, mitigate and adapt to climate change [183], it is rather surprising that not more has been accomplished. It seems climate change has been silenced and neutered when it comes to political debate, there is no discussion and the subject is shunned. I wonder why. Why can't we discus in private what we are doing to limit our carbon footprints? Why can't we get outraged over the villains that are risking the future of humanity for oil? Why is it not fashionable to make ecological statements? Another question: if 80% of people want this change, why are the politicians not outbidding another in their most radical solutions to climate change?

The answer to all these questions is similar and equally vague: because the topic does not live in the minds and does not resonate in the hearts of the populous. In the next sections I will attempt to dissect why that is, what can be done, and what is the role of the citizens of this world.

> *A world of dew,*
> *And within every dewdrop*
> *A world of struggle.* [309]

15.1 Spread Truth

Innate to the zeitgeist is the idea that because all is subjective, that everybody their views and ways of life are valid. Added to this there is a certain sensitivity that does not allow us to violate another, even when that violation would not entail more than a clash of opinions for the delusional and a wake-up call for the disassociated. If we want sufficient change to happen, it must start everywhere, all at once, continuously, at the same time and it will start with statements that break the taboo. Be the doomer. If you feel you can do nothing, then you can still protest.

Breaking the taboo is as simple as speaking up and starting the discourse, for example by sharing that you are scared for the future and that there are things you do not want to happen. Do not spare the children the truth as their sharp minds are close to mankind's last hope. If you can do nothing you can still remain true, the core of saving the world will be the establishment of values and norms based in truth. Society controls its citizens and through new values and norms can man stop himself from killing himself. Shame on polluters!

How in the name of all that lives and will live on Earth this creation of the Lord is it possible? We have normalised being the problem. We have normalised the destruction. The delusional and the dissociated should not be feeling comfortable. This is not okay. We will die. Why are you not vegan? Do you own a bicycle? How come you have failed to act on climate change? How do you envision a liveable, breathable future? Have you decided we will just die, or are you delusional or just plain evil? What is it about apocalypse that you do not understand? Such question should be asked. We can collectively do better. We do not, in fact, have to spend our lives trying to be maximally unoffensive and this is deeper than bullying. This is rewriting the human conscious and morality.

15.2 The Revolution Will Not Be Centralised

If a new normal is be established, where will it begin? As all climate action it should begin everywhere all at once immediately. The beginning is destruction of the old. Do not be normal. Do not be normal, anything is better than the sick ways of the average person. Dare to disagree, find what you value; what are your values and thus what you think should be normal, and then act. Do not be normal. The revolution begins where people stop being normal, because this is the act that sets a new norm.

15.3 The News is Not for the Weak

Does everybody need to watch the news? Probably not for it is quite unbearable and saddening to the point that this supernatural awareness of suffering will interfere with healthy functioning. But now, should everybody be aware of the complete reality of the situation? Wholeheartedly: yes. Even if the truth will not set them free, but rather drown them in anguish, even then they must be exposed to it.

While it is certainly unnecessary that everyone watch the news until they get depressed, it is necessary that there is enough consciousness of the problem, in general, so that the feelings of shame, guilt and angst (which are to some extent a part of every society) can manifest and have their function in guiding behaviour. I am wholeheartedly in favour of manipulating people into right action.

15.4 Sink All Superyachts

It is not a good look on me to be writing about physical confrontation, for I am a coward who will not do it. The bravest thing I will have done in this lifetime is not kill myself.

However, the peaceful activism of the past 50 years has largely failed, which leads to the conclusion that now is the time for different strategies. A protest that does not disturb the peace is a parade. Regimes do not abdicate until they are forced to do so; the oil will flow until either it becomes economically unfeasible or until the pipelines are blown. My main point of critique towards Extinction Rebellion is that none of their actions have hindered the fossil fuel industry; it has just been the public that has been shocked and annoyed. It does not take courage to destroy or pretend to destroy an artwork, only a lack of shame. It has not worked because the workers of apocalypse have had nothing to fear and the populous has only been angered. (Further reading: Andreas Malm - How to Blow Up a Pipeline)

Terrorism works—provided it stays below a certain threshold and does not become cruel barbarity [229]. This point requires emphasis: if the violence can be described as ‘brute’, ‘extreme’, ‘radical’, et cetera, then it will fail to convey any message other than that ecological activists are lunatics and their goals are lunacy. If it took the destruction of the Pyramids for man to live into the next century it would certainly be worth it but, alas, this would only entrench the delusional further into their beliefs that the other side is crazy. Terrorism often fails to achieve its goals, but guerilla-warfare that targets its enemy and not the innocent is much more effective [2]. The sabotage of private jets by paint over windows must have prevented more emissions than most emit in their lifetime. It is rather surprising that acts of actual eco-terrorism—beyond peaceful protests and petty vandalism—have been so rare. Sink all superyachts.

Paradoxically, or with nuance: violence will have a (minor) place in the revolution but the greatest steps towards a solution will be achieved through peaceful protest. During civil war, nonviolent campaigns can pressure governments into seeking negotiations and can foster democratization [1]. (Further reading: M.K. Gandhi - Non-Violent Resistance)

It is important to realise: the revolution is not an all out war against all of technology, or all of humanity even, or a war on the government or institutions in general—it is very specifically a war against the current energy regime; fossil fuel and its beneficiaries, and the monolith corporations which propagate globalist commerce and drive consumerism. All out war is to be avoided because wartime is rarely time of quick industrial development, and there is plenty to develop. Where a regime change is decided necessary this is generally in a neoliberal capitalist state that has the many ruled by the few: no battles in the revolution, only assassinations. These days it would seem all it takes to kill a man is a skilled hacker, a drone and an explosive.

Chapter 16

Journalism and Accountability

There has hardly ever been a worse time to become a journalist. From social media one would get the impression that nobody is reading newspapers, and that if someone does they certainly do not believe what they read. Indeed, the journalist has fallen from grace. However, they are of pivotal importance for the fate of planet Earth. I will now write about the two large problems that the journalist must solve:

16.1 Misinformation

Misinformation manifests in two ways: firstly there are those who have dug themselves in too deep and it is more likely that they should die than that they will ever change their belief. It has been said that science only advances so slowly because the old generations literally have to die for they will never accept the ideas of the new generation. One should not attempt to reason with such cases, for they are lost, but in the case such discussions arise it is best to first check that they are delusional by asking if they themselves can think of something that would convince them, which there never is. Throughout the rest of the discussion it is best to attempt to convince the spectator, not the interlocutor.

The second shape of misinformation is found in being partially wrong: ‘yes, climate change is real but it will only be a problem by 2050’, and is caused by ignorance: ‘I cycle to work everyday and eat one kilo of meat to recover from cycling. Don’t worry meat is natural so that is fine.’ Make no mistake, there will forever be actors in bad faith who spread partial truths and ignorance on purpose. The meat industry will go to great lengths to convince us all that eating meat is not that bad, while it most certainly is. The journalist has the important duty to verify what is being said by influential figures and scientists. There should be a lot on the line for both scientists and journalists to not be wrong: should a scientist or journalist have been found guilty of spreading misinformation, then, in an ideal world, they should be completely shunned from their profession and live the rest of their days as a pariah. Problematically, we live in a post-truth society, so such trails-by-media may not have the desired outcomes. Luckily, the post-truth problem is only a skill-issue that affects the stupid and intelligent journalists should be able to solve it by making trustworthy sources reputable.

16.2 The Nameless, Faceless Villains

Here is an idea: climate change is being caused by humans. Not "humans" the abstraction, no, actual living and breathing humans with names and faces. Let them be known! Climate justice would have meant that the already bankrupt West would go more bankrupt so it can pay for the damages caused by ecological disaster in the third world. This will never happen. Climate justice could also mean retribution for the villains who have caused it, even if this retribution was merely public disgrace. I believe that the impact of a list of the world's top polluters, with name and face on display in a publicly available magazine, cannot be underestimated. Bring back shame-culture, and bring it back rigorously.

Chapter 17

Rule

The ruler of Shu had his eyes on Wu and came as far as the Three Gorges.
In the year of his demise, too, he was in the Palace of Eternal Peace.
The blue-green banners can be imagined on the empty mountain,
The jade palace is a void in the deserted temple. -Du Fu

The world is in polycrisis and I would not like to be in the shoes of our leaders, for they are presented with impossible choices only. This chapter addresses the policy makers of the world, and assumes they are rational agents, or at the least that they have an ounce of sensibility. Wherever there are leaders that have taken a delusional or dissociated stance on climate change one may argue that resistance or even revolution is a civic duty, but violence is not advised: 5.5% of global emissions are currently caused by war. The instability caused by too large or radical social reform may also significantly delay progress on climate action; civil war is rarely a time of great industrial development.

Any leader that cares about the well-being of their people should take climate action. If these leaders are not insane they will be naturally inclined to do this, and because most people are not insane there is very large public support for climate action.[1]

This chapter shall be a discussion and speculation on why so little has been achieved politically for climate action given that 80% of people worldwide want more to be done [183]. I will go over solutions and the current problems in democracy that prevent these, and the problems that arise from international tensions.

[1] Further reading: peoplesclimate.vote

17.1 Failing Democracies

There is no correlation between democracy and the amount of climate action achieved: Bhutan, which is a monarchy, Afghanistan, which is a caliphate, and North-Korea, which is a dictatorship, have achieved sustainable electricity production percentages of 100%, 89.4% and 53.4% respectively in 2020 [296], which were all significantly above the global average of 28%. In 2023 the entire world could muster a mere half trillion dollars worth of investments in sustainable energy, which is a nauseating disgrace. Why is it that democracy is so inept at achieving change?

Firstly, that so little money was available world wide for investment in sustainable energy is a clear indication that most of the world's governments are corrupt. The clearest example would be the United States of America, where the public has virtually no choice as the only two people they can chose between largely have the same sponsors. It seems that half a century of greed as the highest ideal in society has been rather destructive in terms of the social and ecological, although admittedly a lot of capital has been created. Democracy is failing because it is corrupt, and this can only be fixed should the public elect honourable leaders, should the streams of money involved in campaigns become transparent and should there either again be media that serves the people or a return of media-literacy. If there are no good leaders around to vote for, seriously consider becoming such a leader. We direly need people that are sufficiently incorruptible.[2]

Secondly, in a democracy progress is often made taking one step back for every two taken forward. It is the political structure of compromise: if half of the people want A and half want B then in general a democracy will produce a result in the middle of A and B that all people will be equally dissatisfied with. This is generally good because it ensures the stability of a country and the satisfaction of its peoples, but it also means that the rate of change is slow. Ancient Rome in times of crisis suspended democracy in favour of dictatorship, and I fear a equally radical shift is necessary to achieve anything in modern times. We must be pragmatic.

Ideally, the politician and the people live in a symbiotic relationship, where the people pick the politician because he makes the right choices, and the politician makes the right choices because he serves the people. Sometimes in practice the relation is completely parasitic: the people pick the politician out of confusion or for lack of a better option and the politician feeds of the people while making choices in service of some lobby which funds the confusion that keeps the politician in office. More often the relation is merely somewhat parasitic: the people elect a politician who keeps them happy, and

[2] Further reading on European corruption: www.ftm.eu
Further reading on American corruption: www.opensecrets.org

the politician makes choices that serve the happiness of the people. This system is equally broken as it incentivizes the politician enabling the addictions and self-destruction of the people while the well-being of the people or the fate of the country are not considered. I strongly believe the concept of re-election fundamentally breaks democracies as it necessitates the serving of something different from the greater good.

What is true everywhere is that people have a general sense for the flaws of democracy and are disillusioned with their leaders: there is a huge vacuum in the political arena that is to be filled by authentic leaders. People that have the courage and ideals to say: ”This is what I will do. It will hurt a lot but it will be better.” The world will not be saved by people-pleasers and the people are done with their scammy politics.

17.2 The International Stalemate

Why is hardly any tax on greenhouse emissions? It is the single most obvious climate action that most of the world fails to take and here is why: the countries who go first will lose some industry to the countries that go last. It is of economic disadvantage to go first in implementing a climate tax. That is the entire reason and international cooperation would be the entire solution. I feel sad writing a section on this problem, as its existence raises questions by making it seem as if mankind has not got a single decent bone in its greedy body. Where is the desire for justice? Where is the willingness for sacrifice in service of a greater good? Are there only evil people at the top? Who will have the courage to lead the way towards a international tax on emissions?

17.3 The Need for Peace

War simply costs us too much in terms of emissions and if mankind is to reach the 22nd century treaties must be made to delay all great conflicts until at least after 2050. It seems highly unlikely that wars will be completely avoided for such a long period, but if the United States and Russia were able to have a conflict without war for 40 years then surely our world leaders can figure something out.

I am not particularly opposed to violence, but I have vowed that I will not serve in war for as long as I live because of the ecological reasons mentioned above: the complete oppression or even the eradication of my people would be preferable over the war that definitively destroys the liveable planet and eradicates mankind completely. Realistically though, such a war for survival is unlikely and it is far more likely that I will be asked to serve in a war for some economical gain to my country.

Chapter 18

Law

Law is that which is mandated by government in the benefit of the general public. We do not like getting robbed so we made it illegal. We do not like getting killed so we made it illegal. All but 8 countries in the world have signed the Paris Climate Convention agreement. We do not like societal collapse or even extinction because of climate change so we made it illegal. There is much potential in law for the reductions in emission to be achieved that are necessary for survival.

18.1 Suing the Great Polluters

In several countries such as the Netherlands and Switzerland, the people have been able to sue their governments because they failed to meet the Paris agreements. The social experiment of a legal conviction of the entity with the monopoly on punishment is still ongoing. If you fear that nothing much would happen this was not the case. Many good outcomes where achieved, as the governmental apparatus tends to listen well to laws. There is a very real possibility that we could, if we tried, delay the advent of apocalypse indefinitely by freezing all emission related processes through bureaucratic intervention.[1]

If the people can sue the state then no entity is too big to fight in a legal battle, companies and conglomerates included. That it is unexplored potential to sue all parties involved in the destruction is apparent. I call upon lawyers to sue companies, conglomerates, countries and larger organisations that are not meeting the targets of the Paris agreement. While it is true that money can buy a lot of control over legal battles, it is untrue that money alone decides what is justice. David may be victorious over Goliath. It is all possible.

[1] Further reading: climatecasechart.com

18.2 Enforcing Law

It is unlikely that companies and people will submit to new laws as diligently as the administrative branch of government would. Corruption is the main enemy here. After some instance of manifesting apocalypse has been established as illegal by judiciary verdict, even more lawsuits may be required to establish that law is indeed enforced. These may boil down all the way to lawsuits towards individuals, and can only be achieved in the presence of a weary public eye.

If laws can be enforced, this judiciary way of emission prevention would be most effective, and a very rapid reduction of emission may be achieved.

18.3 Declaring Climate Emergency

The goals set in Paris have not been reached. The world has heated +1.5K. Every country that has such clauses in its constitution can declare a state of emergency when the existence of the country is threatened. Democracy is a beautiful thing that is very just, but it is also slow and in this instance it may be too slow. When Rome was in crisis it elected a dictator to steer through the storm. We need to do the same if climate action everywhere, all at once is to be achieved.

18.4 The Carbon Tribunal

Many of the people that were active in the misinformation campaign that lead to the current existential threat for mankind are still alive and can be trailed. They have lied about the most important science since the dawn of man and we have still have the receipts. We know who was in charge at the time, we know who was chairman of the American Petroleum Institute when they chose to silence the Robinson report [517] and all later scientific evidence of the risks they were exposing mankind to. We know who was in charge all the way from those days until now. Yet if it is up to the politics, especially the politics of the United States, these tycoons will be free to walk to their bunkers as the world starts to burn. They should be executed, it is only just. I do not know at what court, but these have been crimes against all of mankind, and crime demands punishment.

Chapter 19

Economics

This world:
A fading
Mountain echo,
Void and
Unreal. -Ryokan

The international consumerist economy is the main reason for carbon emissions. We cannot keep shipping goods that could be produced locally across the globe because it is cheaper monetarily, for it is not cheaper in terms of carbon emissions. Similarly, we cannot continue the production of goods that break easily by design so there can be more sales. We must solve every destructive shortcut—pollution, non-recyclable products, planned obsolescence, etc.—that industry takes. We may be making money but the price is our lives. If this is to be achieved by the people or by law or by industry itself I do not know.

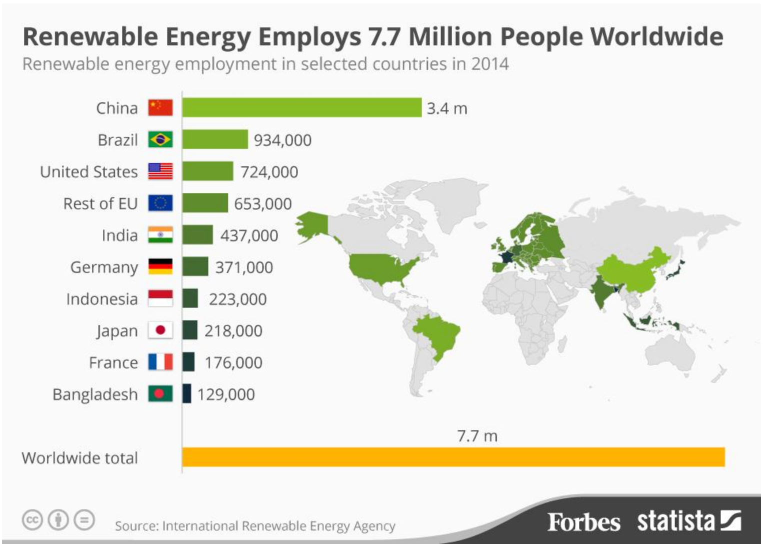
The machine must be broken if man is to live. Yes, the market is subject to the choice of the consumer. This means very little however if the mind of the consumer is by and large subject to the media, which are all owned. If the consumer can achieve freedom of choice, the system may be broken from the bottom up. If the employee can achieve the freedom to work on what is righteous, the system may be broken from the middle. If the owner can achieve freedom from greed and envy, the system may be broken from the top.

