

# The Great Simplification

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[00:00:00] **Tad Patzek:** We operate at the level of policy, politics, moral requirements, and wishful thinking, but we forget about the underlying physical systems, which is the giant infrastructure that provides us with these fluxes of power and materials that we then use without thinking about them. And research extraction will cause additional terribly negative effects on the biosphere.

[00:00:27] By the time you really see how bad this is, it's already delayed.

[00:00:38] **Nate Hagens:** Today, I'm pleased to be joined by chemical engineer, physicist, and my friend, Professor Tad Patzek, for an overarching discussion on the mathematics and physics that explain why and how energy and materials underpin our modern world, as well as the resulting effects on climate, biospheric integrity, and the long-term viability of human civilization.

[00:01:03] Tad Patzek is a professor emeritus of Chemical and Petroleum Engineering and Director of Upstream Petroleum Engineering Center at the King Abdullah University of Science and Technology in Saudi Arabia. Prior to that position, he was the lowest K and Richard D. Folger leadership professor and chairman of the Petroleum and Geosystems Engineering Department at the University of Texas in Austin.

[00:01:27] Additionally, he was previously a professor of geoen지니어ing at the University of California Berkeley, as well as a researcher at Shell Development, a research company managed for 20 years by M. King Hubbard. He is also a full presidential professor in Poland, which is the highest honor and also served as a member of the DOI Macondo Well Advisory Committee.

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[00:01:51] Tad's research focuses on the thermodynamics and ecology of human survival and the future of food and energy supply for humanity. Most recently, he has accumulated his life's research into his upcoming book, *Thermal Power and Climate Change: A Data Driven Analysis of Cause and Effect 1800 to 2100*. In this conversation, Tad walks us through the underlying math and physics that shape the paradox of our entire industrial economic system, including why it needs to grow to remain stable, but also why it must shrink in order to preserve the ecological foundation that it's built upon.

[00:02:34] Tad is one of the smartest, uh, earth scientists I've ever met, and if you enjoy getting into the numbers and technical foundations of humanity's predicament, I think you'll enjoy and learn a lot from this episode. Before we begin, if you'd like to dig deeper into the great Simplification, I invite you to subscribe to our Substack newsletter, which you can find the link to in the show description.

[00:02:58] With that, please welcome Professor Tad Patsick. Tad Patsic at Long Last, welcome to the program.

[00:03:06] **Tad Patzek:** Well, I'm glad to be here. Thank you for having me.

[00:03:08] **Nate Hagens:** I have known you at least 15 years. Uh, I've known of you and your work for longer than that. I think I first came across it on a Patsic and Pimentel, uh, agricultural, uh, scientific paper 25 years ago, probably.

[00:03:25] That's- that's way back in the day. You're probably the smartest energy, uh, earth science, thermodynamics, uh, person in my personal sphere, so I'm- I'm really happy to, uh, what- what, uh, is likely to be a deep dive on the thermodynamics of- of civilization with you today.

[00:03:43] **Tad Patzek:** Well, uh, thank you for entrusting me with all of that.

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[00:03:48] **Nate Hagens:** Yeah. Let's start by announcing that you have recently written a massive book, uh, which I have read/skimmed. I skipped over some of the math, uh, called Thermal Power and Climate Change: A Data Driven Analysis of Cause and Effect. But it's not only about climate change. It delves into the biosphere and energy and materials and complexity and AI and other issues at the heart of our current global crises.

[00:04:19] So let's start this conversation at a- at a very high level. If you, with all of your research and accolades, had to name the one physical variable that quietly controls our fate, what- what would it be? Energy or CO2 or copper or water or temperature or- or something else and why?

[00:04:36] **Tad Patzek:** Obviously, it's energy and not just energy, but energy per unit time or power.

[00:04:45] Um, because everything else, uh, climate change over population, you name it, comes from excessive amount of energy available to humanity. An average human being, uh, develops a metabolic power of little more than 100 watts, of which roughly 20 watts are used to sustain our brain and nervous system. But contrast, an average American consumes approximately 10,000 watts of continuous power, 24 hour per, uh, hours per day, uh, seven days a week, and that's about 100 times more than we need to stay alive.

[00:05:35] A factor of 100 is the difference between running at six miles per hour and flying a jet at 600 miles per hour. It's huge. Another way to- to visualize this huge difference, uh, I've been using for years or decades now comes from biology. If I were to metabolize 10,000 watts as food energy, I would need the body of a 40 ton male sperm whale, an animal roughly a stall as a five-story building.

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[00:06:18] In other words, modern citizens command an enormous amount of power, and that extraordinary power throughput through our societies causes their brittleness, uh, and susceptibility to- to failure.

[00:06:36] **Nate Hagens:** Well, you said, you said, um, uh, an important qualifier, which I don't think I've really explored a lot here. You said in addition to energy per unit time.

[00:06:45] So why is that important relative to just energy?

[00:06:49] **Tad Patzek:** Well, in fact, power is the single most important physical quantity that drives our civilization. If I had lots of energy, but I would have to expand this energy over a century, not over an hour, I don't care. I only care about a 300 horsepower engine in my car, and I care about a jet flying at 600 miles per hour, uh, having thousands of horsepower in its engines and so on.

[00:07:27] And so we- one of the most, um, often made, um, o- o- often, uh, taken misconceptions is equating energy with power. It's power that counts. And in fact, the complexity behind, uh, most social questions can ultimately be reduced to that one variable, the power flowing through a society. Um, so it is also important that- that modern society uses only 30% of its power as electricity and mechanical work per unit time, uh, but the remaining 70% is heat, useful heat and, uh, unavoidable thermal losses.

[00:08:18] So we define actually, uh, I define, uh, uh, uh, advanced societies as those that possess large amounts of surplus power beyond the minimum needed to s- for survival. And these societies then can afford to have many functions that go far beyond basing human necessities, such as food, drinking, water, shelter, and national defense.

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[00:08:47] And in the most ... I- I- I'll just add one more thing. If you really wanna strip it down, then the minimum civilization, uh, that lasts has only two organized systems, agriculture and the army.

[00:09:01] **Nate Hagens:** What do you mean?

[00:09:02] **Tad Patzek:** Agriculture to feed people, the army to defend them. A- and, you know, in our prior book with Joe Tainter, we actually devoted some time to that notion, um, how Constanabal, uh, uh, actually kept going for several centuries by doing just that.

[00:09:21] **Nate Hagens:** So let me stick to the power thing for a second. Do you have any examples of, uh, society or a nation or a culture that had a lot of energy, but not a lot of power? And- and in contrast, a society that had a lot of power, uh, in addition to the energy? And why- why is that, um, i- i- is some example there, maybe?

[00:09:43] **Tad Patzek:** That's a difficult question because it mixes historical epochs and geography. So, uh, a society that had access to a lot of power, solar power through its area was, for example, the Roman Empire. But the only thing in ancient times you could do is you could acquire more power and more material flows by acquiring more area and robbing cities and subjugating and slaving, uh, and slaving other nations.

[00:10:19] So that's how it went for centuries. The first nation that accessed a lot of power early on in the late 17th and 18th centuries, uh, was England, uh, because England had a lot of easily accessible coal, uh, you know, outcropping to the surface. So it was easy to power the English Industrial Revolution early on in the 1750s and later, uh, mining and agriculture, uh, saw that England became the dominant world power.

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[00:10:56] So England, by its nature, uh, is an island that has ... Doesn't get a lot of solar power, but then it supplemented that solar power to an unbelievable degree by coal and then later other fossil fuels. So England, for example, in 1820, I- I- I have the exact date in the book, was as dependent on coal as the United States was dependent on all fossil fuels in 2010.

[00:11:31] So that's one of the, uh, uh, misunderstandings, how early, um, uh, external power, exosomatic power, became important to the wellbeing of modern societies.

[00:11:46] **Nate Hagens:** Just one more, uh, question on this. I think we'll talk about renewable energy later, um, but is there a difference on the power output from, uh, fossil fuels, uh, and solar and wind and- and things like that?

[00:12:00] And- and why is that important to this part of the conversation?

