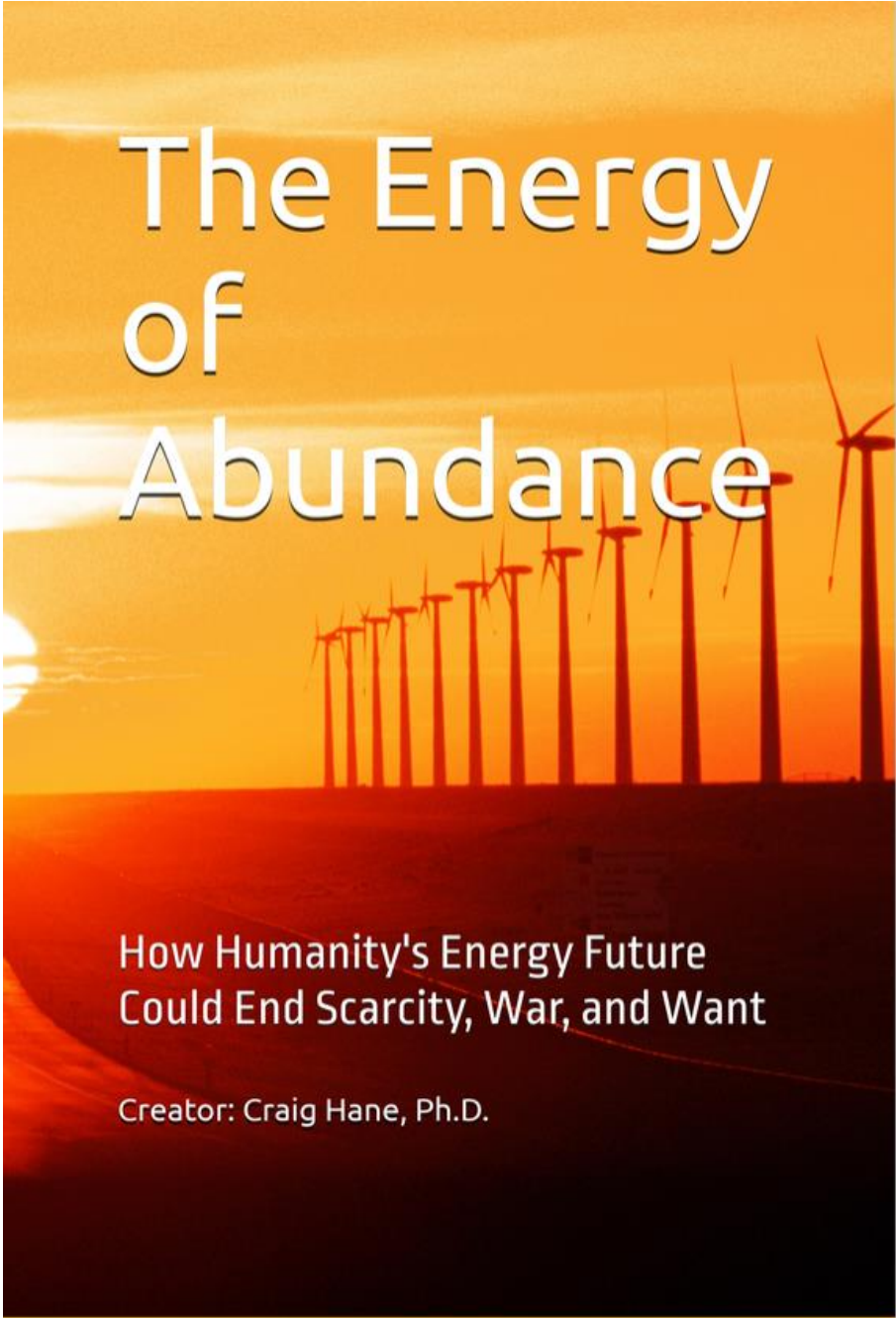




# The Energy of Abundance

How Humanity's Energy Future  
Could End Scarcity, War, and Want

Creator: Craig Hane, Ph.D.



