

Media Kit: CLIMATE CHANGE and the road to NET-ZERO

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Short Book Description

CLIMATE CHANGE and the road to NET-ZERO blows away the entrenched idea that solving global warming requires a trade-off between the economy and environment, present and future generations, or rich and poor, and reveals why a twenty-year transition to a zero carbon system is a win-win solution for all on planet Earth.

Long Book Description

CLIMATE CHANGE and the road to NET-ZERO is a story of how humanity has broken free from the shackles of poverty, suffering, and war and for the first time in human history grown both population *and* prosperity. It's also a story of how a single species has reconfigured the natural world, repurposed the Earth's resources, and begun to re-engineer the climate. The book uses these conflicting narratives to explore the science, economics, technology, and politics of climate change. *NET-ZERO* blows away the entrenched idea that solving global warming requires a trade-off between the economy and environment, present and future generations, or rich and poor, and reveals why a twenty-year transition to a zero carbon system is a win-win solution for all on planet Earth.

Short Author Bio

Dr Mathew Hampshire-Waugh is a former director at a global investment bank where his work focussed on renewables, electric cars, batteries, and biofuels. The author gained his doctorate in materials chemistry from UCL, working on nanomaterials to enhance the performance of energy-saving windows and solar panels.

Long Author Bio

Dr Mathew Hampshire-Waugh has spent the last ten years working as an equity analyst at global investment bank. He resigned his role as director in 2019 to commit to writing on climate change and new energy technology full time.

During a decade as an investment banker, the author of *NET-ZERO*, Mathew Hampshire-Waugh has worked with the top executives of many multi-billion-dollar companies, and built relationships with many of the world's largest investment managers. Mathew's work centred on forecasting technology trends, financial performance, and the intrinsic value of companies involved in markets including renewable energy, electric cars, battery technology, and biofuels. His role was to publish and pitch share price recommendations to the world's largest institutional investors, hedge funds, and private wealth managers.

Prior to his career in the banking industry, Hampshire-Waugh gained his doctorate in materials chemistry from University College London, where he worked on novel coatings and nano-materials for use in energy saving glazing and solar panel design. During his doctorate Mathew registered a patent for an efficiency enhancing coating for solar modules, published numerous scientific papers, and engaged in public speaking, consultancy, and media outreach for the BBC, Teachers TV, and other outlets.

Book Reviews

“An excellent layman's perspective of the climate problem today, how it has evolved over time, and the different approaches to solving the problem. I recommend it highly.” - **Mark Z. Jacobson, Professor of Civil and Environmental Engineering at Stanford University and author of 100% Clean, Renewable Energy and Storage for Everything.**

“Mathew brings his wide ranging experience of financial markets, particularly in modelling and forecasting, to add a unique insight to the climate challenge. On one hand, helping us understand how fossil fuels drove prosperity and let the world's population escape the poverty trap, whilst on the other how rising levels of CO2 in the atmosphere placed the world at mortal risk. In this book, Mathew's financial understanding comes to the fore, revealing why we need a sound understanding of economics, climate science and financial modelling to give us the signals we need to act today.” - **Mark Campanale, Executive Chairman of the Carbon Tracker Initiative and founder of the 'unburnable carbon' capital markets thesis.**

“Provides a clear understanding of the technical complexities of reaching zero carbon. Hampshire-Waugh approaches the subject with intellectual rigour, boundless curiosity, and compelling story telling. A must read for anyone interested in climate change and net-zero.” - **Vincent Gilles, Chief Investment Officer at Clim8 Invest.**

“The book that says it all and answers all questions. A comprehensive account of the history of humanity that has led to not only increased prosperity, but also climate change. And the actions and systems change that is now required to prevent dangerous global warming.

Backed by data, analysis and science, Hampshire-Waugh explains how climate change, if left unchecked, threatens to unravel 200 years of human progress. But it need not end this way. The author shows that building a net zero carbon economy is within human reach through focused innovation, riding down the experience curve and reaching scale in clean energy technologies and solutions. Mathew shows how we can solve climate change and air pollution whilst driving development in the poorest parts of the world, and without compromise for those already accustomed to the highest quality of life. Hampshire-Waugh lays out the economic, technological, social and political considerations, showing that even with a global population growing to at least 10 billion, we can achieve greater human progress and prosperity with much lower energy consumption, at a much lower cost, through a net-zero transition. Our efforts to scale up and invest in clean energy technologies over the next 20 years will determine life on earth for the next 100 with long-term benefits far outweighing the short-term costs. Alternatively take no action and we are left with dangerous tipping point risks.