19.1 Conscious Consumption

Where there is no money the economy stops existing rather soon. Should we eat less meat and consume less fossil fuels? It might be wise. It may not be completely achievable overnight but any action or effort towards change and minimising has value. It may be rather disappointing to hear that in your choices of purchase you make the most of a contribution in your life. Not eating meat will stop the emissions and eating less will diminish it. The same can be said for consuming fossil fuels.[1]

19.2 Conscious Labour

The choice of career is the single most important decision determining what your impact on the world will be. Some companies built on unsustainable industries are not to last, unless they completely reinvent themselves. The people working in these sectors all posses the capability to find service and employment in the new sectors of and beyond the transition: there is job and entrepreneurial potential in this new energy market where sources like wind and sun cost nothing. Green energy economies will have to be built as soon as possible.[2]



19.3 Smash the Monolith

Ex-president of the United States of America Jimmy Carter recently said about his country: ”now it’s just an oligarchy with unlimited political bribery

[1]Further reading: footprintcalculator.org
[2]Further reading: 80000hours.org

being the essence for getting the nominations for president or elected president." Oligarchy means to be ruled by a few, and we all know they are the super wealthy that own everything. Companies are often (partially) owned by other companies of which the first are subsidiaries. These companies themselves are often again subsidiaries to other companies, ad nauseum, until at the top we find four corporations that amongst themselves compete for complete domination of the "free" market and the world. By means of capitalist ownership they have enslaved the World. They are what drives politics (they buy it), they are who decide over more than presidents and they have the most control over what happens on Earth, second only to the laws of physics. The monolith that has paralysed the world by the chains of the slave must crumble. Death to BlackRock, death to Vanguard Group, death to State Street Corporation, death to Berkshire Hathaway, death to monopoly for it does not generate climate action.[3]

19.4 Neoliberalism is a Death Cult

We in the West live in a neoliberal society whose culture has largely infected the whole world. Neoliberalism supposedly means freedom and so it would seem that these are the freest times in which man has ever lived, but this is just false. The market may be free, man is not. Behold: the free world, where companies get near unlimited power to exploit Earth and to rape nature—meanwhile man has been practically robbed even from the possibility of living without a car. Neoliberalist capitalism has achieved two things: the destruction of nature and the enrichment of the wealth owning class. Meanwhile modern man is less free than a medieval peasant.

The world is on a path towards capitalist feudalism where a decreasing amount of people own an increasing amount of the wealth. This needs no source: verify for yourself that, rare exceptions excluded, the only amongst the young who own a house do so because of their house owning parents. Indeed, the defining characteristic of the new nobility is home-ownership, but the distinction between the small nobility and the emperors of this world must be made. Fear the Rothschild family who was a part of this trend when the feudalism of old had not even ended yet—this family, which has since probably abandoned the name, has more power than entire countries. Fear the wealth owning class, who get richer of their assets faster than what labour can earn. Fear them, for all the control that this money can buy.

I believe that by and large the elites have brainwashed themselves into thinking that climate catastrophe is unavoidable. As mentioned before, the planet can in fact still be saved but it will require something unthinkable for

[3]Further reading: Simon Johnson - The Quiet Coup

the super rich: a tax on their wealth. They would rather we all die than abdicate.

19.5 Funding the Transition

To achieve a sustainable planet an absolutely massive amount of investment is required, in some cases without any perspective of profits in the future. To make matters worse we are about to experience a major recession as the dream that is modern monetary theory shatters. Meanwhile there still is enough money in the world to fund all technological solutions that mean we may live, of course there is! The money has not disappeared. It just belongs to the wrong people: those that would rather invest it in 100 billion dollar private bunkers. Although the wealth owning class will thwart this at every step of the way, they will pay for the energy transition and any other technological measure needed for survival. Here is how it can be done:

It should be possible to first sue the state into declaring climate emergency, to then, once the state has become an environmentalist crisis actor, have it confiscate whatever wealth it deems necessary to achieve the climate goals of Paris—as it is in fact legally obligated to meet these targets. When the question of how we will fund the transition arises then, because of lobbyist on behalf of the wealth owning class, politicians will suggest that actually the people must pay increased taxes and the media that are also owned by the elite will say the same. Yet it is just categorically stupid to demand this as that is simply not where the money is. The middle class will be drowning in debt and poverty caused by the coming recession, there will be nothing to take. Then we will tax the rich. The Rothschilds may flee, but what they own they cannot take with: the gold stored in banks will remain in those banks, the properties they own cannot leave and neither can their factories.

There is need for action everywhere, all at once, which can only happen if it is funded. Throughout the recession, it is necessary to invest every last penny and dime into green energy and other parts of the solution, which may possibly end up generating wide new fields of employment.

Part IV

Book of Metal Technological Solutions

Chapter 20

The Plan

God is light: pious are those who see—in this darkest hour more than ever, we cannot do without the light. By the grace of God and through the labour of genius much truth has been unveiled, much fact has been established, much enlightenment achieved, collectively known as science. To persist we will need all of its insights; to prevent apocalypse inventive, technological action is needed. Combating climate change is an effort that will span centuries: it is unlikely that the people alive today will ever see normal weather again. As of now (2024) the most urgent part of the solution is aggressive mitigation of the rising temperature and CO_2 concentration [40]. As we increasingly succeed in meeting energy demands with green sources instead of fossil fuels, this will lead to less cooling aerosols in the air while the greenhouse gases are still present. This could continue result in dangerous levels of heating, even when further emissions are prevented: some form of artificial cooling will likely be a necessary part of remaining at +1.5K without entering annihilation territory [400]. Through mitigating temperature rise can we safely get off oil and stop exacerbating our carbon problem. Mankind will have to continue cooling the planet through engineering for quite some time: only once we have captured enough carbon dioxide and methane to guarantee our safety can we stop cooling. The plan consists of cooling, removing greenhouse gases and stopping pollution.

> *O snail,*
> *Climb Mount Fuji,*
> *But slowly, slowly!* [310]

It will take 15 chapters to cover all the science and technology we will need, because we will need a lot: ways to cool the planet, ways to remove greenhouse gas from the air, ways to make nearly all energy consumption electric, ways to make electricity without emission, ways to meet the rest of energy demands greenly, et cetera. These plans and the revolution, that is all there is to how the world will not end. I will attempt to provide an introduction to all relevant fields, yet as I try to keep this book short this will be little more than mentioning the relevant terms you can look up should you want to research them. Each subject is big enough to warrant dedicating a lifetime to, so picking 1 or 2 and sticking with them is advised. Because the work is necessary, and because there is a lot of it to be done, and because few people can do it, you will find a job if you apply yourself to any of these fields and specialise in them. To any young people reading I have this message: be diligent, don't do drugs, stay in school, be the best young scientist you can be, and Godspeed.

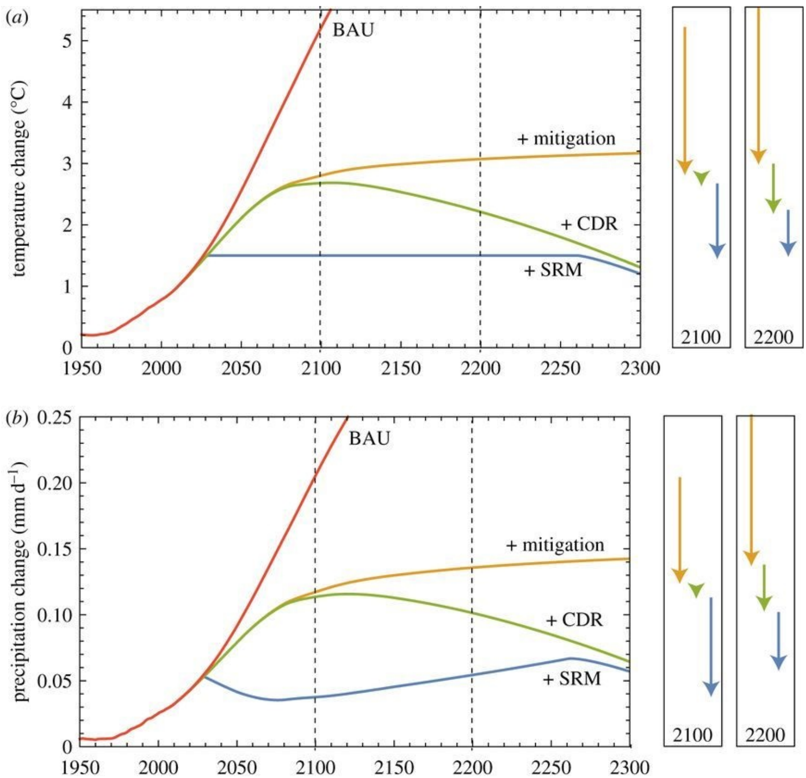


Figure 20.1: Four scenario's were simulated by scientists: (Red) Business as usual. (Yellow) Mitigation, which means we eventually stop fossil. (Green) Mitigation + carbon dioxide removal. (Blue) Mitigation + carbon dioxide removal + solar radiation management. Image source: MacMartin et al. 2018.

Chapter 21

Biodiversity Preservation

Earth's biodiversity faces a crisis of staggering scale, with extinction rates accelerating far beyond the natural background [105, 487]. As food chains collapse and ecosystems unravel, new and uncertain equilibria begin to form [472]. The relaxation after each disturbance—whether deforestation, invasion, or extinction—takes generations to unfold. Humanity has not yet witnessed the full echo of its destruction [361]. And yet, humanity is inseparable from the web it has torn: our food, our air, and our climate depend on the invisible labour of countless species [391]. To live, we must prevent the death of the living world.

21.1 Understanding Biodiversity

Biodiversity is the variety and variability of life on Earth, encompassing all organisms, their genetic material, and the ecosystems they inhabit [659]. It exists at three levels—genetic, species, and ecosystem diversity—and together these define the health of the planet. Diversity is resilience: the richer the web of life, the more capable it becomes of withstanding disturbance [158]. Beyond its utilitarian value, biodiversity is intrinsically sacred—life's own expression of complexity and persistence [614]. Its loss imperils ecosystem services, productivity, and stability [398, 273]. A silent erosion of diversity is a silent approach to collapse.

Threats to Biodiversity

Many of Earth's species are in direct competition with humankind for habitat and survival—and they are losing [641]. Biodiversity is threatened on all fronts:

- **Habitat Destruction**: The conversion of natural landscapes into farmland, cities, and infrastructure remains the chief driver of extinction [168]. Deforestation, wetland drainage, and coastal development fragment the continuity of life.
- **Climate Change**: Rising temperatures, shifting seasons, and extreme events disrupt entire ecosystems [184, 462]. Climate change amplifies every other threat.
- **Pollution**: Chemical contamination, plastic debris, and nutrient runoff poison soil, water, and air [560], undermining the foundations of ecological health.
- **Invasive Species**: The global trade network has become a conveyor belt of invaders. Non-native species displace local ones and rewrite ancient balances [552, 142].
- **Overexploitation**: Unsustainable hunting, fishing, and logging deplete populations faster than they can recover [525].
- **Socioeconomic and Political Drivers**: Poverty, corruption, and conflict accelerate ecological decline by fuelling illegal extraction and weakening protection [576].

21.2 Strategies for Biodiversity Preservation

Efforts to preserve life take many forms—from restoring forests to reforming economies. All share one principle: life persists only where it has room to breathe.

Habitat Conservation and Restoration

Without a place in the world, no being can persist. The most direct path to preservation is the protection and recovery of habitat [167].

- **Protected Areas**: National parks, wildlife sanctuaries, and marine reserves form the backbone of conservation [443]. They are the last strongholds of the wild.
- **Wildlife Corridors**: Corridors reconnect fragmented landscapes, enabling species to migrate, mate, and adapt [223].
- **Land-Use Planning**: Agroforestry and eco-friendly agriculture integrate production with preservation [353].
- **Ecosystem Restoration**: Healing degraded lands and reefs restores both biodiversity and the services upon which humans depend [89].

Species Conservation

Even as ecosystems are saved, individual species require rescue from the brink [498].

- **Captive Breeding and Reintroduction**: Breeding programs maintain genetic diversity and replenish wild populations [25].
- **Habitat Management**: Managing and adapting environments for critical species—providing food, nesting sites, and control of invasive species—prevents extinction [180].
- **Conservation Genetics**: Genetic insight guides these efforts, revealing population structure and sustaining evolutionary potential [11].

Sustainable Nature–Human Relations

To halt biodiversity loss, humanity must revise its relationship with nature. Conservation cannot succeed while consumption remains unexamined.

- **Sustainable Agriculture**: Agroecology and organic farming reduce ecological footprints while supporting local resilience [67].
- **Fisheries Management**: Enforcing catch limits and marine reserves allows ocean life to recover [666].
- **Community Engagement**: Empowering local stewardship binds human prosperity to ecological health [96].
- **Indigenous Knowledge Systems**: Traditional ecological knowledge offers deep, place-based wisdom for sustainable governance [607].
- **Green Militarization**: In some regions, anti-poaching units and protected enforcement remain necessary to defend nature's last refuges [148].

Global Policy

Nature ignores borders; so must preservation [390]. International cooperation is the scaffold upon which survival depends.

- **Convention on Biological Diversity (CBD)**: The CBD seeks to conserve life, promote sustainable use, and share genetic benefits equitably [369]. Though its 2020 goals were missed, its 2050 vision endures [463].
- **United Nations Sustainable Development Goals (SDGs)**: SDG 15 demands the restoration and protection of terrestrial ecosystems, linking conservation directly to human development [527].

Local Policy

While global compacts set direction, the battle for biodiversity is fought locally. Governance rooted in place is the most enduring [522].

- **Protected Area Networks**: Regional conservation networks maintain ecological continuity across landscapes [20].
- **Species Protection Laws**: Enforcement of legal safeguards curbs poaching, trade, and exploitation [521].
- **Habitat Restoration Initiatives**: Local reforestation and wetland revival anchor resilience where it is most needed [27].

21.3 Biodiversity Monitoring and Assessment

To protect life, we must first witness it. Observation is the foundation of preservation.

- **Remote Sensing**: Satellite imagery and drones reveal patterns of loss and recovery invisible from the ground [622].
- **Citizen Science**: Public participation in monitoring both enriches data and deepens connection between people and place [420].
- **Genetic Sequencing**: DNA-based monitoring uncovers hidden species, tracks genetic health, and detects invasive threats [61].

Conclusion

The fate of biodiversity depends on how the many threats—climate, exploitation, fragmentation—interact and amplify one another [532]. What is clear is that life endures only where enough of it remains connected [466, 122, 630]. Across science, governance, and the front lines of conservation, every act of protection is an act of defiance against extinction. To preserve biodiversity is not merely to save species—it is to defend the possibility of a living world.

Chapter 22

Planetary Cooling

Earth's climate is a delicate balance of energy exchanges, primarily driven by the Sun's radiation. Earth's energy budget describes how the planet absorbs and reflects solar energy, and how this energy is redistributed through various processes [618]. It is largely determined by the planet's albedo; the fraction of solar radiation reflected back into space, and by the greenhouse effect. Increasing albedo is a way to cool the planet.

Solar geoengineering (SG), is a set of strategies to actively cool the planet

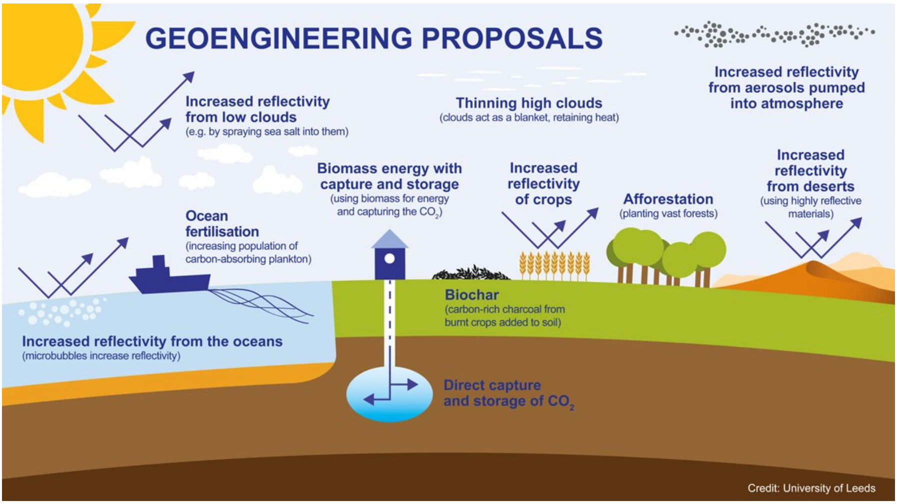


Figure 22.1: The illustration shows several examples of geoengineering proposals. Image source: University of Leeds.

by managing the energy budget [308]. These strategies aim to increase Earth's albedo, thereby reflecting more sunlight and reducing the amount of heat trapped in the atmosphere. The idea is to provide a temporary solution by bringing the energy budget to zero [173].

The science of solar radiation management is young and incomplete. Before any cooling will be done answers must be found for many questions [181]: the technological questions about feasibility and undesirable consequences, the ethical question of SG, and policy questions about the direction of research. The author can think of research questions such as how much cooling must be achieved to meet targets, where they must be implemented and by which method. One worrisome tipping risk area where SG could step in would be the great icecaps in summer: the Himalayas, the global northernmost areas and global southernmost areas. We do not want ice to melt: it decreases albedo and there is methane release. Another vulnerable area to be cooled would be anywhere at risk of fire, which would cause catastrophic biodiversity loss and carbon dioxide release. And of course, there are the coral reefs which will not survive without drastic intervention.

22.1 Land-based Cooling Strategies

Several land-based strategies can increase Earth's albedo:

- **Forestation and Soil Restoration**: planting trees and restoring soil health can significantly enhance land albedo [251]. This approach, known as "brightening the land" involves selecting tree species with high albedo and managing soils to maximize their reflectivity. Plants evaporate water and the ensuing clouds have even more reflectivity.

- **Mirrors and Bright Surfaces**: M.I. Budyko proposed the use of mirrors or reflective surfaces to increase Earth's albedo [87]. This idea, while technologically challenging, could be applied to deserts and do much for the energy balance. The brightening of surfaces and installation of mirrors also has application in urban areas for combating heat islands.

- **Reflective Plants**: Certain plant species have higher albedo than others. It has been suggested that cultivating crops with higher albedo could be a viable strategy to cool the planet [328]. Reflective plants could play a role in food security by keeping temperatures on farmlands moderate.

- **Ice Shields**: Polar ice plays a crucial role in Earth's albedo. Perovich and Polashenski explored how the albedo of Arctic sea ice changes over time, emphasising the importance of ice-albedo feedback in climate regulation [483]. By repeatedly spraying water over ice in winter it may grow quicker so as to achieve reflective cooling for maximal duration when it becomes warmer again.

Most of these technologies will have only a minor effect on the energy budget of Earth. Others may not be scalable to where they would have sufficient impact. Even so, all these technologies have applications in locally cooling down some of the milieus that will begin overheating in the years to come.