# **The Energy of Abundance**

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# PART ONE: THE PROBLEM WITH ENERGY AS WE KNOW IT

## Chapter 1: The Age of Scarcity Energy

For most of recorded history, energy was local and limited. A civilization ran on the muscle power of humans and animals, the burning of wood, and — eventually — the harnessing of wind and flowing water. Then, in the span of about two centuries, humanity discovered it could burn the compressed remains of ancient life: coal, oil, and natural gas. This discovery didn't just power engines. It rewrote the map of human power itself.

Fossil energy is not evenly distributed. A relatively small number of regions sit atop enormous oil and gas reserves, while the vast majority of nations sit atop none. This single fact — an accident of geology millions of years in the making — has quietly shaped nearly every major conflict, alliance, and empire of the last 200 years. Wars have been fought over pipelines. Governments have been propped up or toppled based on their oil reserves. Entire militaries exist substantially to protect shipping lanes carrying fuel from one part of the world to another.

Energy, in other words, has always been a scarce and unevenly distributed resource — and scarcity, throughout history, breeds both dependency and conflict. Nations without their own energy reserves have had to trade for it, beg for it, or fight for it. Nations with abundant reserves have wielded enormous leverage over those without.

This chapter sets the stage for the rest of the book: what if this fundamental condition of scarcity — the thing underneath so much of the last two centuries of geopolitics — simply stopped being true?

## Chapter 2: The Hidden Cost of "Cheap" Energy

Fossil fuels are often called cheap, but this is only true if you ignore most of their actual cost. The sticker price at the gas pump does not include the trillions of dollars spent by nations maintaining naval fleets to protect shipping lanes, the economic shockwaves that ripple through the world every time a regional conflict threatens a pipeline or a strait, or the money spent propping up unstable governments simply because they happen to sit on valuable reserves.

Nor does it include the environmental cost — the carbon released into the atmosphere, the local pollution that shortens lives in industrial cities, the oil spills that devastate coastlines and fisheries. And it doesn't include the strategic fragility built into a system where a huge share of the world's energy has to pass through a handful of narrow chokepoints — straits and canals that, if blocked even briefly, can send shockwaves through economies on the other side of the planet.

This is the quiet, distributed cost of an energy system built on scarce, geographically concentrated fuel. It's a tax paid not at the pump, but in defense budgets, diplomatic compromises, environmental damage, and the ever-present risk that a single point of failure somewhere in the world could disrupt supply chains everywhere.

The question this book asks is simple: what if none of this were necessary? What if the core ingredients of energy were not buried in a few lucky locations, but were instead available almost everywhere on Earth, all the time?

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## Chapter 3: What "Abundant Energy" Actually Means

The idea at the center of this book is not exotic science fiction — it's a natural extension of physics and chemistry already understood today. Sunlight strikes every part of the globe. Water covers roughly 70% of the planet's surface, and water molecules contain hydrogen — one of the simplest, most energy-dense fuels in the universe.

If we can build systems that reliably and cheaply use sunlight to split water into hydrogen and oxygen, and then use that hydrogen (directly, or converted into other fuels) to power our world, we are no longer dependent on what's buried under any particular patch of ground. We are dependent only on sunlight and water — both of which are, for practical human purposes, limitless and universally available.

This is the concept of an "energy commons": a set of technologies whose core inputs cannot be monopolized by any single nation, cartel, or region, because they exist everywhere. This doesn't mean every country will develop these technologies at the same pace, or that inequality disappears overnight — but it does mean that, for the first time in human history, the fundamental raw materials of energy are not scarce.

The rest of this book explores the specific technologies that could make this vision real, realistic timelines for their development, and — most importantly — what it might mean for humanity if scarcity-driven energy conflict became a relic of the past.