Mathew shares his personal journey to net-zero and the changes he and his family have made to reduce their personal carbon emissions without any compromises to lifestyle. Showing that together we can shape the future and empower change.” - **Geetu Sharma, Founder of AlphasFuture LLC, a sustainability focused investment business.**

Sample Interview Questions

- 1) You argue that fossil fuels have created huge increases to human prosperity – why is it time to leave them in the ground? What about developing countries striving for progress?
- 2) You say the evidence for human induced global warming is irrefutable – what makes you so sure?
- 3) What happens if we make no further change to human systems – what are the physical impacts from climate change?
- 4) And what is the economic cost of climate change? How do these problems compare with other world issues?
- 5) Some people argue we will be richer in the future and with better technology – should we not wait to solve climate change when we are better equipped?
- 6) You talk about tipping points in your book and liken the Carbon Crunch to the Credit Crunch – can you tell us more about the risks involved?
- 7) What about climate engineering and negative emissions technologies are these viable options?
- 8) What is the best way to eliminate carbon emissions and reach net-zero? Is it reducing population or consumption? Or technological change?
- 9) What does a sustainable net-zero energy system look like in the future? Which technologies will play the biggest role?
- 10) What changes need to happen in agriculture to reach net-zero?
- 11) Why do you estimate Net-Zero will be cheaper than the equivalent fossil fuel system when energy agencies and government analysis says it will come at a cost to the economy?
- 12) What technological breakthroughs do we still need to get to zero?
- 13) How can wind and solar end up cheaper than fossil fuels whilst creating more jobs?
- 14) What is the total cost of getting to net-zero and how does the world pay for the upfront investment?
- 15) Why is 20-years the optimum speed in your view?
- 16) Why has change been so slow and are you confident we will avert disaster?
- 17) What are the best actions individuals can take to speed up the shift away from fossil fuels?
- 18) What have we learnt from the response from COVID-19 with respect to the climate crisis?
- 19) How much faster do we need to transition to do it in 20 years?

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Front Cover Image

CLIMATE CHANGE AND THE ROAD TO NET-ZERO



Mathew Hampshire-Waugh

Full Cover Image

Science • Technology • Economics • Politics

CLIMATE CHANGE and the road to NET-ZERO is a story of how humanity has broken free from the shackles of poverty, suffering, and war and for the first time in human history grown both population and prosperity. It's also a story of how a single species has reconfigured the natural world, repurposed the Earth's resources, and begun to re-engineer the climate. The book uses these conflicting narratives to explore the science, economics, technology, and politics of climate change. *NET-ZERO* blows away the entrenched idea that solving global warming requires a trade-off between the economy and environment, present and future generations, or rich and poor, and reveals why a twenty-year transition to a zero carbon system is a win-win solution for all on planet Earth.

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CLIMATE CHANGE and the road to NET-ZERO