22.2 Sea-based Cooling Strategies

The ocean covers a significant portion of Earth's surface, and several strategies aim to increase its albedo:

- **Buoyant Flakes**: This method consists of the dissemination onto nutrient-deficient ocean surface waters of rice husks coated with reflective materials to increase oceanic albedo, and could also contain slow releasing nutrients for phytoplankton, facilitating carbon sequestration by the algae as an extra benefit [40].

- **Nanobubbles and Ocean Albedo Enhancement**: J. Clarke introduced the concept of FizzTop, a device that generates nanobubbles in seawater to enhance ocean albedo [115]. This method offers a novel approach to cooling the planet by increasing the reflectivity of the ocean surface and because of its strong local cooling effect has many applications such as protecting coral reefs.

- **Seawater Atomization**: There has been a proposition to inject seawater into the atmosphere, forming bright clouds that reflect sunlight [534]. This method, also known as cloud albedo enhancement, has the potential to cool the planet significantly.

Again, some solutions will only have use locally in protecting certain temperature sensitive spots: they may serve the preservation of nature more than the cooling of the planet.

22.3 Air- and Space-based Cooling Strategies

Modifying the atmosphere to increase albedo is another set of strategies:

- **Marine Cloud Brightening (MCB)**: MCB is a technique to make clouds brighter by injecting sea salt particles into the atmosphere [502]. This approach aims to increase the reflectivity of low-lying marine clouds and it is debated if it would be safe [174].

- **Cirrus Cloud Thinning**: Both Gasparini et al. and Feingold et al. explored the idea of thinning cirrus clouds to reduce their warming effect [434]. Cirrus clouds trap outgoing longwave radiation, and thinning them could potentially have a cooling effect. Cirrus cloud thinning however shows no promise for substantially cooling the planet [210].
- **Stratospheric Aerosol Injection (SAI)**: SAI is a method to inject reflective aerosols into the stratosphere [615]. This approach mimics the cooling effect of large volcanic eruptions [653]. It is the most dangerous of all mentioned strategies as it threatens to deplete the ozone layer, but it cannot be overlooked as it might be the only technology with enough of a cooling effect [340, 277].
- **Space-based Reflectors**: there is the proposal of placing reflective structures in space to redirect sunlight away from Earth [419, 47]. This concept, while technologically demanding, could provide a powerful cooling effect but may only be warranted several decades into the future.

The air-based solutions are the least innocent of the three. When they involve putting chemicals in the air we have to be acutely aware of any consequences this may have; we do not need an extra existential threat right now.

Conclusion

Although geoengineering strategies offer a range of potential solutions to cool the planet, each of them comes with its own set of challenges, risks, and uncertainties. Careful research, modelling and planning are of the utmost importance. Some have spoken out in favour cooling methods [478, 508], others have rejected the idea of artificial cooling entirely [60]—for the last I state my case: when man lit fire it began a terraforming project it did not mean to start. Now there is no going back. We will all die because of a heated Earth that we cannot live on when the tipping points are crossed. It is a 'when' not an 'if'. The existential threat is man-made and therefore it requires equally artificial solutions. Yes, there is grave danger in toying with the weather but we have been doing so for a while and we are in danger now. Will we be ready? Not the question if we should but if we could is what occupies the mind of the author.

Chapter 23

Carbon Removal

The time gained through geoengineering must be utilized for large-scale carbon removal. These systems address the root cause of climate change by reducing atmospheric CO_2. While the theory is sound, most methods are far from industrialized [445].

Carbon removal is crucial for achieving the Paris Agreement goals [647]. Scenarios typically start with afforestation, adding other methods over time.

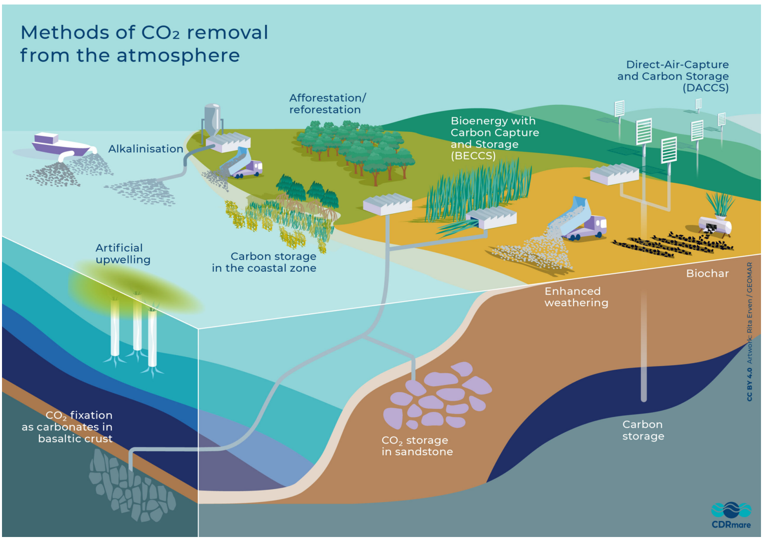


Figure 23.1: This illustration contains several examples of negative emission technologies. Image source: Rita Erven, GEOMAR.

The challenge is immense: we must remove 2-10 gigatons of CO_2 annually [211]. No single technology can achieve this [203], luckily there are many.

23.1 Nature-Based Solutions

Nature has always stored carbon. Methods enhancing this capacity are cheap and readily available, but compete for land-use and because they are cyclic the carbon is not stored forever. These methods involve enhancing natural carbon sinks. One example of a sink is carbon burial in lakes and reservoirs [425]. Ocean fertilisation will be omitted from this discussion as the science is in agreement it is too risky and uncertain [595].

- **Afforestation & Reforestation**: Forestation has gigaton-scale potential [203]. It has begun globally, with more trees being planted than removed in Europe and Asia [187]. Forests provide biodiversity and climate benefits. Planting diverse species enhances resilience [387]. Forestation's potential decreases over time as forests mature and trees die, releasing some of the sequestered carbon. Forest fires are a risk. Boreal forests have a local warming albedo effect, potentially offsetting cooling benefits, but still mitigating high CO_2 levels [649].

- **Soil Carbon Sequestration (SCS)**: SCS through improved agricultural practices can significantly contribute to carbon storage, meanwhile improving soil quality [363]. SCS happens when soil organic carbon increases. Climate-smart practices increase carbon inputs or reduce losses. The potential is several gigatons per year [203]. SCS enhances agricultural land-use. Some methods may increase methane or nitrous oxide emissions, but these can be avoided [574].

- **Farming for Biomass**: Fast-growing plants like hemp [556], bamboo [672], and kelp [48] have carbon sequestration potential. Carbon-negative building materials, such as bamboo lumber and hemp-based concrete, can store CO_2 long-term [4]. Biomass plantations compete with agriculture for land-use, and carbon sinks are short-lived [238]. Biochar, a stable form of carbon produced from biomass pyrolysis, has potential in aiding soil carbon sequestration [661]. Engineered living photosynthetic biocomposites show promise for intensified biological carbon capture [283].

- **Coastal Ecosystems & Blue Carbon**: Enhancing coastal ecosystems and promoting sea grass growth can sequester up to a gigaton of carbon annually [401]. This could be, for example, installing kelp forests and seaweed beds along the coastline for carbon sequestration and coastal protection [114]. Preserving and restoring coastal ecosystems can make the entire coastline a carbon sink.

23.2 Industrial Carbon Removal

Industrial carbon removal methods focus on capturing CO_2 directly from industrial exhaust or even the atmosphere. These technologies offer a direct approach to reducing atmospheric CO2 concentrations and are crucial components of comprehensive carbon removal strategies [124].

Carbon Capture and Storage

Not everyone is happy about carbon capture and storage (CSS), which involves catching CO_2 emissions at the source [303]. There is the argument that CSS is an immoral technology for it facilitates more oil use quite directly: most of the CO_2 that is captured is used for enhanced oil recovery [549]. CCS is useful for heavy industry, plant retrofits, natural gas processing, and electrofuel production [281]. CCS has been proven to work but struggles to achieve net-zero because of energy demands. CSS can be applied to biofuels, known as bioenergy with carbon capture and storage (BECCS), making it a net-negative technology with a potential of up to 5 gigatonnes of CO_2 removal per year [203]. The scale depends on biofuel production, which is land-limited. The methods include post-combustion capture, pre-combustion capture, and oxy-combustion [329]. Capture technologies include absorption, membrane gas separation, chemical looping combustion, calcium looping, and solid sorbents [399, 69, 88]. There are currently over 40 running CCS facilities which capture one thousandth of carbon dioxide emissions [225].

Direct Air Capture

Direct Air Capture (DAC) captures CO_2 directly from the atmosphere. It has a potential of up to 5 gigatonnes of carbon removal by 2050 [203]. The DAC process consists of three stages: contacting, capture, and separation [56]. In the contacting stage, atmospheric air containing CO_2 is transported to the equipment. In the capture stage, CO_2 binds and in the separation stage external energy is applied to separate CO_2 from the capture material, producing a pure CO_2 gas and regenerating the chemical media for reuse. DAC can be broadly categorized into two mature technologies: liquid DAC and solid DAC. Liquid DAC uses liquid solvents to absorb CO_2 from the air and solid DAC employs solid sorbents for chemisorption [163]. Beyond these, there are several other technologies under development, including electro-swing, moisture-swing, and membrane-based methods. These technologies all capture

CO_2 and some show promise because of increased energy efficiency, simpler operation, and lower costs [380]. DAC pilots exist, but supply chain and middle-scale pilot problems prevent full-scale industrialization [63].

Underground CO_2 Storage

Underground CO_2 storage is feasible [302]. The reservoir of deep saline aquifers where the gas may be stored is virtually limitless [258]. Captured CO_2 must be transported, which could come with logistical complications, and long-term monitoring is required. There is a risk of leakage in the case of earthquakes.

23.3 Geochemical Carbon Removal

At a fundamental level, most geochemical NETs are simply an acid-base neutralisation [95]:

$$\text{Acid } (CO_2 + H_2O) \;+\; \text{Base (alkaline mineral)} \rightarrow \text{ Salt (carbonate or bicarbonate)}$$

These methods mimic and enhance natural geological processes that store carbon over geological timescales, making them more definitive solutions than increasing biological carbon sinks. Although not expected to be ready at scale before 2050, geochemical carbon removal is in theory only limited by mineral resources which are plenty, which makes it a promising technology for further future [402].

- **Mineral Carbonation**: Tt can permanently store CO_2 in solid form [178]. In situ mineralisation involves the injection of supercritical CO_2 or a CO_2 rich fluid into alkaline rock formations, where it can be absorbed and stored [335]. Because there are many suitable rock formations underground, how much carbon can be stored this way mainly depends on how much CO_2 we can capture [526]. Ex situ mineralisation techniques involve industrial sources of CO_2 rich gases that react with large areas of alkaline materials, such as olivine or serpentine [669]. Lastly surficial mineralisation techniques are methods where air or low purity CO_2 gas reacts with alkaline materials in piles, fields, pools, or large indoor spaces such as greenhouses typically, which typically happens over far greater timescales [95]. Although ex situ mineralisation and surficial mineralisation could remove as much carbon as we could mine alkaline resources, in practice the mining may cost too much energy for it to be a viable option [526].
- **Ocean Liming**: Adding alkaline substances to seawater, increasing alkalinity and promoting CO_2 uptake [104]. It can mitigate ocean acidi-

fication and improve conditions for calcifying organisms [536]. Alkalinity enhancement can further increase the ocean's CO_2 absorption capacity [216]. Altogether it is estimates that several thousands of gigatonnes could be sequestered [526], but there is environmental risk. The plan could backfire catastrophically if the oceans eventually release all these gigatonnes of carbon back into the air. Also, the additionality problem raises concerns about the effectiveness as natural oceanic buffering might counter the process [35].

- **Enhanced Weathering**: This method accelerates the natural process of rock weathering to sequester CO_2 [635]. It involves the application of finely ground minerals, such as olivine or basalt, to land or ocean surfaces, where they react with atmospheric CO_2. Enhanced weathering, when done at sea, has a more direct impact on marine ecosystems with potential risks and co-benefits that must be carefully considered [36].
- **Biomineralization**: Biomineralization one part of natural geochemical cycles of nutrient elements such as carbon, where organisms capture elements from their environment that remain stored in minerals after their death [97]. Microalgae can utilize CO_2 for mineral carbonation [670]. Bacteria employ diverse mechanisms for carbonate mineralization [242]. Fungi can mineralise carbon and store it in the form of calcite [62].

Conclusion

Carbon removal is a crucial component of the energy transition. The methods outlined in this chapter, including nature-based solutions, industrial carbon removal, and geochemical carbon removal, offer a comprehensive approach to addressing the carbon problem. However, it is important to note that carbon removal is not a silver bullet and must be accompanied by aggressive prevention efforts to reduce fossil emissions.

The potential of these technologies is vast, but they are not without challenges. Further research, development, and deployment are necessary to realize their full potential. As we strive towards a sustainable future, carbon removal will play a critical role in achieving net-zero emissions and mitigating the impacts of climate change.

Chapter 24

Non-CO_2 Greenhouse Gas Mitigation and Removal

While carbon dioxide (CO_2) remains the primary driver of global warming, a significant portion of the Earth's radiative imbalance stems from other greenhouse gases—chiefly methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). Although these gases occur in lower atmospheric concentrations, their heat-trapping capacity is vastly greater: methane is roughly 28 times, and nitrous oxide about 265 times, more potent than CO_2 over a 100-year period [300].

These non-CO_2 gases originate from agriculture, waste, industrial processes, and refrigeration. Their shorter atmospheric lifetimes mean that reductions yield relatively rapid climate benefits, making their mitigation one of the fastest ways to slow warming this century. Addressing them complements CO_2 reduction and forms an essential part of any holistic climate strategy.

24.1 Methane

Methane (CH_4) is responsible for roughly one-third of current global warming [72]. It is short-lived compared to CO_2, but its strong radiative forcing makes early reduction efforts highly impactful.

Key mitigation pathways include:

- **Agriculture:** Improved manure management, altered livestock diets, and precision feeding technologies reduce enteric fermentation and associated methane emissions [588, 299].

- **Waste Management:** Capturing landfill gas and implementing anaerobic digestion of organic waste lower emissions while producing renewable biogas [668, 389].

- **Energy Sector:** Replacing fossil fuels with renewables, sealing methane leaks from oil and gas infrastructure, and monitoring fugitive emissions all directly reduce atmospheric CH_4 [293, 581].

Methane removal and valorization approaches turn waste into resource:

- **Anaerobic Digestion:** Converts agricultural residues and food waste into biogas for clean energy [46, 240].
- **Landfill Gas Capture:** Collects and flares methane or uses it for electricity generation, preventing atmospheric release [162].
- **Biochar:** Produced via pyrolysis, biochar improves soil health and reduces emissions from agricultural soils while storing carbon long-term [17, 362].

Integrating mitigation with such recovery systems enables a double dividend: reducing warming potential while generating renewable energy.

24.2 Nitrous Oxide

Nitrous oxide (N_2O) is both a potent greenhouse gas (GWP 265) and a destroyer of stratospheric ozone [504]. Its emissions arise mainly from nitrogen fertilizers and industrial production of nitric and adipic acids.

Mitigation strategies target the largest sources:

- **Agriculture:** Precision fertilization, crop rotation, and nitrification inhibitors increase nitrogen-use efficiency, curbing soil N_2O emissions without harming yields [253, 299].
- **Industry:** Deploying selective catalytic reduction (SCR) and process optimization in chemical manufacturing cuts industrial N_2O emissions dramatically [381, 137].
- **Waste Management:** Advanced wastewater treatment and biogas recovery reduce both methane and nitrous oxide emissions from organic waste streams [389, 668].

Emerging removal technologies include:

- **Biological Scrubbing:** Harnessing microbial communities to convert N_2O into inert N_2 gas through denitrification [253].

- **Chemical Scrubbing:** Using alkaline reagents to capture and neutralize N_2O from industrial exhaust streams [381].

- **Soil Nitrogen Management:** Improved soil monitoring, cover cropping, and regenerative practices reduce nitrogen surplus and thus N_2O fluxes [299].

The combination of better fertilizer practices, industrial controls, and biological conversion offers one of the clearest paths to rapid mitigation.

24.3 Hydrofluorocarbons (HFCs)

Hydrofluorocarbons (HFCs) are synthetic refrigerants with GWPs thousands of times greater than CO_2. Though their total emissions are smaller, their projected growth—especially in emerging economies—makes them a critical target [71]. The 2016 Kigali Amendment to the Montreal Protocol represents a global commitment to phase them down.

Mitigation measures focus on reducing leakage and transitioning to alternatives:

- **Refrigeration and Cooling:** Adoption of natural refrigerants (CO_2, ammonia, hydrocarbons) and tighter maintenance standards could cut emissions by 80% by mid-century [452].

- **Foam Manufacturing:** Shifting to low-GWP blowing agents and optimizing production reduces industrial HFC use [624].

- **Industrial Applications:** Process redesign and leak detection in semiconductor and solvent manufacturing further reduce emissions [300].

Emerging removal technologies show early promise:

- **Thermal Oxidation:** Converts HFCs to CO_2 and water, achieving near-complete destruction under controlled conditions [570].

- **Catalytic Decomposition:** Employs specialized catalysts for lower-energy breakdown of fluorinated compounds [321].

- **Adsorption and Capture:** Advanced sorbents can trap HFCs for safe storage or reuse [373].

Eliminating HFCs offers a rare climate win-win: fast mitigation, technological feasibility, and global political consensus.

Conclusion

In sum, the mitigation and removal of non-CO_2 greenhouse gases are vital accelerators of climate stability. They represent the near-term levers that can cool the planet within decades, buying time for the longer struggle against carbon. Rapid action here is not merely technical—it is moral, for each molecule of methane, nitrous oxide, or HFC spared from the sky is a small redemption for the fire we have unleashed.

Chapter 25

Remediation

Environmental remediation is a critical process aimed at restoring ecosystems degraded by anthropogenic activities, ensuring ecological health, and securing long-term sustainability. This chapter explores comprehensive remediation strategies, addressing land, water, and air pollution, and highlights the importance of integrating these methods into broader conservation efforts.

25.1 Land Remediation

Bioremediation

Bioremediation harnesses the natural capabilities of microorganisms to degrade or detoxify pollutants in soil. This approach is particularly effective for hydrocarbons, heavy metals, pesticides, and organic solvents [501]. Microbial bioremediation often involves optimizing environmental conditions, such as pH and nutrient availability, to enhance the metabolic activity of the microorganisms [407].