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# PART TWO: THE TECHNOLOGIES OF THE FUTURE

## Chapter 4: Solar's Second Act — Beyond Panels

Solar power today already produces some of the cheapest electricity in human history in many parts of the world, but the technology is still evolving rapidly. Traditional silicon solar cells are being challenged and complemented by perovskite crystals — a class of materials that can be manufactured more cheaply and layered with silicon in "tandem cells" to capture more of the light spectrum, pushing efficiency well beyond what silicon alone can achieve.

Beyond traditional panels, researchers are developing solar paint (photovoltaic material that can be applied like a coating to almost any surface), solar windows (transparent photovoltaic glass that generates power while still letting light through), and floating solar farms that can be deployed on reservoirs and calm coastal waters without competing for land.

The most ambitious idea is space-based solar power: satellites in orbit that collect sunlight 24 hours a day (unfiltered by atmosphere or interrupted by night) and beam the energy back to Earth as microwaves, to be converted into electricity by ground stations. This sounds like science fiction, but small-scale demonstrations have already begun.

**Plausible timeline:** Next-generation, cheaper solar materials could become mainstream in the early-to-mid 2030s. Space-based solar power will likely remain in the demonstration phase through the mid-2030s, with meaningful deployment possible from the 2040s onward if cost and engineering challenges are solved.

## Chapter 5: Splitting Water — The Hydrogen Economy

At the heart of an abundant energy future is a deceptively simple chemical process: electrolysis, which uses electricity to split water ( $\text{H}_2\text{O}$ ) into hydrogen and oxygen. If that electricity comes from solar, wind, or other renewable sources, the resulting hydrogen is often called "green hydrogen" — a fuel with no carbon footprint at the point of production.

Hydrogen is remarkable stuff. Pound for pound, it contains roughly three times the energy of gasoline. Burn it, and the only byproduct is water vapor. It can power fuel cells that generate electricity silently and efficiently, or be burned directly in modified engines and turbines. In principle, hydrogen could fuel cars, trucks, ships, and even planes, with zero carbon emissions at the point of use.

The challenge has never been making hydrogen — it's making it *cheaply and efficiently*, and then *moving it around* once it's made.

### The Transport Problem — and Ammonia's Elegant Solution

Hydrogen's biggest practical weakness is that it is the lightest element in the universe. As a gas, it takes up an enormous amount of space for the energy it contains. To transport meaningful quantities, you either have to compress it under extremely high pressure or cool it down to about  $-253^\circ\text{C}$  to turn it into a liquid — both of which are expensive, energy-intensive, and require specialized, heavily reinforced tanks and infrastructure. Shipping hydrogen across oceans in its raw form, at the scale the world would need, is currently impractical.

This is where ammonia enters the story — and why many energy researchers consider it one of the most important "hidden" technologies in the entire clean energy transition.

Ammonia ( $\text{NH}_3$ ) is a simple molecule: one nitrogen atom bonded to three hydrogen atoms. Nitrogen makes up about 78% of the air around

us, so it's freely available everywhere. When you combine nitrogen from the air with green hydrogen (made via electrolysis), you get ammonia — and crucially, ammonia is vastly easier to store and transport than pure hydrogen. It liquefies at a much more manageable  $-33^{\circ}\text{C}$  (compared to hydrogen's  $-253^{\circ}\text{C}$ ), or can be kept liquid under modest pressure at room temperature. The global shipping industry already has over a century of experience safely transporting ammonia in bulk, because it has long been used to make fertilizer.

In effect, ammonia acts as a "carrier" or "lunchbox" for hydrogen: you pack the hydrogen into the ammonia molecule for the journey, ship it anywhere in the world using existing, well-understood infrastructure, and then use a process called "cracking" to split the ammonia back into nitrogen and hydrogen once it arrives at its destination. The nitrogen is released harmlessly back into the air it came from, and the hydrogen is ready to be used as fuel.