[00:12:03] **Tad Patzek:** The so- called renewables, which are in effect, uh, machines that we construct for a limited time using fossil energy mostly, uh, then work using acquiring renewable, uh, solar energy flows, be it light or wind or water, you know, the derivatives of solar energy, but they are like a mist, like, uh, in the air.

[00:12:39] They are what they are. It- the- you know, the amount of solar energy doesn't change and clouds can disrupt them. Uh, so they operate on a diametrically different principle than a highly dispatchable, flexible battery, which are fossil fuels.

[00:13:02] **Nate Hagens:** If you drew the modern world as a flow diagram, w- what are the three biggest energy flows and the three biggest, um, material flows that- that keep us alive?

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[00:13:13] **Tad Patzek:** Well, so first, I need to put a little plug for you. Uh, the global industrial civilization is called by us, the fossil amoeba, and you were the first one to call it that. Uh, but really, it is a far from equilibrium giant system of systems which continuously transforms energy and material and dissipates free energy.

[00:13:38] That is who we are, okay? But among all these fluxes of energy or power, uh, remember, power, energy per unit time, and materials, there are six that, uh, take precedence. The first one is the fossil fuel energy or power, right? And so, uh, that is coal, oil, and natural gas provide together 80 to 85% of global power supply, primary power supply, and this fuels power, transportation systems, electricity generation, industrial processes, and most agricultural machinery and agriculture.

[00:14:23] And their combined power throughput, uh, you know, roughly today would be 15,000 gigawatts or 15 terawatts on average, and 18 terawatts for peak periods where we use more because of heat or- or- or something.

[00:14:43] **Nate Hagens:** My knowledge of that probably indirectly, uh, down the waterfall came from you, but 18 terawatts is the equivalent of 180 billion 100 watt light bulbs turned on- Yes.

[00:14:56] twenty four seven. Yeah.

[00:14:57] **Tad Patzek:** Yeah. A- and again, that 18 terawatts is just for brief moments, for an hour, for- for a minute or so.

[00:15:04] **Nate Hagens:** Yeah.

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[00:15:05] **Tad Patzek:** But we have dispatchable power, so in- in peaks, we can actually exceed the average power. The global economy is nine- is a- is now a 19 to 20 terawatt machine.

[00:15:17] **Nate Hagens:** Right.

[00:15:17] **Tad Patzek:** Okay? And so 15 of which are fossil fuels on average.

[00:15:22] Then the next, uh, flux of energy is solar energy captured by agriculture. And so photosynthesis converts solar radiation into chemical energy, which is stolen crops, pastures, and forests, and the global photosynthetic flux is huge, enormous. Uh, uh, and our agriculture, you know, only captures a- a- a- a little part of it, well, you know, 10 to 25% together with pastures and forests, but still it's a giant, uh, amount of energy.

[00:16:01] And so in- in humans in agriculture, roughly appropriate 15 to 25% of all, uh, uh, solar light that falls on the planet on average. And agriculture alone, our crops, appropriate between 10 and 15% of global plant production. And since you were asking me about photovoltaics, you know, uh, uh, renewables, agriculture's, um, um, efficiency in, uh, in sequestering solar rate is between half and 1%, and that actually is, um, generous, okay?

[00:16:53] Uh, a solar photovoltaic plant can acquire 20 to 23% of, um, solar energy, so an order of magnitude more. So our machines are 10 times or 20 times more efficient than agriculture than plants, but they are also a lot more fragile.

[00:17:22] **Nate Hagens:** And more costly.

[00:17:24] **Tad Patzek:** Uh, yes. And so, and the third extremely important flux of power through our societies is electricity.

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[00:17:37] Electricity is the purest, um, form of free energy. It can be converted to mechanical work with almost 100%, um, efficiency. And so, on average, uh, about 3.4 terawatts of global power is generated as electricity, and that is the most useful form of all power we have. So that's the three, uh, p- uh, fluxes of power.

[00:18:13] **Nate Hagens:** I'm a little confused though, because fossil fuels create electricity, and so does solar creates electricity. Yeah. So is there an overlap in those three categories?

[00:18:22] **Tad Patzek:** Yes, but majority of electricity, uh, depending on the country, 50, 60, 70%, 80%, uh, is generated from thermal power sources, so coal, natural gas, and nuclear reactors, uh, and- and then there's hydropower, huge, and then distinctly below them, there is solar power and wind turbines.

[00:18:53] Um, and there is, of course, biomass burning, but that usually doesn't contribute to electricity unless it's cogeneration. And so, um, that let's say three terawatts of electricity, you have to multiply them by three, roughly, to- to get to 10 terawatts of primary power that generates them.

[00:19:16] **Nate Hagens:** So, um, fossil hydrocarbons, solar via agriculture and electricity are the energy fluxes.

[00:19:24] What about the material flows that keep us alive?

[00:19:27] **Tad Patzek:** Again, let me, uh, let me, um, put another plug for power. These are actually power fluxes, not energy fly. They are energy, but energy per unit time.

[00:19:36] **Nate Hagens:** Ah,

[00:19:37] **Tad Patzek:** okay. Okay.

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[00:19:38] **Nate Hagens:** Do you often correct your students with that error? Because I think that's an error that is often made in discussions about energy in the future.

[00:19:44] **Tad Patzek:** Well, that error, Nate, will come up further in our discussion, has to come up because the misunderstanding of, um, energy transitions, which are really power transitions and misunderstanding of how can we fight climate change or climate breakdown stems lots of misunderstanding is based right there. We equate elect- non-dispatchable energy with dispatchable power, and nothing could be more wrong.

[00:20:20] **Nate Hagens:** Mm.

[00:20:21] **Tad Patzek:** Okay? So, so, so let's be very careful here because I don't want the listeners to get the impression that we talk merely about energy. We're talking about highly dispatchable, flexible, easy to store power.

[00:20:40] **Nate Hagens:** You know, one of the catchphrases that I use a lot is that our culture is energy blind. Um, but the reality is I think power blind is a better descriptor, but the word power, at least in our current social, uh, narratives is about social power and the power of billionaires and politicians.

[00:21:01] And I don't think we understand what you're, you're describing here.

[00:21:04] **Tad Patzek:** Well, that's another disconnect, right, because, um, in our, uh, social discourse about anything related to climate, energy systems, and what are you, we operate at the level of policy, politics, moral requirements, and wishful thinking, but we forget about the underlying physical systems, which is the giant infrastructure that provides us with these fluxes of power and materials that we then use without thinking about them.

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[00:21:39] So I, I think we're gonna have to talk about this more, uh, you know, s-come back to this.

[00:21:45] **Nate Hagens:** We will. I have 98 questions written down, so, um-

[00:21:49] **Tad Patzek:** Well- No,

[00:21:50] **Nate Hagens:** no. Don't,

[00:21:51] **Tad Patzek:** don't kill me, please.

[00:21:52] **Nate Hagens:** No, no, no.

[00:21:53] **Tad Patzek:** Okay.

[00:21:53] **Nate Hagens:** So, so keep going. Yeah. You talk about power fluxes. What about material fluxes?

[00:21:57] **Tad Patzek:** So the number one material flux in human economy is water.

[00:22:03] And water withdrawals are used mostly for agriculture, but also for industry and for domestic use. And the total amount of water, uh, withdrawn per year is 4,000, uh, cubic kilometers per year. And so you can imagine this as a cube made of water, which is 16 kilometers on the side. So that cube would, would extend, uh, from ground surface to way above the tropopause into the stratosphere, and it will reach, uh, from Oakland where I sit, Oakland Hills, to southern San Francisco and then sideways.

[00:22:51] So that's come out, uh, the amount of water we use every year.

[00:22:55] **Nate Hagens:** Fresh water.

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[00:22:56] **Tad Patzek:** And ... Yeah, fresh water. Uh, non-fresh water doesn't count.

[00:23:01] **Nate Hagens:** Okay.

[00:23:01] **Tad Patzek:** And so irrigation accounts for roughly 70% of that water, or 75. So 3,000 cubic kilometers out of 4,000 cubic kilometers goes to sustain our agriculture, modern full production.