Phytoremediation

Phytoremediation employs plants to absorb, stabilize, or transform contaminants in soil. This method is gaining recognition for its cost-effectiveness and minimal environmental disruption. Key techniques include:

- **Phytoextraction**: Uptake of heavy metals, such as lead and cadmium, by hyperaccumulator plants like *Thlaspi caerulescens* [150].
- **Phytostabilization**: Immobilization of contaminants in the soil matrix to prevent their migration into the environment [585].

- **Phytodegradation**: Breakdown of organic pollutants through plant metabolic processes, often facilitated by the presence of specific enzymes [476].

- **Rhizofiltration**: Absorption of contaminants by plant roots in aqueous environments, particularly effective for removing heavy metals from contaminated water [421].

Chemical and Physical Methods

Chemical and physical methods provide more direct and often faster solutions for soil remediation. These include:

- **Soil Washing**: Separation of pollutants from soil particles using water or chemical solutions, followed by treatment of the contaminated washate [345].

- **Thermal Desorption**: Removal of volatile contaminants through heating, vaporizing the pollutants and capturing them for disposal [637].

- **Stabilization/Solidification**: Binding contaminants into a stable matrix to reduce their mobility and bioavailability [658].

- **In-situ Chemical Oxidation**: Application of oxidizing agents to break down organic pollutants directly in the soil [259].

- **Nanotechnology Applications**: Use of nanoparticles to enhance the degradation of contaminants or improve the efficiency of other remediation techniques [616].

Plastic and PFAS Remediation

Plastics and per- and polyfluoroalkyl substances (PFAS) are persistent pollutants that pose significant environmental challenges due to their resistance to degradation and widespread presence in ecosystems [83]. PFAS, often referred to as "forever chemicals," are highly stable and can accumulate in both aquatic and terrestrial environments, leading to adverse ecological and human health impacts [267]. Plastic pollution, on the other hand, affects marine ecosystems, leading to the entanglement and starvation of wildlife, while microplastics infiltrate food chains, raising concerns about bioaccumulation in humans [337]. Remediation efforts require innovative and integrated approaches to address these pollutants effectively.

Several strategies have been developed to tackle these pollutants:

- **Thermal desorption for PFAS-contaminated soils**: This method involves heating contaminated soils to high temperatures, causing PFAS compounds to volatilize and be captured in a controlled environment [571]. It is particularly effective for localized contamination but requires significant energy input.

- **Advanced oxidation processes (AOPs)**: AOPs, such as Fenton's reagent and photocatalysis, utilize reactive oxygen species to break down PFAS and plastic byproducts into less harmful compounds [537]. These methods are highly effective but can be challenging to scale up for large-scale applications.

- **Specialized filtration systems**: Filters incorporating activated carbon, ion exchange resins, and nanofiltration membranes have shown success in capturing PFAS and microplastics from water sources [646]. While effective, their high maintenance costs and potential for filter clogging limit widespread adoption.

- **Enzymatic degradation of specific plastic types**: Researchers have engineered enzymes, such as petFilmase, to target specific types of plastic, offering a more eco-friendly degradation pathway [673]. This approach holds promise for reducing plastic waste in landfills and oceans.

25.2 Water Remediation

Wastewater Treatment

Effective wastewater treatment is critical for removing a broad spectrum of contaminants, including heavy metals, pharmaceuticals, and emerging pollutants like microplastics and PFAS. Advanced treatment processes are now necessary to meet stricter environmental regulations and protect public health [461].

A variety of technologies are employed in modern wastewater treatment:

- **Membrane filtration systems**: Reverse osmosis and nanofiltration are widely used for desalination and removal of dissolved solids, including PFAS and microplastics [154]. These methods are highly effective but face challenges related to membrane fouling and energy consumption.

- **Activated sludge systems**: These systems utilize aerobic and anaerobic microorganisms to degrade organic contaminants and remove nutrients such as nitrogen and phosphorus [161]. While cost-effective, they are less effective against recalcitrant compounds like PFAS.

- **Constructed wetlands**: These natural or engineered systems mimic the functions of wetlands to filter wastewater through plant uptake, microbial activity, and physical filtration [667]. They are environmentally friendly but require larger land areas and are less efficient for industrial effluents.

- **Advanced oxidation processes (AOPs)**: AOPs are increasingly used to degrade refractory pollutants such as PFAS and certain pharmaceutical compounds [469]. Their high operational costs remain a barrier to widespread adoption.

Bioremediation and Phytoremediation

Bioremediation and phytoremediation offer sustainable alternatives for treating water and soil pollution by leveraging the natural capabilities of microorganisms and plants. These methods not only reduce contaminant levels but also restore ecosystem functions [58].

The following approaches are currently being explored:

- **Algae-based bioremediation**: Certain algae species possess the ability to adsorb heavy metals and degrade organic contaminants, making them a valuable tool in water treatment [109]. Their growth rates and biomass productivity present potential challenges for large-scale applications.

- **Floating treatment wetlands (FTWs)**: FTWs utilize aquatic plants to absorb nutrients and contaminants from water, creating a self-sustaining ecosystem. They are particularly effective for nutrient removal and can enhance biodiversity in impacted water bodies [428].

- **Bioaugmentation with pollutant-degrading bacteria**: Introducing specialized bacteria into contaminated environments can enhance the degradation rates of pollutants such as hydrocarbons and some PFAS compounds [639]. This method requires careful monitoring to prevent unintended ecological consequences.

The integration of these remediation techniques is essential for achieving long-term environmental sustainability and mitigating the effects of hazardous pollutants on ecosystems and human health.

Chemical Remediation

Chemical methods are employed to target persistent and hard-to-remove pollutants, often in industrial or contaminated water systems. These techniques involve altering the chemical properties of pollutants to render them harmless or remove them from the environment:

- **Coagulation-Flocculation**: This process uses chemicals such as aluminum sulfate or ferric chloride to aggregate suspended particles, making them easier to remove through sedimentation or filtration. Coagulation-flocculation is widely used in wastewater treatment to remove turbidity and heavy metals [327].
- **pH Adjustment and Precipitation**: Adjusting the pH of a solution can induce the precipitation of certain pollutants, such as heavy metals, into insoluble solids that can be easily removed. This method is particularly effective for removing metals like lead and mercury from contaminated water [495].
- **Chemical Oxidation-Reduction**: Oxidation-reduction (redox) reactions can break down complex pollutants into simpler, less harmful compounds. For example, potassium permanganate and hydrogen peroxide are commonly used to oxidize organic pollutants in wastewater [469].
- **Adsorption Using Activated Carbon**: Activated carbon, with its high porosity and surface area, is highly effective in adsorbing organic pollutants and heavy metals from water. This method is particularly useful for treating industrial effluents and contaminated groundwater [157].

Eutrophication Mitigation

Eutrophication, resulting from excessive nutrient inputs such as nitrogen and phosphorus from agricultural runoff, urban wastewater, and atmospheric deposition, leads to harmful algal blooms, hypoxia, and the degradation of aquatic ecosystems [354]. Mitigation strategies aim to reduce nutrient availability, restore ecological balance, and enhance water quality. Below, we outline key approaches to eutrophication management:

- **Constructed Wetlands for Nutrient Removal**: Constructed wetlands have emerged as a sustainable approach to mitigating eutrophication by removing excess nutrients from water bodies. These systems leverage the natural processes of plants, soil, and microorganisms to facilitate nutrient uptake and microbial decomposition. According to a comprehensive review by [147], constructed wetlands can achieve nutrient removal efficiencies of up to 80% for nitrogen and 70% for phosphorus, depending on the design and local conditions.
- **Alum Dosing for Phosphorus Precipitation**: The application of aluminum sulfate (alum) is a widely used method for controlling phosphorus levels in freshwater systems. Alum reacts with phosphorus to

form insoluble aluminum phosphate precipitates, effectively reducing nutrient availability for algal growth. Research by [324] demonstrates that alum dosing can reduce phosphorus concentrations by 60% while preventing the formation of harmful algal blooms. However, this method must be carefully monitored to avoid potential impacts on aquatic life.

- **Biomanipulation for Ecological Restoration**: Biomanipulation involves targeted alterations to aquatic communities to restore ecological balance. Techniques include the introduction of predatory fish, the removal of invasive species, and the enhancement of submerged vegetation. A study by [255] highlights the success of this approach in restoring clear-water conditions in eutrophic lakes by suppressing cyanobacterial blooms and promoting the growth of beneficial aquatic species.

- **Aeration and Oxygenation Systems**: Aeration systems are employed to combat hypoxia caused by eutrophication. By introducing dissolved oxygen into the water, these systems support aerobic microbial decomposition of organic pollutants and restore habitats for aquatic organisms. Research by [578] shows that continuous aeration can increase dissolved oxygen levels by 30-50%, significantly improving water quality in eutrophic water bodies.

These strategies, when implemented effectively, can significantly reduce the impacts of eutrophication and restore the health of aquatic ecosystems. However, their success depends on careful planning, site-specific adaptations, and long-term monitoring to ensure sustainable outcomes.

Plastic and PFAS in Water

The presence of microplastics and per- and polyfluoroalkyl substances (PFAS) in water poses significant risks to both ecosystems and human health. Specialized techniques are required to address these contaminants:

- **Microplastic Filtration Using Fine Mesh Screens and Membranes**: Fine mesh screens and ceramic membranes can effectively filter out microplastics from water. These systems are increasingly used in municipal and industrial water treatment plants to address the growing issue of plastic pollution [177].

- **Advanced Oxidation for PFAS Degradation**: Advanced oxidation processes, such as ozonolysis and photocatalytic treatment, can break down PFAS in water. These methods utilize strong oxidants and UV light to degrade PFAS into harmless byproducts [344].

- **Adsorption Using Activated Carbon and Ion Exchange Resins**:Activated carbon and ion exchange resins are effective in removing PFAS from water. These materials adsorb PFAS molecules, preventing their entry into the environment and minimizing human exposure [233].

- **Biodegradation Using Engineered Microbes**: Engineered bacteria and enzymes can degrade certain types of PFAS in water. This bioremediation approach holds promise for addressing PFAS contamination in a sustainable and environmentally friendly manner [671].

25.3 Air Remediation

Air quality improvement is essential for mitigating the impacts of air pollution on human health and the environment. This section focuses on industrial and urban air filtration systems.

Air Filtration Systems

Industrial air filtration systems are critical for capturing pollutants and improving air quality in both industrial and urban settings:

- **HEPA Filters for Particulate Matter**: High Efficiency Particulate Air (HEPA) filters are highly effective in capturing particulate matter, including dust, pollen, and microplastics. These filters are widely used in industrial settings and urban air purification systems [200].

- **Electrostatic Precipitators**: Electrostatic precipitators remove charged particles from the air by using electric fields to attract and trap pollutants. This method is particularly effective for capturing small particles like soot and ash [408].

- **Activated Carbon Filters for Volatile Organic Compounds (VOCs)**: Activated carbon filters are ideal for removing VOCs and other gaseous pollutants from the air. These filters are commonly used in industrial exhaust systems and indoor air purification units [339].

Pollution Control Technologies

Modern pollution control technologies play a crucial role in mitigating environmental damage caused by industrial activities. These technologies aim to reduce the release of harmful substances into the atmosphere and waterways, ensuring a cleaner and healthier environment.

- **Catalytic Converters**: Catalytic converters are widely used to reduce toxic emissions from vehicles by converting harmful gases such as carbon monoxide, nitrogen oxides, and hydrocarbons into less harmful substances like carbon dioxide and water [322].
- **Flue-Gas Desulfurization (FGD)**: Flue-gas desulfurization systems are essential in reducing sulfur dioxide emissions from power plants. This technology removes sulfur dioxide from exhaust gases by reacting it with a sorbent, typically limestone, to form calcium sulfite or calcium sulfate [627].
- **Selective Catalytic Reduction (SCR)**: SCR is a proven method for reducing nitrogen oxide emissions from industrial sources. It uses a catalyst to convert nitrogen oxides into nitrogen and water, significantly lowering the environmental impact of industrial processes [245].

Biological Air Treatment

Biological air treatment systems utilize microorganisms to break down organic contaminants, providing an eco-friendly alternative to traditional pollution control methods.

- **Biofilters**: Biofilters are effective in removing volatile organic compounds (VOCs) and sulfur dioxide from industrial emissions. These systems rely on microorganisms to degrade pollutants, offering a sustainable and cost-effective solution for air purification [342].
- **Biotrickling Filters**: Biotrickling filters are designed to capture and remove gaseous pollutants by using a wet medium where microorganisms thrive. This method is particularly efficient in treating emissions with high concentrations of sulfur compounds [634].
- **Bioscrubbers**: Bioscrubbers integrate physical scrubbing with biological degradation. They are highly effective in treating gases like hydrogen sulfide and ammonia, leveraging microbial activity to achieve high removal efficiencies [432].

25.4 Emerging Remediation Technologies

Nanotechnology

The application of nanotechnology in pollution control has opened new avenues for efficient contaminant removal, enabling targeted degradation of pollutants in various media.

- **Groundwater and Soil Remediation**: Nanomaterials, such as zero-valent iron nanoparticles, are used to degrade chlorinated solvents and other organic pollutants in groundwater and soil, offering a promising solution for contaminated sites [417].
- **Targeted Contaminant Breakdown**: Advances in nanotechnology have led to the development of engineered nanomaterials capable of breaking down specific contaminants, such as heavy metals and polycyclic aromatic hydrocarbons (PAHs), with high efficiency [18].

Electrokinetic Remediation

Electrokinetic remediation represents a cutting-edge approach to contaminant extraction, utilizing electric fields to mobilize and remove hazardous substances from soil and water.

- **Heavy Metals**: This technology is particularly effective in treating soil contaminated with heavy metals like lead and arsenic, as the electric field drives these ions toward collection electrodes for removal [679].
- **Organic Contaminants**: Electrokinetic remediation can also be applied to remove organic contaminants, such as pesticides and petroleum hydrocarbons, through a combination of electric field-induced migration and subsequent treatment [346].
- **Plastics and Per- and Polyfluoroalkyl Substances (PFAS)**: Emerging applications of electrokinetic remediation target microplastics and PFAS, providing innovative solutions for these challenging pollutants [573].

Phytomining

Phytomining, a form of in situ extraction, utilizes hyperaccumulator plants to concentrate valuable metals in their tissues, offering a sustainable alternative to traditional mining practices [424]. This method not only enables resource recovery but also facilitates environmental remediation of contaminated soils by reducing metal concentrations. Studies have demonstrated the feasibility of using plants such as *Brassica juncea* and *Thlaspi caerulescens* for extracting metals like nickel and zinc [617].

Enzymatic Remediation

Enzymatic remediation represents a targeted approach to pollutant degradation, leveraging the catalytic activity of enzymes to break down recalcitrant organic compounds. This method has shown promise in addressing environmental contaminants, including plastics and agrochemical residues. For instance, enzymes such as lactonases and esterases have been employed to degrade synthetic polymers, while laccases and peroxidases have been utilized for the breakdown of pesticides and organic solvents [403]. The specificity of enzymatic reactions minimizes off-target effects, making this approach highly suitable for precision remediation efforts.

- **Plastic Degradation**: Laccases and other oxidative enzymes have been instrumental in breaking down polyethylene terephthalate (PET) and polystyrene (PS) [12].
- **Pesticide Degradation**: Fungal laccases have demonstrated efficacy in decomposing organophosphorus pesticides, reducing their environmental toxicity [239].
- **Organic Solvent Removal**: Esterases and lipases have been employed to degrade volatile organic compounds (VOCs) in groundwater and soil [12].

25.5 Long-term Monitoring and Adaptive Management

Sustained environmental monitoring and adaptive management are critical to ensuring the long-term success of remediation initiatives. These practices enable the identification of emerging environmental challenges and allow for timely adjustments to remediation strategies.

1. **Regular Environmental Assessments**:Periodic evaluations of soil, water, and air quality are essential for tracking the efficacy of remediation efforts and detecting any residual contamination or new pollutant influxes [330].
2. **Adaptive Strategies**:Data from monitoring programs inform the development of adaptive management plans, which may include modifications to remediation techniques, the introduction of new technologies, or the adjustment of treatment intensity [503].
3. **Community Engagement**:Local communities play a vital role in monitoring and maintaining remediation sites. Their participation enhances the sustainability of remediation efforts and fosters environmental stewardship [319].

By integrating advanced monitoring technologies with community-driven initiatives, long-term environmental management can achieve both ecological restoration and societal resilience.

Chapter 26

Renewable and Durable Energy Sources

Renewable energy sources are vital for creating a sustainable and low-carbon future, they are the main act of the energy transition [285]. The following sources of energy can together create a 100% renewable economy [306]: solar, wind, hydroelectric, geothermal and biomass energy. Eaech will be briefly discussed. [1]

26.1 Solar Energy

Solar energy is one of the most promising renewable energy sources. The most technology for harnessing solar power is through photovoltaic cells, which directly convert sunlight into electricity [232]. PV systems can be installed on rooftops, solar farms, or integrated into building materials. However, it is just one of several solar-based energy technologies:

- **Photovoltaic (PV) Cells:** PV cells, primarily made of silicon, convert sunlight into electricity through the photovoltaic effect. The efficiency of these cells has increased significantly, and ongoing research is focused on improving material properties and reducing manufacturing costs [358].
- **Solar Thermal Power Plants**: These plants use mirrors or lenses to concentrate sunlight, heating a fluid to produce steam, which drives turbines to generate electricity [307]. These plants are particularly effective in sunny, arid regions and can store heat for use when the sun is not shining.

[1] Further reading: nrel.gov

- **Concentrator Photovoltaics (CPV):** CPV focus sunlight onto high-efficiency solar cells using optical devices like lenses or mirrors [9]. CPV systems are more efficient than traditional PV cells but require direct sunlight, making them less effective in cloudy regions.
- **Solar Water Splitting:** is an emerging technology which aims to use sunlight to produce renewable fuels like hydrogen [355]. These systems mimic photosynthesis and have the potential to store solar energy in chemical bonds for later use, offering a pathway to clean energy storage.