This is why ammonia is increasingly described as one of the cleanest fuels available at scale — not just because burning it directly can be nearly carbon-free (it contains no carbon atoms at all, so combustion produces no  $\text{CO}_2$ , though it must be managed carefully to avoid nitrogen oxide emissions), but because of its unique role as an efficient, safe, scalable way to move the world's cleanest fuel — hydrogen — from wherever it's abundant to wherever it's needed. Large cargo ships, which currently burn some of the dirtiest fuel oil on Earth, are already being tested and built to run on ammonia directly, potentially decarbonizing the shipping industry that moves roughly 90% of global trade.

**Plausible timeline:** Cost-competitive green hydrogen production is likely in many regions by the early-to-mid 2030s. Ammonia-based hydrogen shipping and ammonia-fueled cargo ships could see meaningful commercial adoption by the mid-2030s, with widespread industrial and shipping use plausible by 2035–2050.

## Chapter 6: Fuel from Thin Air — Synthetic Fuels

Some parts of our world are very hard to run on batteries or hydrogen fuel cells alone — commercial aviation being the clearest example, since airplanes need fuel that is extremely energy-dense, lightweight, and liquid at normal temperatures.

The solution being developed is synthetic fuel: taking carbon dioxide captured directly from the air (a process called Direct Air Capture) and combining it with green hydrogen under heat and pressure to build fuel molecules from scratch — molecules that are chemically identical to the jet fuel, diesel, or gasoline that comes from an oil well, but built entirely from air, water, and sunlight, with no fossil carbon involved.

Because the carbon in these synthetic fuels was pulled from the atmosphere in the first place, burning them again simply returns that same carbon to the air — creating a closed loop rather than adding new emissions, unlike fossil fuels which release carbon that had been safely locked underground for millions of years.

This technology directly builds on the hydrogen and ammonia infrastructure described in the previous chapter — the hydrogen used to build synthetic fuel is the same hydrogen that could otherwise be shipped as ammonia, and the two industries are likely to grow up together, sharing electrolyzer technology, renewable electricity infrastructure, and engineering expertise.

**Plausible timeline:** Small commercial-scale synthetic fuel plants are already being built in the mid-2020s. Cost parity with fossil jet fuel is a realistic possibility by the mid-2030s if production scales aggressively and renewable electricity costs continue falling.

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## Chapter 7: Storing Sunshine — The Next Battery Revolution

Generating clean energy is only half the challenge — the sun doesn't shine at night, and the wind doesn't always blow. Storage is what turns an intermittent resource into a reliable, around-the-clock power system.

Lithium-ion batteries, the current standard, are improving but face real limits: material costs, mining impacts, and a practical ceiling of a few hours of storage for most grid-scale battery farms. The next generation of storage technologies aims to solve this in several different ways:

- **Solid-state batteries** replace the liquid electrolyte in today's batteries with a solid material, allowing for higher energy density, faster charging, and improved safety — a technology already moving toward commercial vehicles.
- **Iron-air batteries** use one of the most abundant elements on Earth (iron) in a reversible rusting reaction to store energy far more cheaply than lithium, though at a lower energy density — ideal for stationary, long-duration grid storage rather than vehicles.
- **Liquid air / cryogenic storage** cools ordinary air into a liquid during times of surplus power, then lets it expand back into gas through turbines to generate electricity when needed — using no rare materials at all, just air, industrial refrigeration, and turbines.
- **Gravity storage** uses surplus electricity to lift enormous weights (often disused mine shafts or purpose-built towers), then generates electricity by slowly lowering them back down.
- **Molten salt thermal storage** stores energy as heat in molten salt, later converting that heat back into electricity — commonly paired with concentrated solar power plants.

No single storage technology will likely dominate everywhere; instead, different solutions will likely be matched to different needs — batteries for vehicles and short-duration backup, and iron-air, liquid air, gravity, or thermal storage for long-duration grid resilience.