[00:23:18] But since we have now, uh, wonderful conflict in the Middle East, let me just talk a little bit about the Gulf Cooperation Council or GCC countries, how they get their water. So, uh, they're mostly, you know, to, to the tune of 70% in Saudi Arabia to 90% in Bahrain and, and Abu Dhabi, uh, their water comes from water desalination, uh, of seawater.

[00:23:51] And they do that together to the tune of 20 to 25 cubic kilometers per year, cubic kilometers per year, 20 ... So there's a huge amount of fossil water generated with fossil fuels, and generation of this water, if you add all of that up, more or less, would require an equivalent of 10 giant nuclear reactors or power supply for a medium-sized European country.

[00:24:24] So that's just water for the GCC countries. Um, and I want to point it out now because that water supply may be in danger.

[00:24:34] **Nate Hagens:** So just, uh, to timestamp this, this is Thursday, March 12th that this is being recorded and things are, uh, as of this recording, accelerating in a worrisome way in the Middle East. Uh, this will probably be out three or four weeks from now, so, um, we'll see what happens when this is aired, when this airs.

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[00:24:51] So, um, okay, water is the first, uh, material flux. Yes. What are the others?

[00:24:55] **Tad Patzek:** Second is food biomass. So food. And so global agriculture produces, uh, of the order of 10 to 12 billion tons of biomass per year, crops, feed, you know, what have you, 10 to 12 gigatons. And of course, the biggest flux, uh, outside of water is sand, gravel, cement, and steel, which together, uh, take about 50 gigatons of production capacity and, uh, uh, per year.

[00:25:32] So 50 billion tons, uh, and that 50 billion tons is, is, um, dominated by aggregates, you know, gravel cement, uh, sand and so on, used for concrete and infrastructure.

[00:25:47] **Nate Hagens:** So from, from that background on energy and material fluxes, where do you think the public discussion about energy and materials is most currently detached from our physical reality?

[00:25:58] **Tad Patzek:** A very fast answer would be everywhere. Uh, uh, but, and, and I'll justify my answer because public discussion is detached from physical reality wherever language of preference, morality, and ideology substitutes for quantitative constraints imposed by mass balance, uh, phys- uh, and power density, land area, time and infrastructure.

[00:26:28] **Nate Hagens:** Is there any possibility that members of our species could do high level discussions in mass balance and physics and land as senior decision makers?

[00:26:43] **Tad Patzek:** Well, a- again, it very much depends on the country, right? So if you, if you look at China, their policymakers are most often engineers and scientists, and they actually understand, would understand what I'm talking about.

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[00:27:00] In the US, neither the public nor the policymakers have, uh, even faint understanding of the issues related to the physics behind, uh, our civilization. And so the, the most important area of detachment would be energy. So public debate often treats energy systems as if though they were instantly reconfigurable by policy investment or more urgency alone.

[00:27:36] So I live in California, people drive their little electric cars and they expect to have electricity to charge them anytime, anywhere, uh, but what they don't understand, there may not be enough electricity to do that in California in particular. And so what we, uh, failed to see is thus far historically in all of our history, modern history, every energy transition was additive, not subtractive, additive.

[00:28:10] So when we started producing, um, uh, oil, we used a lot more coal to develop the oil infrastructure. When we started developing natural gas, well, you, we used up more oil and, uh, uh, and coal to develop the, um, natural gas infrastructure. And right now, we are developing the so-called renewable energy infrastructure, and in order to do that, we have to use more of coal, oil, and gas we can subtract from coal, but then we can add, uh, natural gas and nuclear reactors to do that.

[00:28:50] **Nate Hagens:** Couldn't we, in theory and in time and with innovation, use those renewable technologies to process and create renewable technologies?

[00:29:02] **Tad Patzek:** That's a tricky question, Nate, because it depends how you draw your boundary conditions and how you do your calculations, but i- in my mind, the general answer is no.

[00:29:12] **Nate Hagens:** Well, certainly no to, at a 19 terawatt, uh, sort of throughput level.

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[00:29:17] **Tad Patzek:** Absolutely. But, but the, the, the, the truth is even more pesky. That is, you, you have to have a giant fossil fuel based infrastructure to produce all the beautiful photovoltaic cells and wind turbines, uh, and electrical cars and what have you, and you also need a incredible mining infrastructure which is based on fossil energy.

[00:29:45] But I, I'm not done. So the second major disconnect concerns food, water, and land. S- since most people now live in cities, they think that Food is something that appears, uh, in the store when they snap their fingers, right? What they don't see behind it is the really fragile chains of soil fertility, irrigation, fuel, fertilizers, transport, refrigeration, seasonal labor, packaging, advertising, and so on.

[00:30:27] And, and, you know, and I, again, you just mentioned it at the beginning of our conversation. I've talked about it for 20 years. Um, water, water, the priceless water is discussed as a matter of allocation. That is, we get water because we want to, but we don't understand the hydrology, the storage, the pumping energy, the aquifer depletion, and the climate variability that limit our water supply or may actually deny it.

[00:31:02] So, uh, in each case, the public language abstracts away from the physical substrate and makes social choice, uh, possible, that makes the social choice possible in the first place. So we are disconnected again from physical reality. And of course, your favorite domain would be economics, right? So-

[00:31:28] Well,

[00:31:28] **Nate Hagens:** it's not my favorite domain, but keep going.

[00:31:31] **Tad Patzek:** Well, uh, what I'm saying is, is economics is a claim on future physical production, right? So anytime I reach for a dollar from my wallet

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and want to buy myself a hamburger, somebody had to burn something, mine something, uh, or plow something. And so, again, we, in our detachment, we think that our, um, finance systems, uh, substitutes for physical reality.

[00:32:05] So economic allocations are equal to the physical happenings on the ground, but they're not. And in fact, uh, uh, finance can accelerate or delay, uh, physical processes, right? Mining or development of infrastructure, but it does not substitute for the infrastructure. The fourth detachment is technology, the human ingenuity, right?

[00:32:31] I- it is my obligation to end every remark with a poem, uh, or payan, uh, to human ingenuity because then I will be accepted by others, right? Well, that's not true. Again, human ingenuity and technology does not, cannot, cannot violate physics and thermal dynamics. And so this is the conceptual framework we have when we talk about the miraculous or magical technology.

[00:33:03] And again, don't get me wrong, most technology to most people these days is actually pure magic. Yeah. They can't understand the principles behind the technology and, and what have you. So technology can actually increase efficiency, and it does, but it can also increase the throughput, and it does. So a much higher throughput at higher efficiency is still more depletion of resources per unit time, flux.

[00:33:34] **Nate Hagens:** Let's get into that, um, because I did an academic paper a few years ago on the human economic superorganism, and you mentioned it earlier, uh, that I refer to that as a fossil amoeba, but you're one of the few guests that I've had on that probably understands that better than I do. So, um, let's move into how we, humanity, uh, are using up earth's capacity to support life, otherwise in ecological terms known as overshoot.

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[00:34:06] So can you explain, um, the fossil amoeba in your words, in plain language, including what it eats, how it grows, and, and what happens when the food runs out?

[00:34:19] **Tad Patzek:** So what you are referring to is the, uh, carrying capacity of planet earth, right? That's one of the most complicated, um, and difficult to, to grasp concepts in ecology.

[00:34:38] I mean, in principle, sounds simple. The earth cannot carry more than, uh, and that would be nice if you were a cheetah or a buffalo.

[00:34:48] **Nate Hagens:** Well, because, because all cheetahs and all buffaloes roughly consume the same, but humans have a large standard deviation of our material throughput consumption.

[00:34:57] **Tad Patzek:** And we also have appropriated the stores of energy, the natural battery, which are fossil fuels and minerals.

[00:35:09] And so it is exceedingly easy for us to, um, to exceed our welcome on this planet, earth, um, and overshoot. And so the central thesis of my book is that the current climate breakdown is a direct and immediate consequence of ecological overshoot, which scales approximately as a high power of, uh, as a high power of primary power.

[00:35:47] **Nate Hagens:** You, you need to explain that to us- Yes. ... people that got C+ in calculus. A high power of a high- uh, uh, please.

[00:35:54] **Tad Patzek:** Of the primary power. Right.

[00:35:56] **Nate Hagens:** Okay.