Hampshire-Waugh

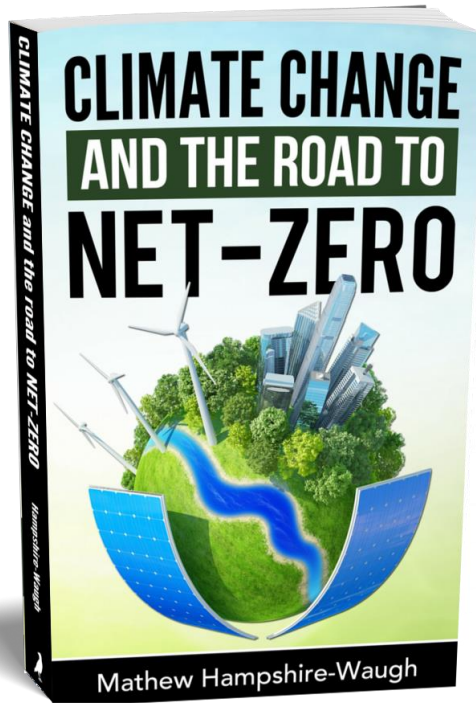


CLIMATE CHANGE AND THE ROAD TO NET-ZERO

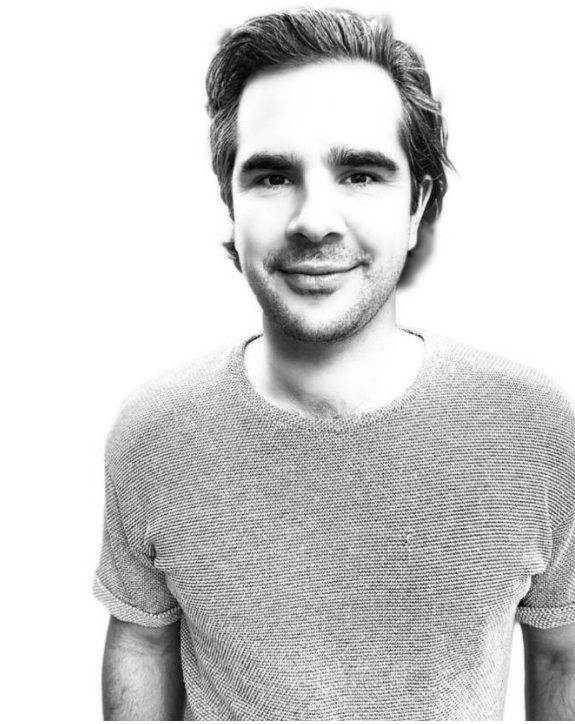


Mathew Hampshire-Waugh

3D Book Cover Image



Author Headshots



Preface

Preface: A Story Unwritten – Planet Earth and Humans

Net-zero: a balance between the emission and removal of greenhouse gases, to and from the atmosphere, by human activity.

What follows is a story.

A story of how humanity has broken free from the shackles of poverty, suffering, and war and for the first time in human history grown both population *and* prosperity.

It's also a story of how a single species has reconfigured the natural world, repurposed the Earth's resources, and begun to re-engineer the climate.

Our story begins with a bitter argument over the future of humanity between two heavyweight eighteenth century scholars, and as it unfolds, we will encounter a cast of colourful characters. From a pioneering female scientist, largely forgotten in history, who first warned about global warming, to a famous chemist who formed the scientific basis for the greenhouse effect as a distraction from his ongoing divorce. We will meet the wealthiest man who ever lived, a computer worm designed to limit the rise of new nuclear nations, and a fictional walrus swimming in the Gulf of Mexico. From fossil fuel tycoons detonating nuclear bombs in the Colorado Mountains to oil executives drinking fracking fluid to appease shareholders. And from the stolen head of an eighteenth century reformist, a drove of pigs living a life so luxurious they brought down a government, to a gaggle of Cold War physicists spreading disinformation and doubt.

At the heart of this story is a wager over the future of our planet. A bet between a celebrity biologist who predicted the impending doom of civilisation unless increases in population and consumption were limited, and a subversive economist who resolutely believed in the power of free markets, technological innovation, and infinite boom.

Where these disparate narratives converge is with the protagonist of our story, carbon dioxide (CO₂)¹. This once innocuous by-product of industrial revolution is now the very definition of anthropic change, threatening to undo two hundred years of progress.

¹ Carbon dioxide or CO₂ is an invisible, odourless gas composed of one carbon bonded to two oxygen atoms.

But this is a story still being written. We will learn how the fundamental science, economics, and technology that underpin climate change forecasts can be adjusted to create drastically different outcomes. Throughout the book I will refer to these three sensitivities as the ‘dials of doom and boom’: the *climate sensitivity* is a science-based value which governs how quickly the temperature will change as we load the atmosphere with CO₂; the *discount rate* is an economic factor which defines how much value we ascribe to future generations; and the *experience curve* is the technological rate of learning which predicts how quickly zero carbon solutions become cost competitive. By tweaking these three dials of doom and boom, turning them up or down, we can completely rewrite the narrative and create diametrically opposed visions of the future using the same science, economics, and technology.

And yet there is an alternative ending. An ending where there is no trade-off between economy and environment, present and future generations, or rich and poor. A net-zero carbon economy. I argue we are at a juncture where the possible range of values for these dials are sufficiently narrow to assert that a rapid transition to net-zero will create a win-win outcome for all sides of the argument. The information is not perfect, the details are not final, but the road is illuminated.

Net-zero offers not only a solution to climate change and air pollution, but an opportunity to create a cheaper, more resilient energy system, a more productive economy, and a better quality of life for everyone on the planet. Net-zero accelerates the ideals of human progress and creates a sustainable society living within the planet’s boundaries and fulfilling our moral obligations to nature.ⁱ

I wrote this book as somewhat of an outsider to the argument, an impartial observer with a background in science and technology and an expertise in financial modelling and forecasting the future. I spent the best part of the last 20 years researching many of the sub-plots in our story; from publishing scientific papers and patents on energy materials as part of my engineering doctorate to forecasting market trends in renewables, electric cars, batteries, and biofuels, during a decade issuing share recommendations at a major investment bank.