26.2 Wind Energy

Wind energy has rapidly become one of the leading renewable energy sources globally [241]. Wind turbines convert the kinetic energy of wind into mechanical energy and then into electricity [90]. The industrialisation of wind energy has manifested, but there are still incomplete areas of research and development:

- **Onshore and Offshore Wind Turbines**: *Onshore wind turbines* are commonly located in regions with consistent wind patterns, while *offshore wind turbines* harness stronger and more stable winds over the ocean, but present greater technical challenges in installation and maintenance [435].
- **Energy Storage Integration**: To improve reliability, wind power systems are increasingly integrated with energy storage technologies, such as batteries and compressed air systems, which help smooth the variability in wind energy production [138].
- **Turbine Design Improvements**: Advances in turbine design focus on enhancing efficiency, such as using taller towers, larger blades, and advanced control systems [315]. These innovations allow turbines to capture more energy from low-wind-speed areas and operate more efficiently in diverse environments.
- **Large-Scale Wind Farm Management**: Managing large-scale wind farms requires optimizing turbine placement, grid connection, and maintenance schedules [360]. Predictive analytics and machine learning are increasingly used to forecast wind patterns and turbine performance, minimizing downtime and maximizing energy output.

26.3 Hydroelectric Power

Hydropower is one of the most established renewable energy technologies, primarily generated by harnessing the power of moving water through turbines

[280]. There are several methods:

- **Dam-Based Hydroelectricity**: Traditional dam-based hydroelectric power relies on the construction of dams to store water in a reservoir. Controlled releases of water drive turbines to produce electricity [650]. These projects provide reliable energy but can have significant environmental and social impacts.

- **Run-of-River Hydro**: Run-of-river hydroelectricity generates power without large reservoirs, using the natural flow of rivers to spin turbines [357]. These systems are more vulnerable to seasonal variations in water flow.

- **Marine Energy Technologies**: Marine energy is an emerging field, utilizing the vast kinetic energy of oceans [602]. Tidal power and wave energy technologies are still in development but hold promise for coastal regions.

26.4 Geothermal Energy

Geothermal energy exploits the heat stored beneath Earth's surface for both heating and electricity generation [305]. There is a variety of them:

- **Shallow Geothermal Energy**: These systems are used for heating and cooling buildings through ground-source heat pumps [397]. These systems are highly efficient and can operate year-round, regardless of weather conditions.

- **Deep Geothermal Energy**: These more expensive systems tap into reservoirs of hot water or steam miles beneath Earth's surface to generate electricity [54]. These systems are less location-dependent than shallow geothermal but require more advanced drilling technologies.

- **Enhanced Geothermal Systems (EGS)**: EGS involve creating artificial reservoirs by injecting fluid into hot dry rock formations [413]. This expands the availability of geothermal energy to areas without natural geothermal resources, offering vast potential for expansion.

26.5 Biomass & Bioenergy

Biomass energy involves converting organic materials into heat, electricity, or transportation fuels [293]. There are two primary methods:

- **Biomass Power Plants**: These plants burn organic materials, such as wood, agricultural residues, or dedicated energy crops, to produce electricity [628]. The carbon released during combustion is offset by the carbon absorbed by plants during growth, making it a low-carbon energy source.
- **Biogas from Organic Waste**: Biogas is produced by the anaerobic digestion of organic waste, including food waste, agricultural residues, and sewage [652]. Biogas plants can provide a local source of renewable energy, converting waste into usable heat and electricity while reducing methane emissions from landfills.

Conclusion

[Will write this]

Chapter 27

Nuclear Energy

27.1 Uranium-based Nuclear Power

Uranium-based nuclear power remains a cornerstone of global energy production, utilizing the fission of uranium-235 to generate heat, which drives turbines to produce electricity. This method is highly efficient but faces challenges related to safety, waste disposal, and resource sustainability [404]. This section explores advanced reactor designs, nuclear waste management, fuel reprocessing, and safety enhancements.

Advanced Reactor Designs

Modern nuclear engineering focuses on advanced reactor designs to improve efficiency and safety. Generation IV reactors aim to enhance fuel utilization and reduce waste through innovative designs like fast breeder reactors [404]. Similarly, Small Modular Reactors (SMRs) provide scalable energy solutions with built-in safety features, making them suitable for diverse applications [664]. Research continues to refine these technologies for widespread adoption [388].

Nuclear Waste Management

The management of nuclear waste is a critical issue, particularly for high-level radioactive waste from spent fuel. Long-term solutions include deep geological repositories, such as Finland's Onkalo facility, designed to isolate waste for millennia [382]. Additionally, waste vitrification—encasing waste in glass—offers a stable storage method, reducing environmental risks [13]. These approaches address both technical and societal concerns [153].

Nuclear Fuel Reprocessing

Nuclear fuel reprocessing recycles spent fuel to recover usable materials like plutonium and uranium, decreasing waste volume and extending resource availability [561]. Countries such as France and Russia have implemented large-scale reprocessing, though proliferation risks remain a concern [175]. Advances in reprocessing technology aim to improve efficiency and safety [442].

Safety Improvements

Following incidents like Chernobyl and Fukushima, safety improvements have become a priority. Passive safety systems function without external power, enhancing reliability during emergencies [338]. Innovations such as core catchers and real-time monitoring further mitigate risks, ensuring safer operations [385]. These advancements reflect lessons learned from past disasters [226].

27.2 Thorium-based Nuclear Power

Thorium-based nuclear power offers an alternative to uranium, leveraging thorium's abundance and potential for reduced waste and enhanced safety [676]. This section examines thorium's potential, Molten Salt Reactors (MSRs), and thorium fuel cycles.

The Potential of Thorium

Thorium presents several advantages: it is more abundant than uranium, produces less long-lived waste, and has a lower meltdown risk [676]. However, its development lags due to technical and economic challenges [411]. Research highlights its promise as a sustainable energy source [332].

Molten Salt Reactors (MSRs)

Molten Salt Reactors (MSRs) are a leading design for thorium-based power. Using molten salts as both fuel and coolant, MSRs operate at high temperatures and low pressure, improving safety and efficiency [371]. Their ability to manage waste by capturing fission products is a key benefit [550]. MSRs remain largely experimental but show significant potential [189].

Thorium Fuel Cycles

The thorium fuel cycle involves converting thorium into uranium-233 via neutron absorption, creating a sustainable energy process [30]. This cycle minimizes waste and maximizes fuel use, aligning with long-term energy goals

[291]. Research continues to optimize this process for practical implementation [234].

27.3 Nuclear Fusion

Nuclear fusion promises clean, virtually limitless energy by fusing light nuclei like deuterium and tritium, mimicking solar processes [198]. Unlike fission, it generates minimal radioactive waste, making it an attractive future energy option.

Ongoing Research into Nuclear Fusion

Fusion research is advancing rapidly, with ITER—an international project—leading efforts to demonstrate fusion's feasibility [312]. Overcoming challenges like plasma confinement and energy output remains critical [126]. Smaller-scale experiments also contribute to progress [348].

Tokamak Designs

The Tokamak design, central to ITER, uses magnetic fields to confine plasma in a toroidal chamber, enabling sustained fusion reactions [654]. Its advantages include proven scalability, though it requires precise engineering [586]. Tokamaks represent the forefront of fusion technology [272].

Other Fusion Reactor Concepts

Alternative designs include the Stellarator, which enhances plasma stability with a twisted configuration [235], and Inertial Confinement Fusion (ICF), using lasers to compress fuel pellets [384]. Private ventures like Helion and Commonwealth Fusion Systems explore innovative approaches, such as magneto-inertial fusion and compact reactors, potentially accelerating commercialization [568, 119].

Chapter 28

Electrification

The prevention of carbon dioxide emissions is a two step plan: first, electrify all energy use, and second, generate all electricity sustainably. This chapter will be on electrification and the first of six chapters that are all on energy. Because energy that is not used will never warm the planet, while sustainable sources remain out of reach, we must try to minimise consumption and to this end we will also include efficiency in this discussion.[1]

28.1 Smart Grids & Grid Optimisation

As a bigger share of energy demand is met with electricity this is bound to put pressure on the grid that provides all this power, leading to net congestion. The obvious solution is more and thicker power lines but there is also smart grids. Smart grids are electrical systems that integrate information and communication technology to enhance the efficiency, reliability, and sustainability of electrical-energy distribution [205]. The fourth industrial revolution [39] has made a lot of things into sensors and computers, which provides the algorithm of the smart grid with data that can be used to optimise energy consumption. In the optimal configuration electricity travels the shortest path from supplier to consumer, minimising energy losses. To know what will be the best available match of source and consumer the grid must be smart enough to make predictions on the effects of weather and time of day on supply and demand, and based off these predictions the grid could then decide the optimal time to charge electric vehicles. A blockchain technology matched with smart meters would take this even further, creating a dynamic marketplace that continuously finds the best energy transactions while never wasting a Joule [603].

[1] Further reading on energy: understand-energy.stanford.edu

A major problem of integrating the internet of things into the energy system is that in doing so the supply chain of electricity becomes vulnerable to attacks from hackers. Many precautions, based in both software and hardware, can be taken to ensure the safety of the network [529].

28.2 Energy Efficiency in Buildings

Construction is very expensive in carbon emissions, so it is better to make sustainable what one can in an old house then to build a new one, even if the new house would be perfectly green. However, 25% of all emissions are caused by buildings [282], so retrofitting old houses is necessary. Most of these emissions come from heating which becomes less necessary with better isolation. One could go even further and omit gas entirely by getting an electric stove and installing a heat pump or connecting to a district heating network.

Now, even if we fully electrify our house we are still not off the hook. The day that all electricity is green will come, but not anytime soon. So even when using electricity it is better to be frugal. Heating and cooling are reason for most of energy consumption in buildings so a smart thermostat that shuts down when nobody is home or everyone is asleep can reduce energy use by 28% [395]. One smart step further we find whole smart houses [431]—which perform similar energy saving actions, but also plan the activity of appliances like dishwashers at times when energy is cheapest.

If a new house is constructed, passive solar techniques may be applied that orient the house in such a way that it cools in summer and heats in winter [592]. There is no special technology to it, but make no mistake, passive solar heating and cooling are a remarkable show of engineering best left to an architect.

28.3 Electrification of Transport

Electrification of Road Transport

Road transport is a major contributor to global CO_2 emissions, accounting for a significant portion of the transport sector's total emissions [512]. The electrification of road transport, including cars, buses, and trucks, is a crucial step towards reducing emissions and improving energy efficiency. Important technologies and innovations include:

- **Electric Vehicles (EVs)**: EVs are a key technology for decarbonizing road transport. They offer several benefits, including reduced emissions, improved energy efficiency, and lower operating costs compared to

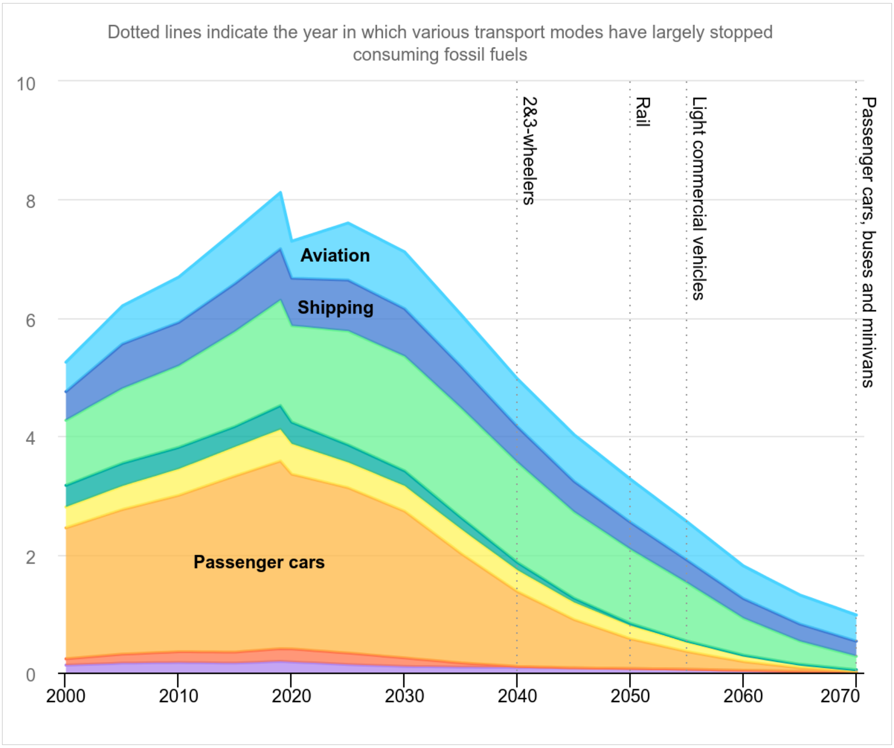


Figure 28.1: Carbon emissions per mode of transport from 2000 to 2070 (prognosis). Image source: IEA.

conventional internal combustion engine vehicles [535]. However, there are challenges associated with the widespread adoption of EVs, such as limited battery range, charging infrastructure availability, and high upfront costs.

- **Charging Infrastructure**: The development of charging infrastructure is essential for the widespread adoption of EVs. This includes the deployment of public charging stations, as well as the integration of charging facilities into residential and commercial buildings [559]. Smart charging technologies, such as dynamic pricing and load management, can help optimize the use of charging infrastructure and reduce the impact on the electricity grid.

- **Vehicle-to-Grid Integration**: Vehicle-to-grid (V2G) integration is a concept where EVs can not only draw power from the grid but also feed electricity back into it during periods of high demand. This technology has the potential to provide grid services, such as frequency regulation and peak shaving, while also reducing the need for additional grid infrastructure [559].

Electrification of Aviation

The aviation industry is a significant contributor to global CO_2 emissions, particularly for long-haul flights [530]. The electrification of aviation is a challenging task due to the high energy requirements and limited energy storage capabilities of current battery technologies. There are several research directions

Electric and hybrid-electric aircraft offer the potential to reduce emissions and improve energy efficiency in aviation. These aircraft use electric motors powered by batteries or hybrid systems, which can provide significant emissions reductions compared to conventional aircraft [530]. However, the development of these technologies is still in its early stages, and further research and development are needed to overcome technical and regulatory challenges.

Electrification of Shipping

The shipping industry is another major contributor to global CO_2 emissions, particularly for long-distance voyages [551]. The electrification of shipping is a challenging task due to the high energy requirements and the need for long-range propulsion systems.

Energy storage technologies, such as batteries and fuel cells, can also play a role in powering electric propulsion systems and providing grid services [551]. Energy efficiency measures, such as hull design optimization, propeller efficiency improvements, and waste heat recovery systems, can help reduce fuel consumption and emissions in the shipping industry. These measures can be implemented in both new and existing vessels [551].

28.4 Electrification of Industry

The electrification of industry is a crucial step towards decarbonization and energy efficiency improvement. It involves the use of electricity to power industrial processes and equipment, replacing traditional fossil fuel-based systems. This section provides an overview of the potential benefits and challenges associated with the electrification of industry, as well as some specific examples of electrification in different industrial sectors.

Electrification of industry offers several advantages, such as improved energy efficiency, and lower operating costs. By replacing fossil fuel-based systems with electric ones, industries can significantly reduce their carbon footprint and contribute to global efforts to combat climate change [456].

The electrification of industry presents several challenges, including high upfront costs, the need for infrastructure upgrades, and the potential impact on grid stability. However, these challenges also present opportunities for innovation and the development of new technologies and business models. For example, the integration of renewable energy sources and energy storage systems can help address grid stability issues and provide additional benefits, such as increased resilience and energy independence [437].

The progress and advancements in electrifying certain key industries will be highlighted below:

- **Chemical Industry**: The chemical industry is a major contributor to global CO_2 emissions, and electrification can play a significant role in its decarbonization. The use of electricity to power chemical processes, such as electrolysis and electrochemical reactions, can reduce emissions and improve energy efficiency [284].

- **Steel Industry**: The steel industry is another major emitter of CO_2, and electrification can help reduce emissions and improve energy efficiency. Electric arc furnaces (EAFs) are a promising technology for steel production, offering lower emissions and higher energy efficiency compared to traditional blast furnaces [372].

- **Industrial Processes and Equipment**: Electrification can be applied to various industrial processes and equipment, such as motors, pumps, and compressors. Smart electrification, which involves the use of advanced control systems and data analytics, can further optimize energy consumption and improve overall system efficiency [110].

Chapter 29

Energy Storage Solutions

The transition to a sustainable energy future hinges on our ability to harness and store power from renewable sources like solar and wind, which are inherently variable. Without robust storage, the grid risks faltering under fluctuating supply and demand, undermining efforts to reduce fossil fuel dependence. Energy storage technologies—ranging from advanced batteries to thermal systems and compressed air solutions—are critical for balancing energy flows, enhancing grid reliability, and enabling widespread renewable integration. Electric vehicles (EVs) also play a growing role as distributed storage units, while hydrogen storage, explored in the next chapter, complements these approaches for long-term needs. This chapter delves into the diverse portfolio of storage methods, highlighting their technical principles, applications, and potential to reshape global energy systems.

29.1 Battery Technologies

Batteries are at the forefront of energy storage innovation, driven by escalating needs in transportation, grid management, and consumer electronics. Their evolution is pivotal for improving energy density, scalability, and affordability, ensuring renewables can meet modern energy demands. Below is an overview of key battery technologies shaping this landscape:

- **Lithium-ion Batteries**: These batteries dominate due to their high energy density, efficiency, and long cycle life, making them ideal for EVs and portable devices. They store significant energy in compact forms, enabling longer driving ranges and reliable power delivery. However, challenges persist, including limited reserves of lithium and cobalt, which raise concerns about supply chain sustainability and environmental impacts from mining. Efforts to address these issues include recycling advancements and alternative material exploration [451].

- **Solid-state Batteries**: An emerging technology, solid-state batteries replace liquid electrolytes with solid materials, significantly enhancing safety by reducing fire risks. They offer higher energy density—potentially extending EV ranges—and longer lifecycles, which reduce replacement costs. Their promise for grid storage lies in stable, high-capacity performance, positioning them as a transformative option for future energy systems [406].
- **Sodium-ion Batteries**: Leveraging abundant sodium resources, these batteries provide a cost-effective alternative to lithium-ion technology. Although they have lower energy density, their scalability and affordability make them well-suited for large-scale grid applications, where space constraints are less critical. Ongoing research aims to improve their performance for broader adoption [678].
- **Flow Batteries**: Unlike conventional batteries, flow batteries store energy in liquid electrolytes that circulate through external tanks, allowing easy scaling by increasing tank size. Vanadium redox flow batteries lead due to their maturity and durability, supporting long-duration grid storage. Emerging chemistries, such as iron-chromium, promise further cost reductions, enhancing their viability for renewable integration [383].
- **Electric Vehicles as Storage**: EVs equipped with bidirectional charging can serve as mobile storage units, feeding electricity back to the grid during peak demand—a concept known as vehicle-to-grid (V2G) technology. This approach transforms EV fleets into dynamic grid assets, improving resilience and optimizing energy use. By leveraging widespread EV adoption, V2G could significantly enhance smart grid capabilities [386].