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[00:35:56] **Tad Patzek:** So, uh, so our overshoot, uh, e- empirically scales as the cube of primary power because just, uh, just, um, behind the primary power, there is human population, and just behind the human population, there's human technology, and all add one to the exponent.

[00:36:21] So it's one plus one plus one. In fact, it's three and a half, not three. And so primary power growth translates almost one-to-one into the expansion of human population, technological capacity, and that implies a very strongly non-near amplifica- amplification of environmental impact.

[00:36:44] **Nate Hagens:** So just let's say it's a cube and not three and a half.

[00:36:48] So that means if there's two, a power, uh, availability of thermal power, uh, a vector of two, then the overshoot impact is eight?

[00:37:01] **Tad Patzek:** Yes.

[00:37:02] **Nate Hagens:** Okay. Uh, I didn't know that.

[00:37:05] **Tad Patzek:** Professor Reese, Bill, would be, uh, more careful in saying about our over- in talking about our overshoot. Depends how you count it and how sophisticated you get in the counting, but it's between five to eight times, yes.

[00:37:20] **Nate Hagens:** Okay. You've used the term, uh, free energy a couple times that none of my guests have used that before, and I know you often talk about that. Can you briefly define that and why it's an important term?

[00:37:32] **Tad Patzek:** Right. So free energy, uh, and it gets more complicated very quickly, but the free energy is the part of energy which can be directly converted into work.

[00:37:43] **Nate Hagens:** So what would, what would be the non-free energy?

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[00:37:46] **Tad Patzek:** That would be, uh, non-free energy would be heat. Okay. Um, because heat cannot be converted by second law of thermodynamics into work with 100% efficiency.

[00:37:57] **Nate Hagens:** So it's the free energy that powers our societies.

[00:38:00] **Tad Patzek:** Not just free energy, concentrated, pure free energy.

[00:38:09] So if I have a 10% copper ore, it is so, uh, which is shallow, it is so much easier to get copper out of it than if I have less than 1% copper ore, which is three kilometers deep. So it's the concentration of free energy and its purity, uh, that matters to us most. And by the way, in most cases, well, actually, almost always, uh, we use that free energy only once.

[00:38:42] We dissipate it and it's gone. So for example, when you generate electricity from coal or natural gas, uh, 60, uh, 70% of primary power in, in your fossil fuel is rejected as heat. Some of that heat can be used to heat up the feed water to the power plant and do other useful things, heat up, uh, human apartments, uh, you know, in, in dwellings around the power plant, but the rest of it will be rejected to the cold universe.

[00:39:19] So 70% of everything we do, you know, plus minus, is rejected as heat to the universe.

[00:39:28] **Nate Hagens:** And how does climate change and global heating fit into this? Um- Ah.

[00:39:36] **Tad Patzek:** Okay.

[00:39:36] **Nate Hagens:** Maybe, uh, I mean, there, there's just a ton of ways to start here. Maybe just start with, uh, we can start where you want, but I'm just curious what you think the single biggest misconception that smart, educated

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people have about global heating and, and what does that cause, what does that misconception cause them to underestimate about our current situation?

[00:39:57] **Tad Patzek:** First of all, climate change causes, uh, an intensification of extremes, so that's just thermodynamics. So global heating alters, not by changing just the mean state of climate, your average climate, but, but reshaping the frequency, intensity, and spatial correlation of extreme events. So a warm atmosphere contains more water vapor and more internal energy, and it amplifies and shifts the hydrological cycle, and it destroys the old statistics of floods, droughts, heat waves, and wildfires.

[00:40:42] And since, uh, civil engineers are usually quite conservative, all of our infrastructure is based on old historical data, which no longer obtains, which no longer is valid. So this new developments in climate actually stress our infrastructure and expose the fragility of our modern systems.

[00:41:06] **Nate Hagens:** More so than just temperature.

[00:41:09] **Tad Patzek:** Oh, much more so. It's not just temperature. Uh, uh, uh, uh, so it, it's everything together, right? So extreme events can be temperature, can be rain, can be flood, can be wildfire, can be many things. So all of them together suddenly, uh, follow different statistics or the so-called statistics of extremes, which are actually richly represented in my book, uh, and explained in an appendix.

[00:41:39] Um, so your Gaussian, your bell curve to which you are used no longer holds. And the Gaussian curve actually basically informs people that events removed from the mean by more than two, three standard deviations, uh, are completely impossible in practice, are improbable. The, the extreme events statistics say that these distributions don't have the fast declining, uh, tails of a Gaussian distribution by the so-called fat tails.

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[00:42:19] And so the extreme events in these fat tails have actually appreciable probabilities of happening. So agriculture is very, very sensitive to temperature threshold, water availability, and seasonal timing. And so if you have s- heat stress during flowering, uh, if you have declining soil moisture, shifting rainfall patterns, it kills the agriculture.

[00:42:45] Uh, and then ocean warming and our activities disrupt fisheries while they kill reefs, coral reefs, which are the oasis of life in the ocean, and that n- negates a very important, uh, source, actually primary source of protein to hundreds of millions of people. Uh, and then you have water system disruption, right?

[00:43:11] So, so how wa- fresh water is stored, uh, depends on your snowpacks, on glaciers, and once the, uh, mountain snowpacks and glaciers, uh, melt very fast, you get lots of flooding in spring, and then you don't have water, uh, in the summer and fall. And one of the most, uh, um, complex situations in water supply, uh, is in fact in Asia where the giant glaciers in the Himalayas are melting like there were no tomorrow, and they have now created thousands upon thousands of melt lakes high up, which then supply ample water in spring and cause flooding and dam failure and what have you, but then later, uh, rivers don't flow, as you can, you could see easily in China, uh, where some of these cities, uh, built next to the rivers, uh, don't have any river flow next to them.

[00:44:21] **Nate Hagens:** You know, you're one of the few guests that I have that really deeply understands climate and, uh, the global biosphere and the physical biogeochemical flows, but also understands energy balance and power and material fluxes in the human system. So if we take the advantage of viewing this in terms of energy balance as opposed to the weather and the temperature, what is the most counterintuitive climate truth, uh, in your opinion?

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[00:44:51] **Tad Patzek:** Uh, that's actually a very interesting question because it is, um, something that is actually co- absolutely counterintuitive. So, uh, you know, if you take average, uh, solar power, uh, coming, uh, to our planet, it's about 240 watts per square meter on average, right? And in equilibrium, that incoming solar power is exactly balanced by the outgoing infrared radiation, uh, from the earth, so 240 watts in, 240 watts out on average, everywhere on the surface of the planet, right?

[00:45:37] And so, and then our climate is stable, temperature doesn't rise and, and what have you. But the, the truly remarkable and counterintuitive fact is that the anthropogenic perturbation of this balance, 240 in 240 watts per square meter out is very small compared to the total energy of the system. And so it's between, uh, 0.7 and one watt per square meter, 240 and one, right?

[00:46:11] Mm-hmm. Less than half of 1%. And so climate deniers would point it out as saying, "Well, who cares?" You know, you get 240, who cares about one watt? But yes, you do, because if that one watt is equilibrium, uh, because of the greenhouse effect, persists for many decades, it actually accumulates an enormous amount of heat on the planet.

[00:46:40] And so if I integrate one watt over the entire surface, because we're talking about averages, right? So it's, it's everywhere. It's, uh, I took out the, the effect of, uh, latitude and night and day. Uh, so, so that one watt on average per square meter of, of planet surface translates into three to 500 terawatts of primary power.

[00:47:09] And so that's 20 times the human economy, one watt, 20 times the human economy. And so that is probably, um, the most, uh, counterintuitive, uh, fact about climate change. It's not the magnitude of power flows, but the long lasting i- this equilibrium in this power flows, um, that changes the climate.

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[00:47:41] **Nate Hagens:** So global heating climate change is but one of the nine planetary boundaries, um, that Johan Rockstrom and others, uh, uh, have constructed, um, a framework for measuring the safe operating space for earth's, uh, biospheric stability.

[00:47:59] If you were to apply a thermodynamic energy imbalance approach to our broader ecological crises beyond just climate change, h- how might that apply or help us understand the other eight planetary boundaries?

[00:48:13] **Tad Patzek:** With everything I said thus far, that is actually childish is simple. All we need to do is not to encroach on, uh, on the planet earth through human activities and everything will be honky-dory.