Like many others, I too am guilty of climate apathy. I always thought the world would solve global warming, just as “we” banned leaded fuel or fixed the hole in the ozone layer. But we are nearly 30 years on from ratifying the United Nations’ framework on climate change and we continue to pump more CO₂ into the atmosphere than ever before. By most measures little progress has been made, and the warnings from scientists grow ever louder and ever more troubling. The world is aligning with long-term net-zero pledges, but the pace of change today is slow and there is little consensus on exactly *how* to reach zero emissions.

I began writing this book to illuminate all sides of the climate debate, to better understand exactly how big an issue climate change is. How does it compare with other global problems? Is there a workable solution? How much will the solution cost? Are there better ways to use our resources? Is it worth doing and if so, how quickly we should act? And finally, why has climate change proved such an intractable problem? I finished writing this book convinced that a rapid transition to net-zero is undoubtedly the best direction of travel.

Predicting the future is inherently uncertain, so I ask you not to read this as a rigorous scientific proof, economic theory, or political white paper, but as a back-of-the-envelope take on the science, technology, economics, and politics of climate change, air pollution and the road to net-zero. Enrico Fermi was the father of nuclear power; he was also famous for his back-of-the-envelope estimates. Using incomplete information he could calculate the blast strength of an atomic bomb by dropping pieces of paper as it exploded, or he could estimate the possible number of alien civilisations in our galaxy with no more than a handful of astronomical observations. Throughout this book I hope to provide enough information to frame the big picture and enough insight to project multiple visions of the future without getting lost in the technicalities.

I'm not a writer, journalist, or political commentator. I'm a scientist and an analyst. Which is why I want to begin by giving away the end. What follows is a synopsis of the book.

Synopsis

Synopsis: Net-Zero – Empowering Action Towards a Sustainable Future

Human Prosperity and Planet Earth

If the history of the Earth were condensed into one day, the story of human civilisation would start just 0.2 seconds before midnight, or 12,000 years ago, as the planet emerged from the last ice age. At this moment in time, concentrations of CO₂ in the atmosphere stabilised at just below 300 parts per million (ppm)² and average temperatures on Earth settled at a comfortable 14°C. Humans advanced from nomadic hunter gatherers to build permanent settlements supported by a newly dependable agricultural yield. We domesticated animals, repurposed land for growing crops, and transformed the Earth's natural resources to support an ever-expanding human empire.

² 300 parts per million means there are 300 particles of CO₂ for every million particles of all the gases making up the atmosphere or 0.03% concentration.

Populations grew, but prosperity did not. Agricultural production slowly increased but any gains were met with more mouths to feed. So, for most of human history, most humans have experienced the same levels of disease, hunger, and violence as all generations before them. Humanity was stuck in what would become known as the Malthusian Trap.

Thomas Robert Malthus, an eighteenth century scholar, asserted how any improvements to human existence would prove short lived because linear resource increases would always be met with exponential³ population growth. He believed humanity would remain forever imprisoned by the shackles of poverty unless action was taken to limit reproduction. And he was right for most of human history, all the way up until he *actually* published his theory when, two centuries ago, at 0.004 seconds before midnight, along came the industrial revolution.ⁱⁱ

This was the moment modern humans mastered combustion, just as Homo erectus had mastered fire. We unlocked millions of years of the sun's energy stored in fossil fuels⁴ and used it to power the machinery of the modern world: transport, industry, agriculture, and convenience living. Both population *and* prosperity not only expanded for the first time in human history; they exploded. And so did carbon dioxide.

The industrial revolution has created unprecedented population growth *and* prosperity. Average incomes have increased from less than \$1,000 to \$18,000 per person per year (in the equivalent of today's money).ⁱⁱⁱ Life expectancy has doubled, child mortality and extreme poverty are ten times lower, and deaths on the battlefield have declined twenty-fold.^{iv}

We are living through a period of unprecedented wealth, quality of life, and relative peace. Yet not everybody is on board. Half the population still has no basic sanitation, clean cooking, or electricity. Nearly one billion people have no access to safe water or sufficient food.^v Population and consumption will continue to grow as developing countries rightfully strive for modern standards of living. So, unless we fundamentally change how our system is powered, CO₂ emissions will also continue to climb, and ever higher concentrations will accumulate in the atmosphere.

Over the last 150 years, modern science has unravelled the complex relationship between CO₂ and temperature. A relationship that dates back hundreds of millions of years into the deep geological record, through the last million years of ice ages, and into the modern archives of the twentieth

³ A linear relationship means that if you double one variable the other variable will also double. Straight line change. Exponential growth is where the rate of increase in one variable increases with the other. Creating ever larger change. A line curving ever steeper.