**Plausible timeline:** Solid-state batteries in mainstream vehicles by the late 2020s to early 2030s. Grid-scale, long-duration storage technologies (iron-air, liquid air, gravity) becoming widespread and cost-competitive through the 2030s and into the 2040s.

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## Chapter 8: Taming a Star — Nuclear Fusion

Fusion is the process that powers the sun and every other star: forcing light atomic nuclei (typically isotopes of hydrogen) together under extreme heat and pressure until they fuse into a heavier nucleus, releasing enormous amounts of energy in the process. Unlike nuclear fission (which splits heavy atoms and produces long-lived radioactive waste), fusion produces very little long-lived waste and carries no risk of a runaway chain reaction or meltdown.

The fuel for fusion — deuterium, a naturally occurring form of hydrogen — can be extracted from ordinary seawater. A single lake's worth of water contains enough deuterium, in principle, to power a fusion reactor for an extraordinarily long time. This is the ultimate expression of the "sun and water" energy vision: a technology that, if achieved at commercial scale, would provide a genuinely inexhaustible power source using one of the most abundant substances on the planet.

The challenge has always been engineering: achieving and sustaining the extreme conditions fusion requires (temperatures hotter than the core of the sun) while generating more energy than the process consumes. Several different reactor designs are being pursued around the world — tokamaks (donut-shaped magnetic confinement chambers), stellarators (a more geometrically complex magnetic design), and laser-based inertial confinement systems that compress fuel pellets with powerful laser arrays.

Progress has accelerated meaningfully in the last several years, with multiple experimental reactors achieving "energy breakeven" moments (producing more energy from a fusion reaction than was used to trigger it) — an important scientific milestone, though still far from the sustained, continuous, commercially useful power generation the world would ultimately need.

**Plausible timeline:** First commercial demonstration fusion reactors are realistically expected somewhere in the 2035–2045 range, per most serious engineering roadmaps, though optimistic private ventures



sometimes project sooner. Broad grid deployment is more likely in the 2050s. This remains one of the most uncertain timelines in the entire book — fusion has a long history of being "30 years away," and continued caution is warranted even amid genuine recent progress.

*Note: By Craig Hane, Ph.D., Creator of this book. A.I. has also been in development for many decades, and only very recently achieved today's abilities. No one saw it happening as fast as it did. A.I. should now accelerate the Fusion Technologies and make them usable within a decade or less. A.I. should also accelerate the creation and adoption of many of these amazing technologies too.*

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## Chapter 9: The Advanced Fission Renaissance

While fusion remains a longer-term prospect, next-generation nuclear fission offers a nearer-term bridge technology. Small Modular Reactors (SMRs) are designed to be manufactured in factories and shipped to a site for assembly, rather than built as enormous bespoke construction projects — dramatically reducing cost overruns and construction time compared to traditional nuclear plants.

Other advanced designs include thorium reactors (using a more abundant, and arguably safer, fuel source than traditional uranium) and molten salt reactors (which use a liquid fuel form that can't melt down in the traditional sense, since it's already molten by design).

These technologies aren't dependent on sun and water in the same direct way as the rest of this book's core vision, but they matter because they provide dense, reliable, always-on power that can support the grid while solar, wind, hydrogen, and storage technologies continue to mature — reducing the world's fossil fuel dependence well before fusion or fully renewable grids are ready to carry the full load.

**Plausible timeline:** SMRs are likely to be commercially operating in multiple countries by the early-to-mid 2030s, with broader adoption through the 2030s and 2040s.

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## Chapter 10: Geothermal Everywhere — Drilling Deeper

Geothermal energy — harnessing heat from deep within the Earth — has traditionally only been practical in volcanically active regions like Iceland, parts of the western United States, and Indonesia, where hot rock sits close enough to the surface to be reached with conventional drilling.

New techniques, often called "enhanced geothermal systems," borrow drilling technology developed by the oil and gas industry (particularly the deep, precise drilling methods perfected during the shale gas boom) to reach far deeper into the Earth's crust — deep enough to access useful heat almost anywhere on the planet, not just in geologically special locations.