[00:48:29] Only that's much easier said than done, right? So, uh, you are referring to some concept of planetary boundaries, which was formed by poll and elic probably in the 70s, which was then developed into these nine, uh, planetary boundaries, which are climate change, biosphere integrity, land system change, fresh water use, bioge- geochemical flows, ocean acidification, uh, atmospheric aerosol loading, stratospheric ozone depletion, and forever chemicals and microplastics and what area, and radioactive waste, okay?

[00:49:11] So you heard me saying biosphere integrity. Well, biosphere integrity can be maintained only if we do not destroy habitats everywhere on the planet by pollution, overexploitation and climate change. And fresh water use, well, human appropriation of surface water and groundwater, uh, for agriculture now depletes most aquifers everywhere on the planet, everywhere.

[00:49:43] Um, and then I said biogeochemical flows, which probably says nothing to most people, but that is actually the nitrogen and phosphorous cycle. And so we have now overwhelmed the nitrogen cycle and the phosphorous cycle,

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but orders of magnitude or several times because of fertilizer use in agriculture and agricultural runoff.

[00:50:08] So that destroys ecosystems far away from Midwest, right? So Midwest is there, but then there's Missouri and Mississippi rivers, and they transport all these nitrogen and fertilizer to the Gulf of Mexico, and there's a big dead area there where, which is anoxic. Um, ocean acidification, well, that's just the effect of CO<sub>2</sub> we produce dissolving, uh, in oceanic water, right?

[00:50:37] And then atmospheric aerosol loading, that sounds abstract, but this is really our soot and smoke and dust which we generate with our, uh, human activities. And of course, some of the gases we generate, uh, for refrigeration, for example, kill ozone, and without ozone layer, we're all dead. So, so that's very simple.

[00:51:04] **Nate Hagens:** Let me ask you this, Tad, because, uh, you and I have been, um, privy to thousands of the same emails over the years, maybe even tens of thousands. Yes. So I know you know an enormous amount about how the climate actually works, uh, and what's in the pipeline. Maybe just speak honestly, um, what is the best case, worst case, most likely case that you see unfolding in the next century, uh, with respect to Earth's, uh, uh, climate and global heating?

[00:51:38] **Tad Patzek:** I think it's time to say something now about what is climate breakdown. So the mostly sole reason of the climate breakdown, uh, global climate breakdown and all its derivative manifestations is the cumulative emissions of CO<sub>2</sub> into the atmosphere, which then partition into, uh, onto land and into the ocean. It doesn't matter how fast almost, what matters is how much, so how much we inject.

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[00:52:15] So, uh, we are now, you know, at, at about 2.6 teratons of CO<sub>2</sub> of injections, and we can go easily up to, to four and six or seven, depending how we continue exploiting, uh, fossil fuel resources.

[00:52:39] **Nate Hagens:** 2.6 teratons doesn't mean anything to me and most of our viewers, um, but maybe just keep explaining.

[00:52:46] **Tad Patzek:** Okay. It means 430, means 430 ppm of CO<sub>2</sub> in the air.

[00:52:51] Okay. That's what it means.

[00:52:53] **Nate Hagens:** Okay.

[00:52:53] **Tad Patzek:** Um, and then we can actually double that amount, uh, not quite from 430, but let's say from more than 300 to 700- Okay. ... uh, that's quite possible. And-

[00:53:08] **Nate Hagens:** Quite possible with our remaining amounts of coal and gas- Yes. ... et cetera.

[00:53:12] **Tad Patzek:** Yes.

[00:53:13] **Nate Hagens:** Okay.

[00:53:13] **Tad Patzek:** And that's the scenario I have in the book. I, I, I, I don't go with, you know, RCP 8.5, 8.5 watts per square meter, the extreme emissions scenario of IPCC because it, it's not going to happen.

[00:53:30] But what will happen is something between RCP 4.5 and RCP 6.0, or, or God forbid, 7.0 watts per square meter.

[00:53:41] **Nate Hagens:** Unless the global economy kind of collapses before that.

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[00:53:46] **Tad Patzek:** Yes, and it will. Uh, it's, it's just a matter of time, and we're working hard, uh, on it just as I'm speaking on March 12th, 2026.

[00:53:57] **Nate Hagens:** So what does that mean, uh, 430 or 700 or anything in between?

[00:54:01] What are gonna be the impacts, uh, in 20 years or 50 years?

[00:54:06] **Tad Patzek:** Again, it depends.

[00:54:08] **Nate Hagens:** I, I hate you scientists. You always say it depends. Um-

[00:54:11] **Tad Patzek:** Well, uh, but I'll tell you what's, what's bad and what's worse, okay?

[00:54:15] **Nate Hagens:** Okay.

[00:54:16] **Tad Patzek:** So what's bad if, if nothing else happens in the global climate system, just this capricious, extreme, uh, global warming, uh, it will not rearrange, uh, you know, monsoons and, and, uh, El Nino southern isilation and North Atlantic currents and so on, which they will, okay, which it will.

[00:54:41] But then we will expect to have two degrees on average of planetary heating by 2050 and three degrees of planetary heating by 2100. And that is a reasonable kind of low-ish scenario of what's going to happen. But before anybody sites aside, you know, say, "Oh, only three degrees." Well, three degrees on average, uh, for the ocean, uh, for the l- uh, for the earth is let's say, I don't know, one, one and a half degrees for the ocean, which is 75% of the planet area, and then six degrees for land.

[00:55:27] Uh, the last I checked, uh, most people live on land. And so, so we will be experiencing six degrees of global heating on average, which mean, which

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means in, during heat waves, that's gonna be eight, 10, 12 degrees, uh, of heating, uh, heating anomaly. In fact, you saw one of our emails today, uh, you know, the Gulf of Mexico Coast right now, before spring started, is experiencing already four and a half degree in places temperature anomaly.

[00:56:06] It's hot. And tomorrow, Los Angeles will be 100 degrees half of more because of a heat wave there. So that's kind of the nice, smooth scenario, but nothing s- is smooth in nature. So while we are emitting CO<sub>2</sub>, oceans are heating, actually they, uh, they absorb 90% of the incoming, uh, excessive imbalance energy, uh, and then everything else on the planet rearranges.

[00:56:41] And the systems, the climate systems on the planet are tightly or not so tightly connected across the entire planet. So it's what changes in one place may cause changes everywhere else. And so- In the preparations to, to this, uh, to this, uh, interview, we talked about the declining Earth's albedo, right? A- a- and, and it is declining, uh, since 2010, uh, uh, to 2035, it may decline, uh, by 1%.

[00:57:24] **Nate Hagens:** So that's the reflectivity of, of the earth.

[00:57:28] **Tad Patzek:** That's the reflectivity of the planet, yes.

[00:57:30] **Nate Hagens:** But 1%, that doesn't sound like that big a deal.

[00:57:33] **Tad Patzek:** Huh. It's huge. It's giant. Uh, uh, once that happens, uh, you essentially add, uh, another forcing of global warming in addition to the greenhouse gases, okay? So comparable forcing.

[00:57:51] **Nate Hagens:** Oh, so that, that's separate than the GHGs. Yes. Is the albedo is, is adding to the t- okay.

[00:57:58] **Tad Patzek:** Yes. Yeah.

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[00:57:59] **Nate Hagens:** Yeah.

[00:57:59] **Tad Patzek:** And a lot of it is caused by the GHGs and, and simply by, well, by a variety of, of phenomena, right? One was that we cleaned up, um, exhaustion from dirty fuel in ships, right, in shiplanes. And so suddenly, uh, these, this exhaustion that contains, uh, uh, uh, oxides of, uh, of cell or sulfur oxides, it doesn't create clouds.

[00:58:32] So that's one. Two, we are exhausting the ocean, acidifying it, killing reefs, and therefore the algae, the zooplankton, the, you know, whatever, the diatoms are producing fewer, uh, uh, dimethyl sulfide, uh, substances or precursors to them that cause condensation of clouds. So the cloud system is not as dense as it used to be, and that's the kind of the root cause of the declining earth albedo because so much of, uh, earth, uh, of solar energy is reflected by the clouds.