⁴ Fossil fuels are formed from dead plant and animal matter compressed and heated in the Earth's crust over millions of years.

century. This is a relationship that has held constant, unwavering through time. The data is clear, the scientific basis sound, and the predictive models have proven accurate so far. Change either CO₂ or temperature and the other will mutually follow; and we now understand how humans are changing CO₂ concentrations in the atmosphere faster than any other planetary event in at least 66 million years.^{vi}

Where eighteenth century scholars debated the perils of an expanding population and the future of the human race, now carbon dioxide, rising temperatures, and climate change have reignited the argument for the twenty-first century. On one side of the dispute sit the neo-Malthusians who foresee a dystopian vision for the future should we not limit population, consumption, and emissions. On the other side of the quarrel are those we might call the cornucopians, drinking from the horn of plenty, convinced that human innovation, technology, and free markets can weather the coming storm. So, who is right? Where should we set our dials of doom and boom as we forecast the future? Are we stumbling into disaster or striding towards ever greater prosperity?

Understanding our Climate Futures to Empower Action

Temperatures are already over 1°C higher than in pre-industrial times. Make no change to our existing systems and most likely we will warm the planet by at least 3°C by the end of this century and by 4.5°C by the middle of the next. Sea levels will rise, and the ocean will become increasingly acidic. Amplifying feedback mechanisms not yet captured in climate models – such as melting tundra, burning forests, or weaker than expected carbon dioxide uptake by land and ocean – may accelerate change even faster.

We are already experiencing three times the number of climate related and (not so) natural catastrophes compared to 40 years ago. The last 20 years have recorded 19 of the hottest in the last two millennia, and with half of the strongest hurricanes on record.^{vii} If we don't change the way we fuel the economy, over the next 80 years 40 million people may die from hunger and natural catastrophes, and 500 million more could be forced to migrate due to extreme heat and rising seas. That would cost the economy \$5 trillion per year.

But the biggest impact won't be from headline grabbing destruction, but from hidden death, suffering, and economic toll. With rising heat, melting ice, and changing weather, more than one third of the global population will lack sufficient clean water and nutrition. The air pollution from burning fossil fuels already kills at least eight million people every year.^{viii} By 2100, one billion lives will have been cut short from respiratory disease and heart failure. The hunger, water shortages,

poor health, and heat, will force labour productivity declines across the economy, bringing total damages to more than \$40 trillion every year or 5% of GDP by 2100.

Compare the death, suffering, and economic toll of climate change and air pollution to other global issues and they already rank in the top three of major world problems, alongside poverty in the developing world and the prevalence of heart disease in rich nations. Continue burning fossil fuels and climate change quickly takes the top spot, before spilling over into nearly every other human problem.

But for our cornucopians the forecast needn't look so bleak. The future isn't simply a bigger, warmer version of the past, and humanity won't just sit back and let rising temperatures and rising seas destroy their food supply, homes, work, and health. If GDP⁵ grows at just half the rate of the last 40 years, average annual income per person will still rise to over \$70,000 by the end of this century. Suddenly, losing 5% of future income becomes a much smaller concern. Why can't future generations simply spend their way out of the problem? Humanity can adapt to a changing climate using an increasingly large pot of wealth to not only minimise associated death and suffering, but also to lessen its economic burden. With the benefit of advanced technologies, more information, and greater wealth, surely future generations are better placed than we are to solve the problem. If done well, climate change could cost the world less than 0.5% of GDP by 2100.

This is where the plot takes another twist. Thus far our story has assumed that climate change follows a manageable or predictable pathway. However, we know that not all change is linear. We know that dangerous tipping points exist where risks grow exponentially and sub-systems may collapse, quickly leading to complete systemic breakdown, whether of the environment, society, or the economy: or all three. The acceleration of melting ice, biosphere feedback, global pandemics, a financial Carbon Crunch, or conflict could trigger a tipping point moment where change is unpredictable and sudden. Damages grow exponentially. The problem may become unmanageable no matter how much money is thrown at it. Tipping points represent a known-unknown event that risks throwing humanity back into the Malthusian Trap unless we take action.

The Earth's systems are currently playing catch up with the rapid increase to the concentration of CO₂ and that means nearly 1.5°C warming is already locked in. Further change is inevitable but should prove manageable. Adaptation will be necessary, but other tactics must be deployed if we are to avoid higher temperatures and unmanageable tipping points.

⁵ Gross Domestic Product (GDP) is a monetary measure of the market value of all the final goods and services produced in a specific time period (usually one year). Divide global GDP by the global population and you get average GDP per capita which is very close to average income per person (ignoring a few adjustments).