This matters because geothermal energy, unlike solar and wind, is available 24 hours a day regardless of weather or season — making it an excellent complement to the more intermittent renewable sources described earlier in this book.

**Plausible timeline:** Enhanced geothermal systems are likely to begin meaningful commercial scaling in the 2030s, as drilling costs continue to fall and more pilot projects prove viability in non-traditional locations.

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## Chapter 11: Wind, Waves, and the Physics of Motion

Wind power has matured rapidly, particularly offshore, where wind blows more consistently and strongly than on land. The newest frontier is floating offshore wind — turbines mounted on floating platforms rather than fixed to the seafloor, allowing wind farms to be built in much deeper water, far from shore, where winds are strongest and visual/noise objections are minimized.

Beyond wind, the ocean itself contains enormous untapped energy in its waves and tides. Various technologies are being developed to capture this — buoys that generate electricity from the rising and falling motion of waves, underwater turbines that work like wind turbines but are driven by tidal currents, and other novel approaches still in earlier stages of development.

These motion-based renewables are a valuable complement to solar and hydrogen: wind often blows at different times than the sun shines, and tides are entirely predictable years in advance (unlike weather-dependent wind and solar), providing planners with a highly reliable baseline to build around.

**Plausible timeline:** Floating offshore wind likely becomes a mainstream technology by the early 2030s. Wave and tidal energy are earlier-stage and less certain, but could become meaningful contributors to regional grids by 2035–2045.

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## Chapter 12: The Grid of the Future

None of the technologies described so far matter much without a grid capable of managing them. A world running on abundant, distributed, sometimes-intermittent energy sources needs a fundamentally smarter electricity system than the one built for the 20th century's large, centralized power plants.

Artificial intelligence is increasingly being used to predict energy demand and supply in real time, matching the variable output of solar and wind with storage systems and flexible demand (for instance, automatically charging electric vehicles when power is abundant and cheap, and pausing when it's scarce).

Smart micro-grids allow individual buildings, neighborhoods, or communities to generate, store, and share their own power — sometimes remaining connected to the larger regional grid, and sometimes able to operate independently ("island mode") during outages or emergencies. In this future, nearly every building, and eventually every electric vehicle, becomes both a consumer and a producer of energy — a fundamentally different, more resilient, and more democratized model than the one-way flow of power from a handful of massive plants to millions of passive consumers.

**Plausible timeline:** AI-managed smart grids are likely to become widespread in developed nations through the 2030s, with global adoption — particularly in developing regions building new infrastructure from scratch — extending into the 2040s.

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# **PART THREE: WHAT ABUNDANT ENERGY COULD MEAN FOR HUMANITY**

## **Chapter 13: The End of Energy Poverty**

Hundreds of millions of people today still lack reliable access to electricity, particularly in parts of sub-Saharan Africa and South Asia. Historically, providing power to these regions meant building the same kind of massive centralized infrastructure — power plants, high-voltage transmission lines, substations — that wealthy nations built over the last century, an enormously expensive and slow undertaking.

Cheap solar panels, batteries, and local hydrogen production offer a different path — one that mirrors how mobile phones allowed many developing regions to skip landline infrastructure entirely and leap straight to wireless communication. Small solar-plus-storage systems can bring reliable power to a village or household without waiting for a national grid to arrive. This "leapfrogging" pattern could allow energy poverty to be solved far faster, and far more cheaply, than the traditional grid-building model would suggest.

## **Chapter 14: Desalination and the Water-Energy Bridge**

Water scarcity is, in many regions, as significant a driver of conflict and hardship as energy scarcity — and the two problems are deeply connected. Desalination (removing salt from seawater to produce fresh water) is a proven technology, but it is currently expensive largely because it requires a great deal of energy.