[00:59:12] But then, because of, uh, global heating, we are also melting ice in the Arctic and Antarctica, and they are also incredibly highly reflective, you know, uh, nice, pure snow reflects 90% of incoming energy, and ocean reflects 10.

[00:59:35] **Nate Hagens:** What does it all mean? Um, like, how do you condense and integrate all, all these things, uh, energy and power and therbodynamics and carrying capacity and climate and albedo?

[00:59:49] Um, w- what, what does it all imply, Ted?

[00:59:53] **Tad Patzek:** Well, what it implies is that collectively, we better start pay, start paying attention. That's what it implies. Um, and so we are not at that point yet, right? Most people are inconvenienced or, or at times traumatized by, uh, climate change. You know, if you have a hurricane in Florida, uh, well, you say, "Oh, well, uh, as they say, stuff happens."

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[01:00:27] But these effects are accumulating and will be more frequent and it will actually go beyond in convincing, um, uh, uh, causing inconvenience to most people. Uh, if you are a homeowner in many places, uh, in the US, including where I live, you may not be able to get home insurance, which means that most people will not be able to buy a home using a bank loan.

[01:01:01] Um, you al- you also, uh, will be paying a lot more for food, and you can blame it on this or that or the other, but the root cause of that is that agriculture is disrupted everywhere to one degree or another.

[01:01:20] **Nate Hagens:** Not because of, uh, fertilizer shortages, but because of climate.

[01:01:24] **Tad Patzek:** Yes. Yes.

[01:01:25] **Nate Hagens:** Yeah.

[01:01:26] **Tad Patzek:** But then your favorite grid with this charging your electrical car because you are also environmentally sensitive may fail when it's hot because it's too o- overloaded by the heat.

[01:01:41] Um, your entire infrastructure, buildings, roads, in fact, are displaced up and down by, uh, the soil moisture declining more and more during summer, and then, you know, sudden outbursts of rain pumping some water into solo layer of soil and lifting clays up. And so buildings everywhere are being quietly damaged, so are roads and bridges are dams, and there's no money to repair them.

[01:02:18] You know, there's more and more deferred maintenance, not just in the US, but yesterday there was a report on Germany, which was third in terms of quality of infrastructure. It now is 19th, because it doesn't pay to, uh, for the repairs. Uh, and so all of that accumulates. And, and let me tell you this, um, uh,

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dear listeners and viewers, by the time you really see how bad this is, it's already delayed.

[01:02:53] **Nate Hagens:** Well, then it's, then you just said, "We have to start paying attention to this. It's too late to pay attention to it. We need to do something about it, " yes? Yes. For those people that have agency or are in government, et cetera, like how, how do you frame, uh, responses to what you've been unfolding, uh, and describing here and what I've been describing for the last four years on this show?

[01:03:14] **Tad Patzek:** Frankly speaking, it is much easier said than done, right? So, so the question you're asking is, how do you get from 10,000 watts I consume every day of power, of primary power, I consume every day as a US citizen, and I can be incredibly virtuous. I can, I don't have to be driving. I, I can, I don't have to be air conditioning.

[01:03:43] I still consume 10 and a half, uh, 10,000 watts, uh, or more as a US citizen, statistical, uh, uh, uh, US person. And so the question for everybody is, how do we get down from 10,000 watts to, let's say, 5,000 watts per person, uh, on annual basis? And that is incredibly difficult. What that would require, for example, would be a complete rearrangement of our transportation infrastructure.

[01:04:17] We would have to dump cars and go to public transportation, uh, to an incredible degree. We would have to really change our eating habits, so no beef under any circumstances, as little pork as possible will eat some other meat, and by the way, fish will become difficult to come by. Um, so eat plants, uh, much more so.

[01:04:46] But, but you see, and by the way, never buy those blue jeans and don't buy things, uh, new clothing every summer or every winter. Don't give yourself

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gifts wrapped in plastic and in paper, uh, and, and, and ignore Amazon, right, uh, with its packaging.

[01:05:05] **Nate Hagens:** This gets back to the carrying capacity question. Yes. Like help me, um, integrate.

[01:05:12] We have a 19 to 20 terawatt metabolism as a global society and we have eight billion people, so there's a wide disparity in consumption amongst those people, but what, what sort of, uh, metabolism might be reasonably sustainable, uh, for humans, especially if we continue to innovate and find alternative sources, et cetera, relative to today's, let's just call it 20 terawatts.

[01:05:38] **Tad Patzek:** I ran this, um, Gedanken experiment or thought experiment, right? Um, and, and I have it in the book, I think in chapter six. Um, so just suppose that humans were rational hum- beings, which were not, and suppose that we looked at how we multiplied in numbers between 1650 and 1920, that's pre-World War II growth of population and industrial agriculture.

[01:06:15] And suppose that we, at that time, before 1920, made a decision not to procreate like we did historically. And so we could then approximate our behavior by a, um, logistic growth curve, which will end up with two and a half billion people living on the planet forever, okay? So let, let's use this as an example.

[01:06:44] A- and the maximum, uh, then peak population growth rate w- would occur in 1810, uh, two centuries ago. But there are several, uh, uh, problems with this reasoning, right? One is that two and a half billion people on earth would require 1850, 1900, let's say, life expectancies, uh, lifestyle, slavery, conflicts, and what have you.

[01:07:14] And average life expectancy, uh, in 1900, let's say, was 32 years, and in 2022 was 72 years. And so if you ratio two and a half billion by the life

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expectancies, you are coming down to one billion people, uh, living on the planet. And then world GDP, uh, in the 19- in 1900 was about 2025 dollars, you know, purchasing power parity, constant dollars.

[01:07:52] And in the same dollars in 2022, it was \$19,000, so that's a factor of eight. And here, I would go ignore my own thinking and, and teaching, and I would say, "Hey, our technology in human ingenuity went so far as to reduce our impact on the planet to a mere factor of two, not eight." So now we're down to half a billion people.

[01:08:20] And then assume that we have modern organic agriculture similar to that in the 1900s, a- a- and optimistically, uh, we assume they could feed four times more or two billion people. And that's not entirely, uh, implausible because in 1900, uh, the human population was 1.6 billion people consuming fossil fuel power at the rate 24, uh, uh, billion person equivalence.

[01:08:55] So 12 s- uh, energy slaves per person in 1900. So, but we don't want to have the same strife and epidemics and what have you, so we end up to, at one to one and a half billion people as a carrying capacity of people that could live comfortably. And for a very long time, I, you know, I don't use the, the term forever because that's operational.

[01:09:26] And so with this optimistic assumption, uh, one to one and a half billion people, we have overshoot by a factor of five to eight, which we mentioned earlier, uh, in our conversation. And so, well, and so there we are. Uh, so humanity, according to my own sustainability definition, uh, of 204 could be only weekly, weekly, unsustainable if we kept our, our numbers at or below one and a half billion people, and each human use primary, uh, energy from biomass and fossil fuels as in the year 1900.

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[01:10:11] **Nate Hagens:** But if we used fossil fuels as in the year 1900, eventually the fossil fuels would also be depleted.

[01:10:17] **Tad Patzek:** Right. Uh, but that would buy us several centuries.

[01:10:21] **Nate Hagens:** Okay. So if someone was a techno-optimist listening to this, uh, conversation, they might say, "Well, on the surface, I might accept your numbers, but we will innovate and find different ways of doing things better so those numbers are too low."

[01:10:38] **Tad Patzek:** Obviously, uh, this type of analysis opens me to all kinds of criticism from every direction. But, and all I can say, fair, fair enough, but I've been thinking about this for, uh, four decades, and that's all I could come up with after four decades of thinking. Uh, so it, it, as they say, folks, it is as good as it gets, and after that, it can get, get even worse, okay?

[01:11:10] So again, a- at least pay attention, and human ingenuity is not a, uh, magical key that unlocks nature with any side effects and, and any, um, negative effects, uh, on the planet, on, to, uh, to the biosphere. And so therefore, don't count on technology to be your savior. It will make our lives easier, but each time it does so, it does so with a huge input of power, power.

[01:11:48] If you don't have that power, you will not have that technology. I mean, I could now tell you how much power is used by an average research university, which is the knowledge, uh, producing power plant or by an average hospital.