At first glance, a technical fix like climate engineering seems the easy, cheap option. But as with most quick fixes, it only solves part of the problem. Limiting solar radiation using space mirrors, aerosols, or cloud whitening, might keep temperatures at bay, but such measures don't solve air pollution or ocean acidification and they run a seriously high risk of going wrong. Negative emissions technologies to remove CO₂ from the atmosphere are lower risk, but more expensive, or can only cover a fraction of emissions. Mitigation of carbon dioxide and the transition to a net-zero carbon economy offers the only complete and low risk path.

Mitigation assumes prevention is better than cure, and yet we are still presented with a range of neo-Malthusian and cornucopian ideals. Greenhouse gases⁶ are the product of population, consumption, energy efficiency, and emissions intensity; so which factor should we target to produce the best outcome? The answer, of course, is all four, but not in equal measure. Attempting to control human reproduction is slow, morally difficult, and practically challenging and the global population should self-limit with growing wealth. Consumption limits are effective but demand a complete re-wiring of socio-economic behaviours and are perhaps best left to activities with little other option. Energy efficiency buys time but never offers a complete solution. The bulk of the change must come from slashing emissions intensity and reaching net-zero.

Systems Thinking to Build Net-Zero

A net-zero transition requires fundamental changes to both our energy supply and our energy demand. Wind and solar electricity coupled with pumped hydro and battery storage can form the backbone of a net-zero economy providing cost competitive, safe, reliable, distributed energy, with no carbon emissions or air pollution. We must electrify everything where possible and where not, switch to hydrogen, biofuels, or carbon capture. Electrification will replace oil-powered transport, gas-powered heating, and coal-powered industry. Global agriculture will need to be modernised to cut waste and lower carbon intensity. Global eating habits will require cutting back on meat consumption to free up enough agricultural land to regrow forests and offset stubborn residual emissions.

Change will be all-encompassing but requires no compromise on quality of life: simply the breaking of old habits. Done well, the transition will barely register for the top 10% of the global population already accustomed to the highest quality of life in developed countries. The remainder of the world will quickly be enabled to raise living standards towards those in the top bracket. The poorest

⁶ Greenhouse gases or GHGs cover all gases that act to warm the atmosphere with the same mechanism as CO₂.

10% will for the first time connect to the modern world with electricity access, clean cooking, and basic amenities. A just and equitable transition for all.

Electricity prices will decline, but as electricity must replace cheap coal and gas heating, so the overall blended price of energy may rise by one third. However, electrification brings large efficiency gains – heat pumps use four times less energy than gas boilers, electric cars three times less energy than combustion engines, and electrified industrial manufacturing can halve energy consumption. A net-zero economy will demand less than half the energy of the equivalent fossil fuel system with no compromise on travel, goods, food, or amenities. Spending on the energy supply declines by one third, despite higher blended prices. The whole system, including the higher upfront cost of equipment, will end up 25% cheaper than the fossil fuel alternative.

Wind, solar, and battery costs are already shrinking by 10-35% every time the number of installations doubles. Hydrogen and biofuels will soon join this commercial experience curve. It's not the passing of time that lowers costs, but the scale of production. Sitting on our hands and waiting for a breakthrough is not the way forward. We have already commercialised 80% of the technology we need so the faster we push, the cheaper it gets. The other 20% merely requires incremental development. The faster we reach net-zero, the sooner we save over \$5.5 trillion per year on our energy system and we avoid worst case climate impacts: we get paid to breathe cleaner air, save lives, avoid climate change damages, and create a sustainable world for future generations.

If that isn't enough, net-zero also cuts air pollution which could save nearly eight million premature deaths per year and create more jobs by directing our energy spending into labour rather than exorbitant profits for petro-states. Net-zero side-steps conflict over dwindling resources and avoids the worst impacts of climate change. A net-zero world will be cheaper to run, cleaner, safer, more reliable, more sustainable, and create more employment than a world bound to fossil fuels.

But let's pause for a moment. Let's sit back, take stock and remember the words of British statistician George Box, that "essentially, all models are wrong, but some are useful".^{ix} The model we will build through the pages of this book is no exception. We can't predict the exact values for our dials of doom and boom: the response of the Earth, the desires of future generations, and the rate of technological progress are inherently uncertain sensitivities. But, I believe that we now have enough information to sufficiently narrow their possible values so that regardless of whether we turn our dials up high or down low, a rapid transition to net-zero will create the best possible outcome for the environment and for the economy. We can avert disaster *and* drive greater human prosperity.