If abundant, cheap solar and hydrogen-based energy becomes widely available, the cost of desalination could fall dramatically — turning the world's oceans, which cover 70% of the planet, into an effectively limitless source of fresh water for drinking and agriculture. Regions that have faced generations of water-driven conflict and hardship — parts of the Middle East, North Africa, and Central Asia among them — could see one of their most fundamental sources of scarcity meaningfully eased.

## **Chapter 15: Rethinking Geopolitics Without Oil Chokepoints**

For over a century, geography has been power. Nations that controlled oil fields, or the narrow shipping lanes and pipelines that oil had to pass through, held enormous strategic leverage over everyone else. If energy can instead be produced locally, nearly anywhere, from sunlight, air, and water, that particular form of leverage begins to erode.

This doesn't mean geopolitical competition disappears — nations will still compete over manufacturing capacity, technological expertise, rare materials needed for specific components, and economic influence. But the very particular, centuries-old dynamic of scarce, geographically concentrated fuel driving conflict and dependency could meaningfully fade, removing one of history's most persistent sources of war and coercion.



## Chapter 16: The Economics of Near-Zero-Cost Energy

Energy is a foundational input to almost every economic activity — manufacturing, agriculture, transportation, computing, construction. If the marginal cost of producing additional energy approaches zero (which is plausible once the infrastructure to capture sunlight and split water is built, since sunlight and water themselves are free), the ripple effects could touch nearly every sector of the global economy.

Cheaper energy could lower the cost of manufactured goods, food production, clean water, and computing (including the energy-hungry data centers powering artificial intelligence). It's important to be honest here, though: energy is not the only bottleneck in the modern economy. Materials, skilled labor, land use, and manufacturing capacity all remain real constraints that abundant energy alone will not solve. This chapter aims to present a grounded, non-utopian view: cheap energy would be transformative, but it is not a magic solution to every economic challenge.

## Chapter 17: Agriculture Without Limits

Modern agriculture depends heavily on energy — for fertilizer production (traditionally one of the most energy- and fossil-fuel-intensive industrial processes on Earth), irrigation, mechanization, and increasingly for climate-controlled vertical farming in urban environments.

Cheap, abundant energy could transform agriculture in several ways: green ammonia (discussed in Chapter 5) could replace fossil-fuel-based fertilizer production entirely; cheap desalinated water (Chapter 14) could unlock irrigation in currently arid regions; and cheap electricity could make vertical, indoor farming economically viable at a much larger scale, growing food closer to where it's consumed and reducing dependency on long, vulnerable supply chains. Given how directly food insecurity has driven historical conflict and mass migration, this may be one of the most consequential — if under-discussed — implications of an abundant energy future.

## Chapter 18: A Realistic Timeline for Global Transformation

Pulling together the technologies and timelines from Part Two, a rough decade-by-decade picture emerges:

- **2025–2030:** Continued rapid growth of solar and wind; early commercial-scale green hydrogen and synthetic fuel projects; first SMRs coming online; early liquid air and iron-air storage deployments.
- **2030–2035:** Green hydrogen and ammonia shipping approach cost-competitiveness with fossil fuels in many regions; solid-state batteries become mainstream; enhanced geothermal and floating offshore wind scale up; smart grids become standard in developed nations.
- **2035–2045:** Synthetic fuels reach cost parity with fossil jet fuel; first commercial fusion demonstration reactors likely appear; desalination and vertical farming scale meaningfully in water- and land-constrained regions.
- **2045–2060:** Broad global deployment of fusion (if successful), full-scale integration of AI-managed grids worldwide, and — if political and economic conditions align — meaningful global reductions in energy poverty and water scarcity.

This timeline is, by necessity, an informed projection rather than a certainty. Technology development rarely proceeds in a straight line, and political will, investment levels, and unforeseen breakthroughs (or setbacks) could shift these dates substantially in either direction.