29.2 Thermal Energy Storage

Thermal energy storage (TES) captures surplus energy as heat, which can later be converted into electricity or used directly for heating, offering a versatile solution for renewable energy intermittency. TES systems are particularly effective in applications requiring consistent energy output, such as industrial processes or residential heating. The following technologies illustrate their diversity:

- **Molten Salt Systems**: Commonly integrated with concentrated solar power (CSP) plants, molten salt systems store solar energy as high-temperature heat, enabling power generation after sunset. Their high energy capacity supports extended dispatchability, making them invaluable for grid-scale renewable projects. Advances in salt compositions aim to improve efficiency and reduce costs [179].

- **Phase-Change Materials (PCMs)**: PCMs store energy by transitioning between solid and liquid states, absorbing or releasing heat at near-constant temperatures. This property makes them ideal for compact, high-density storage in applications like building climate control or industrial heat recovery. Innovations in material design are expanding their use across diverse sectors [554].
- **Underground Thermal Energy Storage (UTES)**: UTES systems store heat in subterranean reservoirs, such as aquifers or boreholes, providing efficient seasonal storage. By capturing summer heat for winter use, UTES supports district heating networks and industrial facilities, reducing reliance on fossil-based heating systems [128].

29.3 Compressed Air Energy Storage (CAES)

Compressed air energy storage (CAES) offers a scalable approach to storing energy by compressing air and releasing it to drive turbines during high demand. Its compatibility with renewable sources enhances grid stability, addressing variability in wind and solar output. Key CAES variants include:

- **Traditional CAES Systems**: These systems compress air into underground caverns, later combining it with natural gas to generate electricity. Operational in select large-scale facilities, such as those in Germany and the United States, traditional CAES provides reliable, high-capacity storage, though gas use limits its environmental benefits [86].
- **Liquid Air Energy Storage (LAES)**: An innovative approach, LAES cools air to cryogenic temperatures, storing it as a liquid. When needed, the liquid air expands to power turbines, offering high-density, long-duration storage suitable for grid applications. Its flexibility and reduced reliance on geological formations make it a promising technology [547].

29.4 Synthetic Fuels and Biofuels

Synthetic fuels, produced via Fischer-Tropsch synthesis, combine green hydrogen with captured CO_2 to create carbon-neutral hydrocarbons. These fuels are critical for aviation and shipping, where electrification lags, offering compatibility with existing engines [540].

Biofuels complement these efforts, derived from biomass to reduce fossil fuel reliance. Advanced biofuels avoid food crop competition:

- **Second-Generation Biofuels**: Sourced from lignocellulosic materials like agricultural residues, they minimize land-use conflicts [269].
- **Third-Generation Biofuels**: Produced from algae, these offer high yields on non-arable land, with ongoing research enhancing cost-effectiveness [269].

Hydrogen as a Storage Medium

For long-term, large-scale energy storage, hydrogen stands out, bridging the gap between renewable surplus and demand. Produced during periods of excess renewable generation, hydrogen can power fuel cells, turbines, or industrial processes, offering versatility unmatched by other storage methods. Its detailed role, including production and storage methods, is explored in the next chapter.

Chapter 30

Hydrogen Economy

Hydrogen is a light element that carries a heavy promise. It is at once a technological tool and a rhetorical beacon: a way to imagine energy without soot, an economy run on water and electrons. But hydrogen is not a miracle; it is a chemical vector that must be produced, stored, transported and used with discipline. This chapter synthesizes the technical state of hydrogen in 2025, its principal pathways, the engineering limits and the societal stakes—melding the activist tone of this manifesto with up-to-date technical referencing.

30.1 From Gray to Green: Production Pathways

Today the majority of global hydrogen is produced from fossil feedstocks (steam methane reforming and coal gasification). Low-emissions hydrogen pathways include *blue* hydrogen (fossil feedstock plus carbon capture), *turquoise* hydrogen (methane pyrolysis producing solid carbon + H_2), *pink* hydrogen (nuclear-driven electrolysis), and *green* hydrogen (water electrolysis powered by low-carbon electricity). The International Energy Agency reports that global hydrogen production and demand are growing, but that low-emissions hydrogen still represents only a small share of supply (as of the mid-2020s). The deployment gap between announced projects and commissioned, operating capacity remains significant; many announced projects face cost, financing and permitting headwinds. [292, 278, 458]

Electrolysis technologies

Electrolysis is the principal route for green hydrogen. Primary electrolyser families are: alkaline electrolysis (AWE), proton exchange membrane (PEM), anion exchange membrane (AEM) and high-temperature solid oxide electrolysis (SOEC). AWE is mature and cost-effective for steady operation; PEM offers rapid ramping and higher pressure outputs ideal for coupling to variable renewables but currently carries higher capital costs due to precious-metal catalysts; AEM promises low-cost materials but remains emergent; SOECs offer very high system efficiencies when industrial heat integration is possible but face materials and durability challenges at scale. Estimated electricity consumption for modern electrolyzers is roughly 50–55 kWh per kg H_2 (lower heating value basis) and pathway costs critically depend on the availability of very cheap, low-carbon electricity. [77, 631, 38]

30.2 Storage, Transport and Carriers

Hydrogen's volumetric energy density is low: at ambient temperature and pressure it is diffuse, which forces engineering solutions: high-pressure compression (350–700 bar), cryogenic liquefaction (-253°C), or chemical carriers (ammonia, methanol, LOHCs). Each option trades energy, cost and infrastructure complexity. Liquefaction consumes a substantial fraction of energy and incurs boil-off losses; compression is energetically cheaper than liquefaction but requires heavy tanks; long-distance maritime transport is most efficiently done as an energy carrier (ammonia or methanol) rather than as compressed H_2. Underground salt caverns can provide large-scale seasonal storage in suitable geologies, enabling seasonal balancing of renewable electricity via hydrogen buffer capacity. [444, 292]

Ammonia and other carriers

Ammonia (NH_3) is a dense hydrogen carrier that is liquid under moderate conditions and leverages existing global ammonia shipping logistics. Green ammonia can be synthesized with green $H_2 + N_2$ (Haber–Bosch) and used either directly as a fuel (with NO_x controls) or cracked to release H_2 near the point of use (which requires high-temperature catalysts and energy). Liquid organic hydrogen carriers (LOHCs) offer safe, ambient-temperature transport of hydrogen but require catalysis and thermal management to release H_2. Methanol and e-fuels are carbon-containing products made from H_2 and captured CO_2; they are convenient fuels for existing engines and shipping but are energy-intensive to produce. The overall message: carriers enable trade and long-distance transport but introduce conversion energy losses and infrastructure demands. [444, 278]

30.3 Power-to-X and Industrial Use

Hydrogen sits at the node between electricity and hard-to-abate sectors. Power-to-Hydrogen enables seasonal energy storage (converting surplus renewable electricity to H_2), Power-to-Gas (synthetic methane), Power-to-Liquids (Fischer–Tropsch e-fuels) and Power-to-Chemicals (green ammonia, methanol). Hydrogen is especially promising in three industrial roles:

1. Direct chemical feedstock replacement (green H_2 for ammonia and methanol production).

2. High-temperature industrial heat and as a reductant (e.g., H_2-DRI for steel).

3. A feedstock for synthetic fuels for aviation and shipping where energy density and infrastructure constraints make batteries impractical.

However, every conversion step (electricity $\rightarrow$ H_2 $\rightarrow$ fuel $\rightarrow$ motive power) incurs efficiency losses; thus, hydrogen should be prioritized where direct electrification or batteries are not feasible. [301, 292, 608]

30.4 Transport: Where Hydrogen Wins and Where It Loses

Hydrogen's competitive advantages are most visible in heavy transport (long-haul trucks, shipping, aviation via e-fuels) and in remote or non-electrified rail lines. For passenger vehicles and short-range urban transport, battery electrics often beat hydrogen on round-trip efficiency, capital cost and infrastructure readiness. Fuel-cell trucks and buses offer quick refuelling and lower mass penalties than battery alternatives on very long routes, but require the buildout of refuelling infrastructure and often depend on early hydrogen hubs to achieve economics of scale. [278, 38]

30.5 Economics, Environment and Policy

In the mid-2020s, green hydrogen costs are dominated by electricity price and electrolyser CAPEX. Where renewables are very cheap and electrolyzers are scaled, modeled LCOH (levelized cost of H_2) approaches targets of \$1–2/kg in exceptional locales, but typical costs remain higher. Policy levers—carbon pricing, production tax credits, public procurement, hydrogen offtake agreements and a hydrogen bank—are essential to bridge the cost gap during industrial scaling. At the geopolitical scale, hydrogen creates new trade patterns: solar/wind-rich countries may export hydrogen carriers to industrial importers, but this risks new dependencies and potential "green colonialism" if local benefits and environmental safeguards are not guaranteed. [292, 278, 458]

Green hydrogen can deliver substantial emissions reductions for industrial sectors and reduce local air pollution. Yet water demand, land use for renewables, rare metal demand (for catalysts and membranes) and the lifecycle footprint of intermediate carriers require careful lifecycle assessment and social planning. Blue hydrogen risks "locking in" fossil value chains and suffers from methane leakage and potential low capture rates; therefore strict methane mitigation and high capture factors are non-negotiable for blue projects to be genuinely climate-beneficial. Equitable planning, local participation, and transparency are central to ensuring that hydrogen projects contribute to a just energy transition rather than extracting value from vulnerable regions. [608, 59]

Hydrogen's Achilles heel is efficiency. The round-trip efficiency from renewable electricity to usable motive power via H_2 and back is often below 50%. This fact underpins a simple policy rule: prioritize: **(1) avoidance and efficiency**, **(2) direct electrification where feasible**, **(3) hydrogen for hard-to-electrify uses**, and **(4) synthetic fuels only where necessary**. Wasting renewable electrons through avoidable conversion chains is both costly and ethically questionable when rapid decarbonization is imperative. [631, 254]

A pragmatic hydrogen strategy has several pillars:

- Scale cheap, reliable renewables while preserving ecosystems and water resources.
- Invest in electrolyzer manufacturing at scale, supply chains for critical materials, and support R&D into low-cost, low-precious metal designs (AEM, advanced PEM, SOEC materials).
- Deploy hydrogen where direct electrification is impractical (steel, chemicals, long-haul shipping and aviation via e-fuels).
- Create strong standards for lifecycle emissions reporting, methane control, and social safeguards.
- Use trade and diplomacy to avoid extractive export models and ensure local value capture.

These pillars demand public support and governance: hydrogen won't scale purely by market forces in the time window needed to avert catastrophic warming. [278, 292, 458]

Conclusion

Hydrogen is both tool and symbol. As a tool it has specific niches in deep decarbonization; as a symbol it lets us imagine a world where engines breath water. Yet symbols can mislead: if hydrogen is used as an excuse to delay electrification or to justify new fossil infrastructure with token capture, it becomes a trap. The ethical demand is clear: use hydrogen where it is necessary and effective, integrate it with broader conservation and electrification strategies, and govern its development to serve people and ecosystems, not merely profit. In this way hydrogen may help stitch a damaged world back together—if, and only if, we pursue it with humility, discipline and justice.

Chapter 31

Sustainable Agriculture & Land Use

The sky's water has fallen, and autumn clouds are thin,
The western wind has blown ten thousand miles.
This morning's scene is good and fine,
Long rain has not harmed the land.
The row of willows begins to show green,
The pear tree on the hill has little red flowers.
A pipe begins to play upstairs,
One goose flies high into the sky. Du Fu

The Earth is not merely a quarry, nor the soil merely a medium for petrochemical growth. Food is the most intimate of human technologies, and our current global food system is the single greatest expropriator of land, water, and atmospheric balance. To survive, we must transition from farming the Earth as a resource to stewarding it as a living system. This chapter rejects the 'more yield at any cost' paradigm and examines the necessary synthesis between ancient ecological wisdom and the measured application of novel technology.

31.1 Traditional vs. Sustainable Agriculture

Modern agriculture has achieved astonishing yields, but at an enormous ecological cost. Today roughly **a quarter of humanity's greenhouse gases** come from food systems, and agriculture occupies nearly **half of the planet's ice-free land** [514].

Industrial "traditional" farming typically relies on monocultures, synthetic fertilizers and pesticides, heavy machinery, and fossil-fuel irrigation to maximize yield. This techno-optimist approach may raise production in the short term, but it exhausts soils, pollutes water, and erodes biodiversity. Large-scale clearing of forests and grasslands for farms has been the main driver of global biodiversity loss, contributing to catastrophic declines in species populations [514, 298].

Working with Natural Cycles

By contrast, sustainable agriculture emphasizes working with natural cycles. It uses crop rotations, polycultures, agroforestry and integrated pest management to build soil fertility and ecological resilience [15].

Organic and agroecological farms generally build higher soil carbon and have lower nutrient runoff per hectare [620]. However, many analyses find that organic yields average only about **75–80% of conventional yields**, meaning that more land is needed to match output [620, 514].

In essence, sustainable farming trades off some efficiency for long-term health: soil and water are protected so that future generations can still farm. The United Nations defines sustainable land use as meeting human needs while maintaining long-term productivity and environmental function [625]. Under that mandate, responsible agriculture must balance productivity with ecosystem care – breaking the old notion that infinite "growth" on finite land is possible.

31.2 Artificial Meat and Plant-Based Alternatives

The Promise of Novel Proteins

In response to the crises caused by livestock, novel protein sources are surging. Animal agriculture generates **14.5–18% of global greenhouse gas emissions** and is the leading cause of deforestation in tropical regions [588, 489]. Cultured (lab-grown) meat and plant-based "meat substitutes" promise to fill bellies without grazing planets under hoof. Cultured meat is grown from animal cells in bioreactors instead of farms.

Proponents point out that it could, in theory, eliminate most land use and animal slaughter. One review notes cultured meat could potentially reduce:

- Greenhouse gases by **78–96%**
- Land use by **82–99%**
- Water use by **82–96%**

compared to conventional livestock [674]. Plant-based burgers (made of soy, peas, etc.) already use far less land and water than beef [489]. These innovations appeal to our conscience and to techno-optimists' faith in gadgets.

The Reality Check

Yet caution is essential. Recent life-cycle studies show cultured meat currently requires enormous energy and highly refined inputs. Using today's methods (with pharmaceutical-grade growth media), cultured beef may emit **4–25 times more CO_2** per kilogram than ordinary beef [496].

Even if media are made food-grade, its climate footprint remains highly variable (possibly 80% lower to 26% higher than beef [496]). In short, "cultured meat is not inherently better for the environment... [It] is not a panacea" [496]. Immense technical breakthroughs (cheaper, clean energy and media) are needed before cultured meat can shrink emissions.

Meanwhile, plant-based meats, while much lower-impact, often rely on monocropped soy or palm oil – crops that have their own deforestation footprints. In sum, alternative proteins can be part of the transition, but they will not magically feed the world on their own. We must also reduce overall meat demand through dietary shifts [657, 584] and reform agrifood systems rather than count on a single silver-bullet substitute.

31.3 Organic Farming and Manure Digestion

The Organic Paradigm

Organic farming exemplifies an older sustainable paradigm: rely on natural fertility rather than petrochemicals. In organic fields, synthetic fertilizers and pesticides are replaced by composts, green manures, crop rotations and biocontrol.

This tends to enhance soil life and wildlife; indeed, most studies find organic farms have richer biodiversity and greater soil organic matter per unit area [620]. Without synthetic nitrogen, organics often emit less nitrous oxide per hectare, and lower soluble nutrient losses into waterways [620].

However, the yield gap means organic farms need more land to produce the same output, so nitrous and ammonia emissions per kilogram of food can be higher than on conventional farms [620]. This underscores that sustainable farming isn't just about being "organic" but about overall efficiency and land use.

Manure Management and Its Contradictions

A key practice in both organic and mixed farms is using animal manure as fertilizer. If left untreated, manure in lagoons emits methane, a potent greenhouse gas. Anaerobic digesters have become popular: they capture methane to produce biogas (renewable energy) and leave a stabilized fertilizer.

In principle, digesters "reduce overall methane emissions and provide many benefits" [160]. In practice, their impact depends on scale and oversight. Some activists warn that on factory farms, digesters have become greenwash. They argue digesters often do not halt environmental harm but can lock in industrial animal production and even create local pollution (ammonia, nitrates) [199].

As one community activist put it, subsidizing manure biogas sometimes "doubles down on the sacrifice of water, land, people, and wildlife for the sake of profit" [199]. Thus, organic practices and manure digestion can contribute to sustainable cycles, but only if paired with limits on farm scale and a return to mixed, humane husbandry.

31.4 Local Food Systems

Reconnecting Farm and Fork

Local and regional food systems seek to shorten the distance from farm to fork. Farmers' markets, community-supported agriculture, urban gardens, and farm-to-institution programs reconnect people with nearby land.

Buying locally-grown food keeps money in rural economies and "helps keep family farmers farming" [31]. It also rebuilds the deep ties between people and the soil that corporate supply chains often sever. Local systems can improve nutrition and community health by providing fresher produce [31].

Beyond Food Miles

In principle, shorter supply chains mean lower transport emissions, though in reality transport is only **∼20%** of food's carbon footprint [165]. (Indeed, an EU study finds transportation causes about 19% of food-system CO_2 – far less than production and land-use changes [165].) Thus, while "food miles" matter less than often imagined, local systems still reduce that slice and offer other co-benefits.

A truly sustainable food system must be diverse and decentralized. Local approaches emphasize seasonal diversity and can adapt to climate limits in each region (e.g. investing in drought-resistant local varieties). They also increase resilience: if global supply chains break down, regional food networks help keep communities fed.

Local food aligns with the philosophical ideal of food sovereignty – that people should have a say in where and how their food is grown [479]. However, we must remember limits: no single village can grow bananas in winter, nor sustain megacities purely by their outskirts. Local systems complement global trade and high-yield farms but do not replace the need for overall diet change (e.g. less meat, less waste) [548]. In sum, local food strengthens community and ecological health, but it must be supported by smart consumption and robust ecology.

31.5 Precision Agriculture and Agrotech

The Tech-Driven Vision

"Precision agriculture" and other agri-tech innovations promise to optimize farming with drones, sensors, GPS, robotics and AI. The vision is compelling: satellites and soil probes pinpoint exactly where to water or fertilize, and robots weed or pollinate on demand.