Net-zero is inevitable. But that doesn't mean the speed of the transition can't be optimised. Continuing to run a fossil fuel economy is inefficient and, just like any other market inefficiency, it can be corrected to drive greater prosperity. Think about the value investor Warren Buffet who buys companies trading below their intrinsic value and profits as they rise, or Silicon Valley venture capital firms who recognise the potential of tech enthusiasts running makeshift operations from their parents' garages. These market players profit from inefficiencies and in doing so they also correct them. Warren Buffet's undervalued investment portfolio appreciates, and Apple, Google and Amazon are born. In the same way, markets will undoubtedly move towards net-zero as the best solution; however, by providing an early helping hand to overcome market inefficiencies, the speed of the transition can be optimised, generating greater wealth, improving health, and accelerating prosperity.

Getting to net-zero will require \$70 trillion of upfront investment, \$46 trillion more than sticking with fossil fuels, but it will create an energy system more than \$5.5 trillion cheaper to run each year. A twenty-year transition provides the best balance with enough time for governments, businesses, and individuals to adjust whilst bringing the system cost savings forward and more than offsetting any losses from fossil fuel assets left stranded or from crowding out other investments. The headline numbers sound daunting but break the transition down over the global population and it seems far more manageable. Over the next two decades, we install just four solar panels, plant 27 trees and develop 16 square metres of biofuel cultivation for each person on the planet. We add the equivalent of one (radiator sized) battery in every house and one wind turbine between every 7,000 people. One quarter of car owners shift to ride sharing and the remaining three quarters replace their old vehicles with electric. Half of broken boilers are replaced with heat pumps. It starts to feel far more achievable. Part way through the transition, we decide whether renewables can cost-competitively carry us all the way to net-zero, or whether support from next generation nuclear or fossil fuels with carbon capture is needed. Either way, the best course of action for the next decade is abundantly clear.

Finding \$3.5 trillion of annual investment also sounds like a daunting task. But the world already invests \$1.75 trillion in mostly fossil fuel energy each year and wastes another \$0.5 trillion on fossil fuel subsidies. We need to redirect this money and find another \$1.25 trillion per year (1.5% of GDP) to deploy in net-zero solutions at a competitive market rate of return. The money is ready and waiting to go. It just needs clear direction from governments and private savers. Net-zero financing will create new and productive investment opportunities, boost jobs, and stimulate the economy whilst creating a cheaper energy system with a ten-year payback.

Bridging the Climate Divide to Accelerate Change

Despite the abundant benefits, progress towards net-zero has so far been slow. Since the International Panel on Climate Change formed in 1990, we have emitted as much CO₂ into the atmosphere as all human history before and in 30 years net-zero energy supply has grown from 12% to just 15% of total energy.^x The hurdles to action range from apathy, misaligned economic interests, inequality, freeriding, and political wrangling to deliberate sabotage: each and all has slowed progress. But ultimately the balance of fear has stopped humanity transitioning away from fossil fuels. The perceived threat of climate change hasn't been great enough to overcome the political, social, and economic risk of transitioning the energy system. But the longer we wait, the bigger and more immediate the threat becomes, the more people die from air pollution and, although the cost benefits of a zero-carbon system will become increasingly clear, our window of opportunity for the best possible outcome will inevitably narrow.

The time has come for governments around the globe, corporates, and individuals to stop stalling and to push towards a better system. We are now lining up, ready to clear the bar, and if we can only recognise the benefits of a net-zero system and act on that recognition, we will leapfrog most of the remaining hurdles. Are you a sceptic who doesn't believe in climate change? Or perhaps you don't care about other countries? Well, net-zero will be cheaper, and it will reduce air pollution in your own country. Do you think net-zero technology is too expensive? Well, total buying and running costs will become cheaper once we are just one quarter of the way through the transition and will end up 25% cheaper than fossil fuels once fully scaled. Don't want to risk change? Once the transition is underway, to remain bound to fossil fuels will become uneconomic, unethical, and unimaginable.

Awareness and willingness to act are certainly on the rise. The unified scientific voice grows louder. 26 countries have declared a climate crisis and protests across the globe are mobilising young and old alike.^{xi} Investors are beginning to push companies for change and media outlets are spreading an ever-greater message of urgency. Over one hundred countries around the world, covering well over half of all emissions, have made net-zero pledges for the middle of this century. However, today's average world leader will be nearly 100 years old when those targets come due.^{xii} Clearly translating the long-term pledges, promises, and good-will into short and mid-term action is crucial. We must create change, not just talk about it. Science will continue to be constrained by burden of proof, business limited by burden of profits, and politics limited by popular votes, but recognise the benefits of net-zero and all become aligned. We already have the tools to expedite

change; from left leaning command and control regulation to right leaning market economics and consumer choice.