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# PART FOUR: THE HARD QUESTIONS

## Chapter 19: What Abundant Energy Won't Fix

It would be dishonest to end this book on a purely utopian note. Many of history's wars and conflicts have been driven by factors that have little to do with energy or resource scarcity at all — ideology, ethnic and religious tension, struggles for political power, and simple human ambition. Abundant energy would remove one major, historically significant driver of conflict, but it would not, by itself, end war or human conflict altogether.

It's also worth being clear-eyed that abundant energy technology could still be hoarded, weaponized, or unevenly distributed. A nation or company that develops dramatically superior fusion technology, or the most efficient electrolyzers, or the cheapest solar manufacturing, could still gain outsized power and leverage — simply of a different kind than oil-field ownership. Abundance in principle does not automatically mean abundance in practice for everyone.

## **Chapter 20: Who Builds the Future — and Who Is Left Behind?**

The transition to an abundant energy world will not happen everywhere at the same pace. Wealthier nations, with more capital, infrastructure, and research capacity, will likely adopt these technologies first — potentially widening, rather than narrowing, the gap between energy-rich and energy-poor regions during the transition period, even if the long-term destination is more equitable.

This raises real questions about international cooperation, technology sharing, and investment. Will breakthrough energy technologies be treated as global public goods, shared openly to accelerate universal adoption? Or will they be closely guarded as competitive and strategic advantages, the way advanced semiconductor manufacturing is today? The answer will significantly shape how quickly, and how equitably, the vision in this book actually arrives.

## Chapter 21: A Blueprint for an Energy Commons

The book closes with a hopeful, but grounded, vision: international research partnerships modeled on successful examples of global scientific cooperation, public and private investment prioritized toward technologies with the greatest potential to reach the most people (not just the most profitable markets), and a genuine global conversation about treating fundamental energy technology — much like clean water or basic literacy — as something the world has a shared interest in making universally accessible.

None of this is guaranteed. But the physics and chemistry underlying this book's vision are already understood today. What remains is a question of human will, investment, and cooperation — whether humanity chooses to build a future where energy, one of the oldest sources of scarcity and conflict, finally becomes what sunlight and water already are: abundant, universal, and free for the taking.

*Note; Craig Hane, Ph.D., Creator of this book. If the Climate continues to get hotter, parts of the world will experience increased Wet-bulb temperatures. This is happening today in the Mid-east countries, parts of India and China, etc. Thus, for those civilizations to survive they must be able to supply Air Conditioning to their workers who currently don't have much, if any. Thus, the things this book anticipates will hopefully come true very fast. I had A.I. create this book for my own education, but also for those of the many members of The Triad Math Army. You may learn all about it at: [triadmathinc.com/tma](http://triadmathinc.com/tma)*

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## Appendix: Glossary of Key Terms

- **Electrolysis:** Using electricity to split water into hydrogen and oxygen.
- **Green hydrogen:** Hydrogen produced via electrolysis using renewable electricity, with no carbon emissions at the point of production.
- **Ammonia (NH<sub>3</sub>):** A compound of nitrogen and hydrogen, used here as an efficient, easily transportable "carrier" for hydrogen.
- **Direct Air Capture (DAC):** Technology that extracts carbon dioxide directly from the atmosphere.
- **Synthetic fuel:** Liquid fuel manufactured from captured CO<sub>2</sub> and green hydrogen, chemically identical to fossil fuel equivalents.
- **Tokamak:** A donut-shaped magnetic confinement device used in nuclear fusion research.
- **Small Modular Reactor (SMR):** A factory-built, smaller-scale nuclear fission reactor design.
- **Enhanced geothermal systems:** Deep-drilling techniques that access Earth's heat in locations without natural volcanic activity.
- **Solid-state battery:** A battery design using a solid electrolyte instead of a liquid one, offering higher energy density and safety.

*Note: All timelines throughout this book are informed estimates based on current research trajectories as of early 2026. They are optimistic-but-plausible projections, not certainties.*