In principle, this could reduce input overuse and increase resilience. The industry claims it will "minimize inputs and the costs and environmental problems" of farming [320]. Major agribusiness players are investing heavily. For example, farmers spent nearly **$25 billion** on tractors and equipment in 2020, reflecting a rush toward automation and data-driven tools [320].

Hype vs. Reality

But the real-world benefits remain unproven. Critics note that much of the hype around precision tech is marketing, not yet reality. Many systems are still prototypes; few have been rigorously tested at scale. As one researcher bluntly observes, "the promises of precision agriculture still haven't been met… there's precious little real-world data proving whether they work" [320].

And "reducing inputs" is not guaranteed: technologies often aim to target inputs more effectively, but total fertilizer or pesticide use might not decline if acreage expands. There is also a social dimension: expensive precision tools tend to favor large farms with capital, potentially widening disparities.

Furthermore, endless faith in tech can distract from simpler solutions (like crop rotation or cover crops) that are often cheaper and equally effective at improving yields sustainably. In sum, precision farming should be seen as one tool, not a silver bullet. It may help improve efficiency, but it does not replace the need to respect biophysical limits or to radically rethink our agricultural models.

31.6 Regenerative Agriculture

The Soil-Building Movement

Regenerative agriculture has become a buzzword in recent years. It emphasizes soil-building practices: no-till plowing, keeping living roots year-round (cover cropping), integrating livestock on pastures, and restoring grasslands.

Proponents claim it can lock carbon into soils, restore degraded lands, and even reverse climate change. Indeed, research shows that well-managed cover crops can sequester significant carbon; for example, pairing cover cropping with no-till could theoretically hold back **∼900 million tons CO_2** annually [32].

The Climate Limits

However, recent analyses urge caution. A 2025 study finds that the practices that sequester the most carbon (no-till plus cover crops) come at a steep cost: crop yields drop dramatically (an estimated **140 million tons less grain** by 2050) [32]. Cover crops alone may even increase yields but sequester less carbon.

If regenerative practices were adopted worldwide on all crop fields, the model projects only about a **1% annual reduction** in global emissions [32]. In other words, regenerative farming "falls short as a climate fix" by itself [32].

As the study's lead author emphasizes, these methods are more about "soil security" than climate mitigation; they are "not the silver bullet or panacea" for the climate crisis [32]. They cannot make up for continued deforestation or high meat consumption.

Ecosystem Benefits Beyond Climate

Despite this, regenerative practices can greatly improve farm ecosystems. Better soils mean better water retention, resistance to drought, and healthier plants. Incorporating trees and perennials through agroforestry can boost biodiversity on farms while providing multiple products [325].

But policymakers and farmers must avoid greenwashing: throwing billions at "climate-smart agriculture" without addressing the root problems (like excess nitrogen or the livestock glut) is dangerous. Regenerative farming should be one part of an interconnected solution that also includes diet shifts, conservation, and fair land policies. We must acknowledge its limitations even as we embrace its strengths.

31.7 Vertical Farming and Controlled Environment Agriculture

Farming Indoors

Vertical farming and other controlled-environment agriculture (CEA) bring food production indoors or into greenhouses under tight control of light, temperature, and moisture. These systems can grow leafy greens and herbs year-round, using far less water and no pesticides. By stacking layers, vertical farms use a fraction of the land needed by field crops. They promise fresh produce in cities, reduced transport, and a climate-independent supply.

The Energy Problem

Yet this new frontier comes with a dark side: energy. Artificial lighting, heating and cooling demands are enormous. In one analysis, even optimized vertical farms needed at least **16–20 kWh** of electricity to produce one kilogram of vegetables [651].

On average, indoor vertical growers report **∼38.8 kWh/kg**, implying about 18.4 kg CO_2 emitted per kg of produce if powered by today's electricity grids [651]. By comparison, outdoor tomatoes are on the order of 2 kg CO_2/kg [651].

Under fossil-heavy grids, vertical produce can have a **much higher carbon footprint** than field-grown crops. Modeling shows that only with nearly fully decarbonized energy can indoor farming avoid being worse than imported fresh produce [106].

In practice, vertical farms today are mostly niche: boutique lettuce or herbs in wealthy cities, often at high cost. They are not a panacea for staple crops or global food security. The environmentalist priority is not necessarily to send farms up skyscrapers, but to keep more farmland connected to nature. However, vertical farming can play a role in diversified, local systems – especially if paired with renewable power – rather than as a replacement for all farmland.

31.8 Sustainable Land Use Policies and Practices

Operating Within Planetary Boundaries

Ultimately, agriculture and land use must operate within planetary boundaries. The science is clear: land use and land degradation are primary drivers of biodiversity loss and climate change [625, 514, 298]. Agriculture has already transgressed multiple planetary boundaries, including those for biosphere integrity, biogeochemical flows, and land-system change [519, 94].

Sustainable land policy must slow deforestation, restore soils, and protect high-value ecosystems (wetlands, old-growth forests, peatlands) even as it feeds people. Achieving this requires systemic change: agricultural subsidies and trade rules must no longer reward short-term yields at the expense of soil or forest.

Policy Reforms and On-Farm Integration

For example, the European Union's reforms (the CAP "Green Deal" and eco-schemes) now tie funding to biodiversity measures and carbon-friendly practices. Likewise, global commodity supply chains need strict "no deforestation" enforcement.

On-farm, practices like agroforestry and permaculture can merge production with habitat. Integrating trees into croplands and pastures can boost carbon storage and microclimates while diversifying farmers' income [325]. Policies should support agroecological principles (diversity, recycling nutrients, local knowledge) across scales [15].

Effective land use planning also means empowering smallholders and indigenous communities, whose traditional stewardship often outperforms modern plow [208, 29]. Secure land rights for them can yield surprisingly large benefits for conservation and equity.

Accepting Biophysical Limits

Above all, society must accept that infinite economic growth on a finite Earth is impossible. Genuine "sustainability" in agriculture means living within biophysical limits:

- Stabilizing population and consumption
- Valuing ecosystem services
- Sharing land equitably
- Reducing food waste (currently ~**30% globally**) [171]

Only with this ecological realism – not blind faith in tech or growth – can we farm in harmony with the web of life.

Chapter 32

Circular Economy & Sustainable Materials

This chapter re-frames the ”circular economy” not merely as advanced recycling, but as a comprehensive economic model designed to eliminate waste, keep materials at their highest value, and regenerate natural systems. It contrasts the destructive linear ”take-make-dispose” model with a circular ”reduce-reuse-remanufacture-recycle” framework. We explore the distinct strategies for technical and biological cycles, the digital technologies that enable circularity, and the role of sustainable materials as the building blocks of this new, persistent economy.

32.1 The Foundations of the Circular Economy

The industrial engine of the linear economy—built on a creed of ”take-make-dispose”—is a vector of its own demise. It presumes infinite sources and infinite sinks, finding neither. This model bleeds embodied energy, engineers volatility, and chokes the biosphere in its own effluent [155]. The circular economy is not mere sustainability; it is a regenerative system, restorative by design. Its principles are stark: 1) Design out waste and pollution; 2) Keep products and materials in use at their highest value; and 3) Regenerate natural systems.

It operates on two distinct nutrient cycles, a concept borrowed from nature’s own wisdom [78]. The **Technical Cycle** concerns finite materials—metals, polymers, glass—which must be kept in closed loops of reuse, repair, and recycling. The **Biological Cycle** concerns renewable materials—biomass, food, textiles—which must be returned safely to the biosphere, becoming feedstock for new life.

The "R" Hierarchy: Strategies for the Technical Cycle

The "R" framework is a hierarchy of value. Each step down represents a loss of energy and integrity; thus, recycling is the final, least desirable option, not the first.

Refuse and Reduce (Dematerialization)

The most potent strategy is the one of elegant refusal. This is dematerialization: designing for lightweighting, for efficiency, and for the radical shift from ownership to access [509]. Why own a drill when one needs only the hole?

Reuse and Repair (Extending Product Life)

Here, we fight entropy. Products must be designed for durability, modularity, and serviceability. This is a political act as much as an engineering one, embodied by the rising "Right to Repair" movement, which demands an end to the blasphemy of planned obsolescence [213].

Remanufacture and Refurbish (High-Value Loops)

In these loops, a product's death is merely a transition. Components are harvested, reconditioned, and given new life, a common practice in automotive and high-end electronics. This creates new markets from old, harvesting value from the waste stream.

Recycle (The Last Resort of Circularity)

When all higher-value loops fail, we turn to the base recovery of materials. **Urban Mining** seeks to recover critical raw materials from the vast, dormant ore-fields of our e-waste and infrastructure [34]. Success hinges on purity, demanding **Advanced Sorting**—using AI and robotics to see and separate what human hands cannot. For complex materials like plastics, **Chemical Recycling** (pyrolysis, gasification) offers a path back to virgin-quality feedstocks, breaking the chain of downcycling [499].

32.2 The Biological Cycle and Regenerative Systems

Bio-based and Biodegradable Materials

Here, we borrow from the biosphere. Materials like mycelium, hempcrete, and algae-based bioplastics (PLA, PHAs) offer a path away from petrochemical dependence [279]. Yet, the challenge is acute: we must ensure these materials are sourced regeneratively and are truly compostable, lest they become just another contaminant in the technical stream.

Nutrient and Energy Recovery

Organic ”waste” is a misnomer; it is a misplaced resource. **Anaerobic Digestion** converts this stream into two products: biogas for energy and digestate, a rich fertilizer to regenerate soil. **Biorefineries** take this further, using biomass like lignin not for fuel, but as a valuable feedstock for a new generation of green chemistry [112].

32.3 Sustainable Materials and Green Chemistry

Green Chemistry as an Enabler

Green chemistry provides the fundamental grammar for a circular world [19]. It demands atom economy, the use of benign solvents, and a reliance on renewable feedstocks. Critically, it calls for *design for degradation*—crafting molecules that perform their function and then disassemble harmlessly, or *design for disassembly*, ensuring they can be recovered whole.

Innovations in Technical Materials

The materials themselves must become intelligent. We see the dawn of self-healing concretes and polymers, which mend their own wounds. We see advanced composites designed for easy separation, and carbon-negative construction materials, such as CO2-cured concrete and mass timber, that serve as carbon sinks within our cities [474].

32.4 Enabling the Circular Transition: Models, Tech, and Policy

Circular Business Models (The Economic Engine)

The transition requires new economic models. The **Product-as-a-Service (PaaS)** model—selling performance, not objects—is chief among them. A company selling ”light” instead of ”lightbulbs” is incentivized to make its products last forever [612]. **Sharing Platforms** maximize an asset’s utility, while **Take-Back Schemes** close the loop, making the manufacturer the steward of the material.

Digital Enablers (The ”Up-to-Date” Section)

Data is the connective tissue of the circular economy. **Digital Product Passports (DPPs)** act as a material's logbook, using blockchain or QR codes to track its composition, repair history, and end-of-life instructions [164]. The **Internet of Things (IoT)** provides real-time data for predictive maintenance, while **AI** optimizes the complex choreography of reverse logistics and waste sorting.

Policy and Social Drivers

Policy must make the circular path the path of least resistance. **Extended Producer Responsibility (EPR)** forces manufacturers to be financially responsible for their products' end-of-life [460]. Governments must use their **Green Public Procurement** power to create stable, large-scale demand. Ultimately, this requires a social shift: from ”consumer” to ”user,” fostering a new culture of repair and stewardship.

32.5 Measuring Circularity

What is not measured cannot be managed.

Life Cycle Analysis (LCA)

LCA is the classic tool, but it must be reframed. The linear *Cradle-to-Grave* analysis must be replaced by a *Cradle-to-Cradle* assessment, which measures not a product's end, but its potential for its next life [78].

Material Flow Analysis (MFA)

MFA provides a map of resources at a city or national scale. It tracks the stocks and flows of materials, identifying where value ”leaks” from the system and where interventions can be most effective [84].

Circularity Metrics

New metrics are needed, such as the Ellen MacArthur Foundation's Material Circularity Indicator (MCI), which moves beyond simple recycling rates to measure the true circularity of a product or company [156].

Conclusion

The circular economy is not an environmental add-on; it is a necessary, systemic shift. It is the only economic model compatible with the finite physics of a closed planet. It is the industrial and economic expression of the manifesto's core message: a system that does not perpetuate the cycles of life is a system already dead. The call, then, is to engineers, designers, policymakers, and citizens: become stewards. Steward the technical nutrients, regenerate the biological. Close the loop. There is no other way.

Chapter 33

Green Finance & Policy

If the linear economy is the engine of its own demise, finance is the fuel that feeds its fire. Money is no mere instrument—it is the bloodstream of civilisation, a river of intent that shapes what will live and what will be lost. For centuries, it has financed our ascent and our ruin alike, underwriting the very forces now threatening to erase their authors. This chapter is not about a boutique market for "sustainability." It is about the great redirection of capital itself—the conscious reprogramming of our collective metabolism toward the preservation of life.

33.1 The Instruments of Statecraft: Policy and Price

The market, when left alone, is a blind god: efficient, merciless, and without conscience. It cannot perceive the cost of a dying river, a fevered sky, or a species' last breath. The first duty of policy is to give it eyes.

Pricing the Externality

Every ton of carbon is a theft from the unborn. **Carbon Pricing** is an attempt to make that invisible crime visible. A **Carbon Tax** speaks plainly—a price upon destruction. An **Emissions Trading System (ETS)** offers a more intricate grammar: a finite budget of sin, traded and auctioned [454]. Both are fragile, often diluted by politics, yet they mark the first flicker of accountability in an amoral machine.

Tilting the Field Toward Life

For a century, we have subsidised our own extinction. Trillions flow each year to the industries of death—oil, coal, and gas [117]. Their unmaking begins when that torrent is reversed. **Renewable Energy Subsidies**, **Tax Credits**, and **Feed-in Tariffs** are not distortions but acts of correction, moral instruments disguised as fiscal tools. The state must tilt the field back toward life.

33.2 Re-aligning Capital: Sustainable Finance

The $300 trillion global capital market is a supertanker aimed squarely at the iceberg. "Green finance" is the trembling hand upon its wheel.

Green Bonds and ESG Criteria

Green Bonds are promissory notes for a livable world: capital bound to regeneration [152]. The rise of **Environmental, Social, and Governance (ESG)** criteria is the slow awakening of institutional capital—the realisation that risk is not confined to balance sheets but woven through atmosphere and soil [264]. Imperfect and frequently corrupted, these are still the early tectonics of a moral economy.

Carbon Markets and the Modern Indulgence

Carbon Offsets are the indulgences of our age. They let the polluter pay to keep sinning [170]. While they can direct money toward restoration, they too easily replace repentance with transaction. We must remember: no account can be settled while the furnace still burns.

33.3 The Global Compact: Diplomacy and Agreement

The atmosphere honours no borders. A molecule of carbon knows no nation. The struggle for climate is the first truly planetary politics.

The Fragile Consensus

The **Paris Agreement** remains the most audacious act of human cooperation yet attempted. Its **Nationally Determined Contributions (NDCs)** are fragile vows whispered between drowning nations [626]. Built upon trust and terror, they are proof that survival may yet unite where ideology divides.

The Currency of Justice

Climate finance for the developing world is not generosity—it is restitution. The Global North owes a debt for centuries of atmospheric plunder [516]. **Technology Transfer**—of green hydrogen, grid storage, and solar craft—is a form of reparation, not charity. Justice must be paid in electrons, steel, and time.

33.4 The Alchemy of Innovation: Funding the Transition

The technologies of survival—carbon capture, hydrogen economies, circular material loops—must scale with the urgency of an emergency. This requires a new alchemy: the transmutation of money into meaning.

Public-Private Partnerships (PPPs)

The state must lead as risk-taker of last resort. Its role is to imagine what markets fear, to build where profit hesitates. Then, **Venture Capital (VC)** and private equity may follow, scaling the proven and tempering the bold [415]. The fusion of public purpose and private speed can either redeem capitalism or accelerate its self-destruction.

The Archimedean Levers

Institutions such as the **Green Climate Fund (GCF)** and the **European Investment Bank (EIB)** act as global fulcrums. Their first-loss guarantees and catalytic finance can shift entire markets [662]. Yet their true power lies not in trillions disbursed but in the confidence they summon—the multiplier of belief.

33.5 The Moral Compass: SDGs and Beyond

The **Sustainable Development Goals (SDGs)** are not merely a checklist; they are humanity's last covenant with itself [528]. Climate action (SDG 13) and clean energy (SDG 7) are inseparable from justice, equality, and peace. To pursue technology without compassion is to automate extinction. To pursue profit without purpose is to worship the void.

Conclusion

Finance is not neutral—it is moral architecture. Every bond issued, every loan granted, every stock purchased is a vote cast for the kind of planet that shall remain. The market that profits from planetary collapse is not broken; it is perfectly designed for suicide. The task of green finance is not to decorate this death machine with green ribbons—it is to seize the controls, reverse the flow, and redirect the entire torrent of human capital toward one non-negotiable purpose: the endurance of life.

Chapter 34

Social, Behavioural and Educational Technologies

The greatest engineering challenge is not the fusion reactor, nor the continental grid, but the human psyche itself. We have built a civilisation that rewards destruction and punishes restraint, where comfort blinds the conscience and where every click, purchase, and journey is a silent vote for collapse. The mind, not the machine, is the true reactor core. To change its output is to rewire the species. This is the meta-technology—the architecture of decision, the art of persuasion, and the relentless pedagogy of planetary survival. No civilisation can outlive its own delusions.

34.1 Understanding Human Behaviour and Climate Action

Between knowing and doing lies the abyss. The human operating system evolved to fear the tiger at the door, not the temperature curve that rises by fractions [593]. We are creatures of immediacy, tuned to the now, while apocalypse unfolds in geologic time. To bridge this fatal mismatch is the first act of climate engineering.

The Psychology of Climate Change

The mind is a master of denial. It shelters itself in optimism bias, distance, and distraction. The threat is always "later," "elsewhere," "not me." Yet as the fires spread and the seas rise, these defenses fracture into *eco-anxiety* and *solastalgia*—the grief of watching one's home dissolve [409]. The task before us is to transmute despair into duty: to transform the climate crisis from a policy debate into a moral reckoning, an identity-defining cause.

The Attitude–Behaviour Gap

The gap between belief and behaviour is the graveyard of good intentions. People care, but caring is not doing. Structural inertia, social pressure, and material scarcity trap even the willing. As the **Theory of Planned Behaviour** teaches, intent dies without power [7]. To change behaviour, change the world around it. Make the sustainable path the path of least resistance. The environment must lead the mind.