Individuals can electrify end uses and source zero carbon electricity, forcing demand away from fossil fuels. Vote with your ballot paper and your wallet, choose credible policy and low carbon products. Politicians will soon respond to the changing polls and companies will soon react to falling revenues. Cut back on meat, the one area of consumption where there is no easy substitute solution (the average diet requires one football pitch of agricultural land, whereas the vegan equivalent requires just the penalty box). Reduce consumption where you can, but this should remain a personal choice. Do we need cars, planes, or washing machines to survive and reproduce? No. But they are culturally and economically embedded in our social systems – giving them up is a perceived hardship and we need to avoid the idea that solving climate change requires hardship or a trade-off between our current and future needs.^{xiii} The clear message is that net-zero is not a zero-sum-game, but a win-win, and we have everything needed to transition without compromise. As ecological economist C.S. Holling states, sustainable development is “not an oxymoron but a term that describes a logical partnership”.^{xiv}

Individuals must recognise their role in changing energy demand; not just blaming government inaction or big business profiteering. Corporates should strive for net-zero as the best sustainable economic outcome; greenwashing⁷ should not be used as a marketing tool. Politics should be used to transition the energy system; climate change should not be used as an excuse to change politics. Yes, there may be significant shortcomings with traditional economics, GDP as a measure of progress^{xv,xvi}, and globalised capital markets, but once we understand that a net-zero system will create a more favourable outcome for both right and left politics, big and small business, the individual, and society, then we can accelerate change for the better.

The last decade of stimulus following the Credit Crunch transformed the economics of wind and solar technology which are now competing with fossil fuel power. No analyst, energy agency, or government predicted just how quickly renewables prices would decline compared to their fossil fuel predecessors. Everyone underestimated how much faster technology moves compared to geology. With the unprecedented stimulus being deployed following COVID-19, we now have the opportunity to transform the economics of supporting technologies such as hydrogen and batteries and to begin the full-scale transition to net-zero. Supply must be deployed five times

⁷ Greenwashing is considered an unsubstantiated claim to deceive consumers into believing that a company's products or services are environmentally friendly.

faster and demand switched nearly ten times quicker to reach an optimal outcome. The solutions are ready: we just need to push.

Our story began with CO₂ as the protagonist and air pollution quickly emerged as an equally dangerous accomplice. But the real twist in the tale is that net-zero can solve both problems whilst accelerating underlying wealth, health, and human progress. Net-zero will be cheaper, cleaner, safer, more reliable, more sustainable, and will create more employment than if we remain bound to fossil fuels. By understanding and acting on this statement we can redefine the argument and create a better future for all on planet Earth.

Synopsis: Net-Zero – Empowering Action Towards a Sustainable Future

ⁱ Johan Rockstrom et al., "A safe operating space for humanity", *Nature*, 461, 2009, 472-475.

ⁱⁱ Thomas Robert Malthus, *An Essay on the Principle of Population*, J. Johnson (London), 1798.

ⁱⁱⁱ Angus Maddison, *Contours of the World Economy 1-2030 AD*, Oxford University Press, 2007. (\$1000 = \$500 in 1990 international USD).

^{iv} Max Roser, Hannah Ritchie and Esteban Ortiz-Ospina, *Our World in Data*, [online], accessed 2020.

^v United Nations, [online], un.org, accessed 2020.

^{vi} Richard E. Zeebe et al. "Anthropogenic carbon release rate unprecedented during the past 66 million years", *Nature Geoscience*, 9, 2016, 325-329.

^{vii} Munich Re NatCatSERVICE, "Data on natural disasters since 1980", [online], munichre.com, 2020, accessed 2020.

^{viii} WHO, "Air Pollution", World Health Organisation, [online], who.int, 2020, accessed 2020.

^{ix} The Royal Statistical Society, "George Box: a model statistician", Sept 2010.

^x BP, *Statistical Review of World Energy* 68th edition, 2019.

^{xi} Climate Emergency Declaration, [online], climateemergencydeclaration.org, 7 Feb 2021, accessed 2021.

^{xii} Shuja Asrar, "Can you guess the age of a leader based on average age of country's population", *The Times of India*, Mar 5, 2021.

^{xiii} Nick Winder, "Integrative Research as Appreciative System", *Systems Research and Behavioural Science*, 22, 2005, 299-309.

^{xiv} C. S. Holling, "Understanding the Complexity of Economic, Ecological, and Social Systems", *Ecosystems*, 4, 2001, 390-405.

^{xv} Kate Raworth, *Doughnut Economics*, Random House Business, 2017.

^{xvi} Mariana Mazzucato, *The Value of Everything*, Penguin, 2018, p76.