[01:12:05] **Nate Hagens:** Let's talk about a knowledge producing power plant in the form of artificial intelligence, because I think that is also part of this, um, conversation.

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[01:12:16] There are many people that believe that AI will help us reduce our energy and resource use because of the knowledge and improving our efficiency and inventing nuclear fusion or whatever. But in your book, you specify that you don't believe that's gonna be the case. Correct. So in your opinion, Ted, why, why might AI increase systemic fragility at the same time while it might improve efficiency?

[01:12:40] **Tad Patzek:** You said might twice in one sentence. It's not might- I do that

[01:12:44] **Nate Hagens:** sometimes.

[01:12:44] **Tad Patzek:** But shall. Shall- So, uh, AI shall increase efficiency and shall increase human fr- uh, fragility of human societies at the same time because AI is all about optimization, uh, according to either clear or opac criteria. So today, it turns out that most of the optimization criteria are quite opac to most people and to most members of each society.

[01:13:19] They may not be a pack to the ruling elites, which use AI, uh, to, um, entrench their power, political power. This time, I'm talking about politics, but that doesn't mean that we are safer because of it. So the AI algorithm for sure can reduce waste, improve logistics, enhance forecasting, and can coordinate complex infrastructures more effectively.

[01:13:51] Sure, goes without saying. But at the same time, it will, through this act of optimization, it will reduce redundancy. So the, the human system will become even more highly optimized on demand, on- time delivery, with very, little, uh, spare capacity, and that will make all our supply chains even more fragile than they are today on March 12th, 2026.

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[01:14:25] Uh, and so what is efficient under normal conditions will become deadly under conditions of stress. Oh, shall we say like the war in Iran? Um, and so that's one. Two, AI, in order to increase everything, uh, according to the criteria with value, which is more, more, more, more, will actually accelerate research extraction everywhere- Yeah.

[01:14:54] make it better and more efficient. And research extraction will cause additional terribly negative effects on the biosphere.

[01:15:03] **Nate Hagens:** If we are building new data centers and having more power, uh, that is directed towards AI, you get back to your power cubed thing. Yes. If we had two more units of power, it's eight units of overshoot.

[01:15:16] **Tad Patzek:** The popular perception is that AI is this nebulous, um, gold-like intellect floating above humanity with no cost, right? It just gives us its wonderful wisdom and optimizations and protein folding and, and genetic engineering and all these things. What we forget is that behind that floating version is a giant, uh, infrastructure, not just the data centers, but all the mining and manufacturing that went into the computer chips and computers and cables and, um, power lines and what have you.

[01:16:00] And, and, you know, and one, uh, data center for AI will consume between 100 to 300 megawatts of electricity. So they will interfere with the stability of grid and with the availability of electricity to, uh, citizens. Um, so, and then, so that's now ... So we talked about, uh, diminished redundancy, acceleration of research extraction, right?

[01:16:35] Now, the energy infrastructure needed by AI, but that's not all. Then there is centralization of decision making, which very quickly, and in many cases, by now, is no longer entirely or at all controlled by humans. So, uh, of course, the counterargument will be you can always flip the switch and disable AI.

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[01:17:03] Now you can't. It's too late for that because then suddenly our national defense and, and, and spying and information gathering and, uh, power generation and everything would go kaboom, okay? So you can't. And so these systems have to operate and they make more and more decisions with less and less human input.

[01:17:29] And so when I say less, in the end, it may be just a few humans who will direct most input to these ever powerful, uh, AI algorithms, which will decide about the fate of everybody. So that's not good, uh, uh, to say the least.

[01:17:47] **Nate Hagens:** In my work, I like to think of the future in terms of possibilities and probabilities.

[01:17:53] And based on the many decades of research and thinking, um, that you've done on this, and that went into your new book, what do you find to be the, the midpoint of the distribution, the most defensible range of, of human and planetary futures?

[01:18:10] **Tad Patzek:** So again, I said that on average, it's one and a half degrees in 2050, three degrees in 2100 for the planet, which is extremely scary.

[01:18:23] If we really get our act together today, not tomorrow, today, uh, it's gonna be less than three degrees in 2100, still probably one and a half degrees in 2050.

[01:18:35] **Nate Hagens:** What does that mean, getting our act together?

[01:18:37] **Tad Patzek:** That means that we will run our economy with less, uh, uh, input from fossil fuels.

[01:18:47] **Nate Hagens:** Does that mean more renewables or just less consumption overall?

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[01:18:50] **Tad Patzek:** Well, thank you for mentioning less consumption overall and more renewables.

[01:18:56] **Nate Hagens:** Okay. Yeah.

[01:18:58] **Tad Patzek:** Okay. When I think about probabilities, then I'll use my favorite phrase, it depends. On a good day, I would say, "Hey, I feel good. Uh, we will have a thoroughly, um, thoughtfully managed transition. So we'll decarbonize energy systems, improve efficiency, adapt infrastructure to changing climate, um, the economic growth will slow, but then again, uh, I don't have time to say how I really detest economists, but, uh, read the book.

[01:19:39] **Nate Hagens:** When you say the, uh, economic growth will slow, do you mean the growth rate will slow or the absolute level of output will s- will decline?

[01:19:49] **Tad Patzek:** Both. So in many cases, absolute, uh, output has to decline because that absolute, that output in fact, uh, generates the climate change. Uh, but, uh, you know, there will be reshuffling of the economies, right, to, to something else, that something else has to grow more slowly, okay?

[01:20:11] So cutbacks in some areas of the economy, slower growth in other areas of the economy, a- and that's quite unfortunate, and I'm not sure that people are ready to even consider this possibility.

[01:20:26] **Nate Hagens:** Well, viewers of this channel are.

[01:20:28] **Tad Patzek:** Yeah, I know. Yeah. So therefore, immediately after my good day, I have a bad morning next day, and, uh, I would say then we will have a turbulent transition.

[01:20:42] Yeah. So everything will, uh, go to hell. Uh, countries will be competing for resources, uh, mineral resources, energy resources, and food. Uh, there will be

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huge potential movements of, uh, humanity from some countries to other countries, and technological innovation will continue, but the governance that goes with this technology will be retreating.

[01:21:13] So we will be ... It, it'll get worse and worse in terms of, uh, civil societies.

[01:21:19] **Nate Hagens:** It kinda sounds like you're describing the last couple years.

[01:21:21] **Tad Patzek:** Yes, sir. I am. Uh, and then, um, of course, uh, that, uh, everything going to hell, uh, is also fragmentation, right?

[01:21:33] **Nate Hagens:** Yeah.

[01:21:34] **Tad Patzek:** So, so there will be more environmental stress, more economic instability, more geopolitical tensions and, and wars and so on, and so general human condition will decline.

[01:21:49] A- a- and that's a given. It's not like I'm talking about something that is an unlikely possibility, it's a certainty. And so once you realize that you will have, you will be hit, all of us, for sure, 100%. Then the next question you need to ask yourself is how do you limit the scope of the hit and the strength of the hit and that you can only do by modifying not only your personal behavior, the behavior of your family and your friends and your parents, um, uh, and so on, but also impacting the political system which produced all of that.

[01:22:36] And, and, and, and I'm not sure how that is going to happen. And of course, now I need to pay homage to human ingenuity, uh, because it is not impossible that there will be novel technologies that actually will improve the human lot and, you know, that, that possibly, uh, uh, fusion is mentioned as one of them, but fusion is a cornucopian idea, right?

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[01:23:08] It's, it's the horn of plenty. We'll have unlimited energy to do whatever we want. Well, it's, it ain't so, by so many reasons that we would have to spend another two hours talking about them, but it will be a different energy portfolio, uh, with all its own risks and, and what have you.

[01:23:28] **Nate Hagens:** I'm gonna, uh, make sure in the, in the show notes and in the comments to have a link, uh, to your book, uh- Yes.

[01:23:36] because there's, there's so much there. And I wanna ask you some personal questions too, as I ask all my guests, but before I get there, what, what final question do you believe listeners should face after processing all the information that you've, uh, lightly covered so far in this episode? And I'm sure there's a lot more too.