34.2 Science Communication and Public Engagement

The battlefield of the 21st century is not fought with weapons, but with words, memes, and trust. The side that owns the narrative owns the future.

Principles of Effective Science Communication

The deficit model—the fantasy that ignorance is cured by data—is dead. Knowledge must be lived, not lectured. Effective communication is communion: dialogue, story, and shared meaning [553]. The role of the communicator is that of a myth-maker—someone who gives the crisis a human face and a moral spine. Facts do not move mountains, but stories do.

Combating Misinformation

Misinformation is not noise; it is a weapon. It erodes the commons of truth and sabotages collective will. Fact-checking alone is reactionary—each correction chases a lie that has already metastasised. Instead, inoculate: teach how manipulation feels before it strikes [418]. Build cognitive immunity by revealing the anatomy of deception. In an age of deepfakes, truth itself must learn self-defence.

34.3 Behavioural Change Technologies and Interventions

Design for the lazy angel, not the striving saint. The future depends less on moral perfection than on systems that make virtue effortless and vice inconvenient. Behavioural technology is the quiet revolution—the rewiring of daily life toward planetary sanity.

Nudging and Choice Architecture

Nudging is the art of invisible architecture. It does not command; it whispers. Default settings become moral scaffolds: green energy as the default supplier, paperless receipts as the norm, public transport as the easy choice [609]. Ethical design means guiding, not coercing—making every good choice the simplest one.

Social Norms and Comparison

We are herd animals, and the herd decides our fate. Feedback loops of comparison—energy use, waste reduction, water conservation—turn sustainability into a shared performance [543]. Visibility is contagion: when the act of doing good becomes public, it becomes popular. Every rooftop solar panel is a sermon.

34.4 Environmental Education and Capacity Building

Education is the seed from which the next civilisation will grow. The child in the classroom today will inherit either a desert or a garden. The syllabus decides which.

Formal Education Systems

The curriculum must be rewritten at its root. Climate Literacy is not a subject but a worldview, the grammar of survival. From early schooling to university, disciplines must be fused: science with philosophy, policy with art, data with ethics. The divided mind cannot solve a systemic crisis.

Pedagogy for Sustainability

Learning must be transformative [589]. It must reveal the interdependence of all systems—ecological, social, spiritual—and teach futures thinking not as speculation but as rehearsal. The student must not only imagine a liveable world, but practice building it.

34.5 Ethical Considerations and Justice

Behavioural technologies wield invisible power. They can enlighten—or they can enslave. Ethics must be their operating system.

Autonomy and Manipulation Concerns

Digital nudging, powered by AI, flirts with paternalism. The line between guidance and manipulation grows thin [599]. Transparency is sacred: every intervention must declare its intent and serve the collective good. Influence without consent is not leadership—it is control.

Equity and Inclusion

Technology, like wealth, tends to climb upward. The digital divide risks creating climate solutions for the few while the many bear the heat. Every intervention must be participatory, co-created with those it affects. Justice demands that the burden of transition not fall upon those least responsible for collapse. No one should be made to atone for the sins of the powerful.

Conclusion

The final frontier of technology is the human heart. We can electrify the grid, capture the carbon, and cool the planet—but if our habits remain unaltered, the apocalypse will return by another name. To re-engineer behaviour is to re-engineer destiny. The mind is the lever, and education is the hand that pulls it. The species that learned to split the atom must now learn to master itself.

Part V

Book of Water
Reaching the 22nd Century

Chapter 35

Morieris!

God is death: pious are those who make peace with their fate—only God is forever, and with God's grace life may last a very long time.

Life—or something we do with it—*is* the purpose, death *has* a purpose in making available the space needed for new life. Growing indefinitely, it will scrape Earth dry. This because of the limits in viable energy provided for the system, and limits in entropy we can persist in: limits to both consumption and pollution. Life requires space and space on Earth is limited. Never was there a species that lived forever, because it would be catastrophe: it would be a pest that lived beyond limits where life is possible. What would happen if all ducks failed to die? No more space where an egg would not get crushed under a hundred trillion feet.

> *Dew falls*
> *Dew vanishes*
> *As my body does ——*
> *Naniwa's things*
> *A dream and more dream* [261]

I like living, and I like man living on Earth. I like life even more and I need life for my living. Life is not: extraction onto exhaustion. Life is: receiving and releasing. I am happy to be throughout some of the cycles of nature. I like living and I must die, like all. To rise and to fall, all such cases. No one persists; we can only copy parts of us into future iterations. Through life and death all exist as a flash—cyclical being, this is. The link that is you, may your time be good, and may it be finite. Verily, to grow old, in mind and body more so than in years, is to become a burden. Smoking is moral, in the sense that it is a net-positive in carrying the economy and for carbon footprint. I like living and I must die.

Death is a duty: morieris!

Chapter 36

An Ethic of Nature

If there is to be lasting life, we cannot save the world by unsustainable means as we would only delay the apocalypse. This sense of the ecological, life in perpetuity, I have attempted to induce from the beginning, but to expel doubt I will explicitly state the principle—one might call it an ethic.

The ethic of nature answers one question: is it moral to end life itself for some personal gain? The answer is decided: no. This ethic involves a consideration for the other in interactions with the world: will this maintain a liveable world for (my) children later? It was inspired by—but exists in contrast to—the animal ethic, which is to procure food, safety, sex and control as immediately as possible. The animal ethic is just to persist and procreate. It is a hierarchy of two values that animals live by:

1. I must persist.
2. I must flourish.

The ethic *of* nature (vs the ethic *in* nature) realises the world is not infinite or invincible and treats it accordingly. It follows from insight that living is a dependent affair; you are nothing without humanity, and that humanity is nothing without nature. This ethic orders four values that stewards of the ecosphere live by:

1. Life must persist.
2. My species must persist.
3. I must persist.
4. I must flourish.

Its conclusion is the necessity of the economy becoming an ecology: a place where resources move in circles so that the whole may go on in perpetuity. In point three and four, the subject is to be understood as the idea of self which includes all we love, thus sacrifice is not evil.

Chapter 37

Closed and Slow Economies

Life means to preserve itself; the meaning of life is to perpetuate the cycles in which it exists. A closed system is superior when this meaning is accepted: a closed system promises enough stability for cycles and patterns to emerge and perpetuate. If the system is running out of something or filling up with something then the process will end, almost instantly when looked at on geological or astronomical timescales. From its inception, international trade has proven, by and large, murderous and destructive.

The man made economy is closer to ecocide than it is to ecology. It looks like this: take from Earth, use and consume, discard into environment. We will suffocate and die from toxicity should this continue, and climate change will likely end us sooner. Products must be designed with their final destination (which is a new cycle) in mind from the beginning. To quote Peter Seeger: "If it can't be reduced, reused, repaired, rebuilt, refurbished, refinished, resold, recycled or composted, then it should be restricted, redesigned or removed from production." Plenty has been written on the subject both outside of this book and inside this manifesto, where a whole chapter was dedicated to the subject of implementing circular economies.

> *River and sky becomes one, with not the finest of dust,*
> *Shining brightly in the sky is that lone wheel of a moon.*
> *By this riverside, what person was first to see the moon?*
> *This river's moon, what year did it first shine upon the people?*
> *Generations after generations of human life, not at all does it deplete,*
> *The river's moon is still the same year after year.*
> *It is unknown who this river's moon awaits for,*
> *Only seeing this long river sending off its flowing water.* [677]

For now there is another big question: is an economy better if its wheels turn faster? My life would not improve if I doubled my coffee intake. My walks are more enjoyable than my runs. Why is it better to sell seven expensive meals of fast food than a single cheap but healthy one? Indeed, war requires an outpacing of the other, and who falls behind gets dominated. Yet as the next world war might show us, money cannot buy victory and volume of money circulation will not either. The American empire, which has the higher GDP, is collapsing while China has spent the last hundred years in preparation. In this case-study, the more neoliberal country with the faster, wealthier economy has the most to fear. Therefore it is known that faster economies are not better for the persistence or freedom of peoples.

The haste which torments contemporary man is in fact wholly unproductive. It is said (by no less than Higgs) to have made science less fruitfull. The abundance of trash scientific papers that make finding a good article so difficult confirm his observation. Slow is very often more aesthetically pleasing, now clearly the morally superior and to me simply a better mode of being.

So that is all there is to it: our system of living in cooperation must be made wholly such that all we take from nature is given back again, such that all we put into nature is taken out again. As long as we cannot live and perfectly preserve the balance, we should try and slow down.

Stop it!

In the body, if it is not vital, it can be stopped by volition.

Figure 37.1: Think of recycling as yet another ecological cycle of nature (but this time one that is maintained by man, instead of by whole ecosystems).

Chapter 38

Visions for Future

Pray, and when you pray you should be specific. The world can only become what we envision it becoming. This book has been me instilling my visions of the future unto you and, verily, because history does not stop here now has come your turn to create the future.

The trajectory of the planet around the sun does seem already predetermined for quite a substantial period of the future—the trajectory of the climate on Earth remains unknown. If man realises it is them who makes apocalypse, and does so thoroughly, and changes behavoir accordingly, then who can tell what the future will look like. Although the Earth will keep warming for a good while it is still unknown how well we will mitigate historical pollution and adapt to the weather conditions of the future. The future is a great present because we still remain ignorant of what she contains. However, we can make our future as certain as that of a man who has jumped a skyscraper and is now in freefall. If man remains blind and continues business as usual, then surely we will cross each threshold and tip the scale. If we fuck this up the cascade of disasters may very well render this planet a place where *homo sapiens* and its cousins cannot breathe any longer. Blessed is the Lord, for the future we know not.

It is up to us, as a collective—but moreso as the visionaries and the dreamers, to think of the future we desire and manifest it. It really helps when a prayer is as specific as possible: your date with your beloved is not going to teleport into your agenda but the courage to ask them the next time you meet might be found if you pray for it. A fantasy is an idea of a place you would rather be—an ambition is an idea of where you would rather be plus a plan for getting there. Of the year 2200 we know two things: that there will still be one and only one Earth for all which lives on it, and that what this place will look like will inevitably have been the making of man.

Chapter 39

Solving Democracy

[This chapter will outline the problems of democracy: that it is slow, susceptible to corruption and often ineffective in representing the diverse peoples that live in them. No solutions are presented, the chapter is a question.]

Chapter 40

Solving Capitalism

[This chapter will outline the problems with capitalism: that it is destructive, does not create happiness or flourishing in the natural sense, that its infinite growth will eat up everything. No solutions are presented, the chapter is a question.]

Chapter 41

Cyles of Destruction and Creation

I awake light-hearted this morning of spring,
Everywhere round me the singing of birds—
But now I remember the night, the storm,
And I wonder how many blossoms were broken. -Meng Haoran

Vernal seas...
all day long swelling, falling
swelling, falling -Yosa Buson, Translation by Adam L. Kern, The Penguin Book of Haiku

[Gonna be a banger.]

Chapter 42

On Hope

The world has not ended and as long as there is life, there is hope. You are still living and while you are, you better not give up. As long as this life is our present we can try our best to hold on to it as dearly as we can. There is no way out anyway, the suffering will be great regardless we hope or not.

Pascal's wager states that faith is better in both the case of God's existence as his absence. Flow's wager works as follows: There is no scenario where

Reality \ Mindset	Hope	Doomerism
We're doomed	We fight and lose	We cry and die
We might live	We fight and win	We cry and die

Table 42.1: Flow's wager

submitting to doom and gloom is useful. It will be difficult. There will be dark days. The future will be bleak at times. No matter what happens, we do not give up. Our actions may be drastic, problematic, dramatic and emotional at times—so what? All is forgotten in a few millennia and besides, it is the way of nature. The only thing that matters is whether the actions are righteous.

As we have seen all is connected. Therefore you matter, a lot. This is at times not immediately clear from lived experience. Faith is required to realise cigarette buds do not belong on the ground and to realise that your car too emits CO_2. Hope is required to think the efforts will be worth it. I cannot state this more emphatically: EVERYTHING MATTERS! Everything you do will end up somewhere. Be good.

As long as the world has not ended it is better to strive for survival in defiance of whatever, opposed to thinking it already over and submitting to being waste and waiting for a death you have already yielded to.

Conclusion

Life will stop one day, this is true. But God willing, it does not have to stop this century. All the solutions are present, we just need to do the labour. If everyone is made part of the mission and just does the work then we will succeed. Let an avalanche of climate action shake the world. There is time left, and the world is in a better place to achieve fast revolution than ever before.

God willing, we will find and spread the awareness of our connected being in nature. God willing, we will overcome all problems and put spaceship Earth on a path of life. God willing, we will persist through the dark night and once more feel the cool breeze when morning comes.

Holy Mary, mother of God, pray for us sinners, now and at the hour of our death. [538]

Blessed mother of the Christ, please watch over the trees.

Most high God almighty, save the oceans.

And in the name of all which is holy between Heaven and Earth, let life win.

Amen.

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About the Author

Max Flow, M.C.
(Alias of a poet and physicist from the Netherlands)

Max Flow is the pseudonym of a Dutch engineer, rapper and philosopher whose thought crosses the boundaries between science, technology and ecology. The name itself is derived from a principle in network theory—*The Max-Flow Min-Cut Theorem*—which states that the maximum rate at which something can flow through a system is equal to the flow through its narrowest passage: the maximum flow is found at the minimal cut. After a lecture on this theorem, the monniker *Max Flow, M.C.* was born—at once a call for everything, everywhere, all at once to act on climate change so we may flow through the green transition at maximum speed, and at the same time a hint at the dual nature of the author's thoughts and writings. *Flow* has a background in both the exact sciences as philosophy, and this combination gives him the unique viewpoint of an ecosopher who is deeply grounded in the hard epistemic sciences and their mathematical understanding of the world.

Trained as a physicist and active in the fields of sustainability and systems engineering, the author brings a technical understanding of energy, technology and the limits of growth into dialogue with ethics and art. Having worked on research and development at the interface of renewable technologies and digital systems, he became convinced that technical progress alone cannot save the planet—if we could have frozen the world, and could have built all green systems while humanity politely waited for the day it could resume consumption, then maybe—now, because the transition will progress too slow, we find the still deeper task of rebuilding the mental and social ecologies that determine how humanity relates to the Earth and her nature. A different physical ecology of slower consumption will necessarily follow after this spiritual revolution.

Autodidact in many subjects, *Max Flow* writes on topics ranging from thermodynamics and complex systems to activism and ecological consciousness. His essays and public reflections explore how science and spirituality can converge in the pursuit of planetary survival. He remains largely anonymous by choice: the ideas in this book should be able to propagate freely, unburduned by any reputation the messanger of these ideas may or may not have. The manifesto should speak for itself; its author is simply one node in a much larger network of those on the side of life. The extensive citational work serves this same purpose: to detach the credibility of the book from the credibility of the author. If the reader should disagree with *Flow* then it is not him the reader needs to argue with, as every claim in the book is backed by literature—not just the author, but this whole body of literature is what the skeptical reader needs to outsmart to base their feelings of knowing better.

The author is relatively young and has been rather unsuccessful in life—meanwhile the message needs backing in authority to hold weight. Hence, you are allowed to think of *Max Flow, M.C.* as the hyperautistic superhero who has in fact read every source used in this booklet to completion—a myth as such serves the message better than any of us flawed mortals ever could. So let us pray this guy called *Max* inspires the wicked to mend their ways and the youth to pursue great things, so that the morning will know a cool breeze and so there will be life.

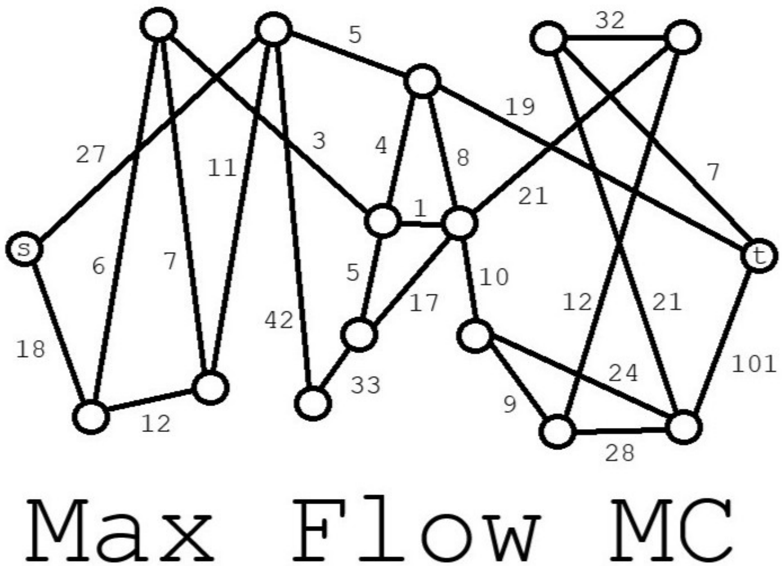

Figure 42.1: Max Flow, M.C. is beyond an author and thinker also a musician using the same alias as a stage name. The music is multilingual Hip-Hop with low fidelity and electronic dance music influences

Support the Work

The message is strongest when the work is charity—however, the work goes faster when a larger commitment of time and energy can be made. It could take 4-8 more months of fulltime work or 2-5 more years of parttime work for the manifesto to see completion. There are very many books the author wants to read, but regretfully reading and study do not pay. Because there is not much time, it has been decided that the author will hereby resort to begging in the hopes of receiving the funds that will allow for full dedication to rapid completion of the project. It is possible to donate one of three crypto coin at the adresses below.

Any donations will firstly go towards maintaining the website that allows for this manifesto's free distribution, secondly to the living expenses of the author while he reads and writes this project to completion, thirdly any provided funds would go towards consulting knowledgeable and authorative figures in the relevant sciences for feedback on and suggestions to chapters relating to their field, and fourthly an editor and proofreaders may be employed. Once the book is done, further donations will be spent on the promotion of the manifesto and on financing reforestation and wildlife preservation efforts.

Support is entirely voluntary and by just reading you are already doing enough and I thank you. The work remains freely shareable, and its message belongs to anyone who welcomes it. From they who can miss it easily, donations are gratefully accepted in the spirit of communitative interdependence and shared responsibility for the future of our planet and race.

Bitcoin	**Ethereum**	**Solana**
`bc1qvvqp9ph3mpc9s9fxujl42skdyp4krgf2qg8486`	`0x8c162cB302c4880C2955fd30155150D4c2dB2a07`	`GHnLGgNfv95sy4a4TwN4jTuujJHq6SGTaCyy3mYoRUtU`