[01:23:55] Uh,

[01:23:56] **Tad Patzek:** uh, you know, I have lots of conversations with my own children on that. And I really like, uh, the attitude by, of my son who's working with other people and trying to reform agriculture in, in the Napa County, uh, you know, and water management and forest management and what have you. Make a difference.

[01:24:22] Whatever you do, try to make a difference. Do something differently and look at yourself as a giant 40-ton animal. Look at every step you make on this planet. If you go down sidewalk or, or down the corridor in your house, imagine yourself being taller than a five-story building because that's who we are and try to slim down a little bit, okay?

[01:24:54] That's all I can say. Unless we slim down and we become orcas, not sperm whales, maybe even dolphins.

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[01:25:03] **Nate Hagens:** Well, there's, there's orcas and dolphins that live in Asia and Africa. It's not the whole world that is sperm whales.

[01:25:10] **Tad Patzek:** I know. A- and in fact, there are many, uh, Himalayan macaques, uh, that are, you know, a few hundred grams that live in other countries.

[01:25:20] Yes. So our, uh, outlook on the world is defined through the prism of our absolutely excessive and largely unnecessary use of power, of primary power. And we need to snap out of it, but it's kind of like snapping out of a heroin high or from a bipolar high. Difficult to do, right? Because we like it.

[01:25:50] **Nate Hagens:** So you, you brought up, uh, your, your son, um, but in a more specific, uh, example, what can someone listening to this episode specifically do now, today, this week, uh, or this month to help address the things discussed in this conversation?

[01:26:08] Or is it ultimately all up to politicians and leaders?

[01:26:12] **Tad Patzek:** It never was up to the politicians or, or, or the leaders. In fact, the best politicians can do is to follow and mold how you think, but it's your thinking and your actions that make the politicians. Um, and so, first of all, I would say feel proud because we have achieved unprecedented, unprecedented technological capabilities, material abundance, uh, vast flows of energy and resources.

[01:26:53] So that's great. But then think about your children and especially grandchildren. I have four of them, and what's gonna be facing them? And trust me, it's not gonna be abundance of everything, because what we now do tests the stability of the entire biosphere of the planet, and it cannot last forever, certainly not even for my limited lifetime, and I'm 74 years of age, okay?

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[01:27:25] So do not be empathetic. Do not fall into inaction. And, and I'm not trying to prescribe what you're gonna do, because, you know, hey, who am I to tell you what to do? However, do think about what you're gonna do from a different perspective. Try to change your perspective, okay? Because only then you will be able to modify your behavior, and that is an absolutely necessary condition for a betterment of human future.

[01:28:04] Without that, nothing will happen.

[01:28:05] **Nate Hagens:** I know you're recently retired, uh, and have been a, not only a researcher, um, but a teacher, uh, for most of your life. So you've dealt with a lot of, uh, students, young humans. What specific recommendations do you have for young people in their teens or early 20s who have become aware of our economic and environmental constraints to the global economy and they have their entire lives ahead of them?

[01:28:33] **Tad Patzek:** Do learn science. Do learn science, not computer science. AI will do it for you. Do learn physics and chemistry and geology and whatever suits you best, but have a firm grounding in science. The weakest part or, or, or perspective of the American society is just the general lack of understanding of science and therefore replacing scientific principles with wishful thinking and false dichotomies and so on.

[01:29:14] **Nate Hagens:** I don't think you watch my podcast much because you're so busy, but you're like the 15th or 20th person that that was their advice to young people.

[01:29:21] **Tad Patzek:** Yeah. Well, but of, because it's so obvious. I'm not trying to be original here. I'm trying to be practical.

[01:29:29] **Nate Hagens:** Yeah.

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[01:29:29] **Tad Patzek:** And so that's one. Two, and that's equally important, learn how to use the 10 fingers of your hand or both hands, okay?

[01:29:41] That is learn how to make things, a piece of furniture, uh, you know, whatever, uh, a fence, um, f- fix somethings in your house, uh, fix the furniture, fix, uh, whatever, okay? Learn how to do this. That's another thing that I'm find And most distressing that so many people today do not understand or know what is the business end of a screwdriver.

[01:30:11] Literally, they don't know how to unscrew a screw or, or unscrew a bulb, uh, let alone replace something and fix something. We will be fixing many more things because they will be failing and Amazon will not be quite working the way it does today to buy a new thing. So that's, so two things. Basic education and practical manual skills.

[01:30:37] Two things which are not original at all, but if most people learn them, b- boy will be a better society.

[01:30:44] **Nate Hagens:** What do you care most about in the world, Ted?

[01:30:47] **Tad Patzek:** Forever, I've cared about nature. Nature is my original love. And so, and without nature, by the grace of which we live, there is nothing. Uh, the second thing I care about is, you know, I need to maintain my health, not abuse myself as I do so often, so I can live as long as I'm needed.

[01:31:14] But then I care about my children, my sweet girl- grandchildren, my students, and my friends. And so it goes. Um, so, you know, it's very personal, but it should be also for you. You should care about few things in this world deeply or deeply enough to change your behavior.

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[01:31:34] **Nate Hagens:** Well said. Uh, as a scientist, you may not like this question, but if you could wave a magic wand and there was no personal recourse to your decision, what's one thing you would do to improve human and biosphere futures?

[01:31:49] **Tad Patzek:** Well, uh, you might be surprised by my answer. I am surprised too. Uh, I would make humans care about the future beyond the real or imagined brick falling on our collective hand now at this moment. So I would imagine I would make humans be not so myopic as we are genetically wired. And that would require a major rewiring of human brain and is very improbable.

[01:32:23] I think that if that happened to most humans, most of our problems, uh, would be solved.

[01:32:32] **Nate Hagens:** Because we, the veil would be removed and a lot more people would, um, tackle the problems— Yes. ... and maybe get meaning from tackling the problems.

[01:32:41] **Tad Patzek:** And see them more clearly. Yeah. Or see them at all. Uh—

[01:32:44] **Nate Hagens:** Yeah. ...

[01:32:45] **Tad Patzek:** perceive

[01:32:45] **Nate Hagens:** them.

[01:32:46] **Tad Patzek:** Yeah.

[01:32:47] **Nate Hagens:** Yeah. So, um, we could talk for 10 hours because your book took me about that long to read. Um, but in the, in the closing moments here, do you have any final comments for people watching or listening who generally understand and agree with what you've laid out here today?

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[01:33:05] **Tad Patzek:** Again, uh, we have barely scratched the surface and everybody's exhausted, including me.

[01:33:13] And so if you don't mind, uh, download my book, it's free, and it's a, uh, hyperlinked, uh, PDF file, and then jump around it as the links lead you from here to there and, and back, and then try to digest some of it, not necessarily math. Math is relegated to appendices, but the basic science of where we are, who we are, and where are we likely to go, and to be 20 and 50 years from now, uh, that will, that might actually do some good to your outlook on the world.

[01:33:55] **Nate Hagens:** Professor Tad Patzek, my friend, um, I hope you will maybe come back, uh, in your newly retired state and, and a round table, maybe with Bill Reese or some others, uh, to take a deeper dive on some of these topics. Thank you for your lifetime of curiosity and scholarship and education and, and, uh, elbow Greece, uh, on behalf of the natural world and understanding human systems, and thanks for your time today.

[01:34:23] **Tad Patzek:** Well, it was my pleasure, late. I insist, and thank you for asking me so many deep and, and logical questions. So hopefully, this will be unneficial for other people as well. Thank you.

[01:34:36] **Nate Hagens:** To be continued, my friend.

[01:34:38] **Tad Patzek:** Thanks.

[01:34:39] **Nate Hagens:** If you'd like to learn more about this episode, please visit [thegreatsimplification.com](http://thegreatsimplification.com) for references and show notes.

[01:34:47] From there, you can also join our Hi-Lo community and subscribe to our Substack newsletter. This show is hosted by me, Nate Hagens, edited by No Troublemakers Media and produced by Misty Stinet and Lizzie Siriani. Our

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production team also includes Leslie Batlutz, Brady Hayan, Julia Maxwell, Gabriela Slayman, and Grace Brunfeld.

[01:35:11] Thank you for listening, and we'll see you on the next episode.