We Can Survive Technology

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On Earth, evolution over hundreds of millions of years has produced numerous agentic forms of life with conflict and cooperation as their main modes of interaction. Among all of those our species stands out as having entered a developmental feedback cycle: technological progress allowing for higher levels of coordination in turn leading to better technology. As a result, humans within a period of just a few thousand years have managed to displace practically all other mammalian life on Earth, dominating and reshaping our environment through planet-spanning societies organized in the form of nation states and systematized innovation through market economies in which corporations compete against each other. While technological advancements have significantly improved our everyday lives, the accompanying world-wide economic developments and industrialization have also led to exponential growth in energy-consuming processes, incurring significant costs on our biosphere as evidenced by shrinking natural habitats, irreversible loss in biodiversity, increased pollution levels, and climate change. Counteracting those costs is severely complicated by the hierarchical multi-agent systems of international governance and globalized mega-corporations we constructed. The constraints under which these collective intelligences act are unparalleled in complexity and size, making meaningful and principled intervention extremely challenging. How much longer we allow these systems to escape into local extrema instead of adjusting incentive structures to drive them towards global solutions now determines the long-term survivability of our kind.

1 INTRODUCTION

In 1955, as a member of the Atomic Energy Commission John von Neumann posed the question whether humankind can survive technology.[1] He already knew that the vasts amounts of coal and oil that had been burned to satiate humankind's hunger for energy would lead to an appreciable increase in average

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[1] https://sseh.uchicago.edu/doc/von_Neumann_1955.pdf

global temperatures over time. In 1964, based on statistics published by the International Energy Agency (IEA), Nikolai Kardashev projected humankind's total energy consumption needs to equal the output of the Sun sometime within the next 3200 years. Looking at the IEA's recent records the world's combined energy consumption grew from around 175 Exajoules in 1972 to over 400 Exajoules in 2016, the vast majority of which we source from fossil fuels like oil, gas, and coal. While remaining several orders of magnitude away from the energy levels that our star produces we would become a Type II civilization within less than half the time Kardashev projected were we to keep up that growth trend.

Some people are quick to point out that these numbers should be interpreted as a direct consequence of population growth. As population growth rate has been slowing to around 1.1% and is expected to drop further, a natural expectation should thus be for the growth rate of energy consumption to start falling as well. Unfortunately, the relationship between population and energy may not be so simple. Total energy consumption has been growing at around 2% annually over a similar time period with a general upwards trend that is projected to continue over the next decade. Moreover, whereas key factors behind the overall slowdown in population growth are better access to health care and education as well as improved life expectancy and income of individuals the main drivers behind global energy consumption are transportation and industrial demand. In other words, energy requirements are growing due to a rapid increase in technological development which continues to drive economic activity worldwide.

Even assuming the total number of people on planet Earth to reach a steady state, barring some catastrophic event exponential growth and continued industrialization is unlikely to subside in local hot spots like Guiyang, Chennai, or Lagos until the end of the century. Meanwhile, energy demands keep rising in the already heavily industrialized economies of western countries as well. The current iteration of ChatGPT, which is mainly based on textual representation, reportedly took around 50 Gigawatt hours (GWh) to complete one round of training. This is the equivalent of around half of what the Three Gorges Dam — the largest power plant on the globe — produces, or about two percent of the energy capacity of the entire country of Sweden. The next iteration of OpenAI's tool is already

in the making, extending support for image and video data, which significantly increases the amount of compute, and thus, energy consumption required for training over purely textual data. Numerous companies all around the globe have since launched product bids and strategic initiatives to replicate this success.

And already, the combined industrialization efforts of our species have severely and measurably affected the Earth's climate. Compared to the late 19th century we are likely to see a 2°C increase in global temperatures by the end of the 21st. According to most models this will translate to rising sea levels, longer and hotter summer seasons, extended events like droughts and heat waves, and decreases in ocean oxygen levels leading to dead zones, among others. The disappearance of the ice sheet and thawing of the northern tundra likely constitute irreversible tipping points, beyond which our collective actions will not be able to contain this greenhouse process. Many second-order effects on our civilization such as crop failures, infectious diseases, loss of biodiversity through mass extinction, conflicts and migratory patterns due to water, shelter, and food security, are not as easily predicted. But whether continued industrialization and technological progress can be made compatible with the sustained habitability of our planet has become one of the most pressing questions of our time.

2 PROFITS ARE UP WHILE INNOVATION IS DOWN

At least for the case of raw energy production this question can be answered with certainty today. Clean and sustainable energy production is not only feasible in theory, but has been successfully demonstrated and deployed in practice. In March, Amazon bought Talen Energy's data center campus which was purpose-built to draw power from its neighboring 2.5 GW nuclear power station. In May last year, Microsoft signed a purchase agreement with Helion Energy to buy 50 Megawatts of power from its future fusion plant, which is planned to go online in 2028. In 2023 alone, China added 217 GW of new solar capacity, more than the entire amount ever installed in the United States, bringing its total to over 500 GW. China's nation-wide renewable energy investments increased by more than 34% in a single year, accounting for more than half the global additions.

Given the seriousness of the matter at hand, one would assume the world's free market economies leading this effort or at least follow suit. Alas, Popper's "Open Society" evidently appears to not be all that interested in saving the planet. Western countries enjoy an abundance of resources and economic status, and yet, basic infrastructure like roads, schools, housing, and health care crumble around the capitalist capitols of the world. Job and social security are reduced to a minimum while food, rent, and transportation are subjected to price hikes, wage growth is capped, and income inequality is peaking.

It may be difficult to reconcile these seemingly contradictory developments at a macro level, but looking from the perspective of distributed optimization systems reveals them as local optima in the solution space of the resource allocation problems that market economies were designed to tackle. To put it less abstract, upon entering the post-scarcity world the free markets of the west have succeeded in replacing technological progress and societal development with the appearance of economic success which is increasingly driven by hyper-extractive business models. Across the globe quasi-monopolies and international conglomerates have become success stories by holding workers and consumers hostage, while exploiting their positions of power to systematically induce artificial scarcity and extract unprecedented profits instead of yielding innovation.[2] Goods and terms of services can now roam freely and unimpeded where humans traveling from one country to another in search of better jobs and improved living conditions are declared illegal, ensuring an abundance of cheap labor. Regulatory obligations and tax liabilities are minimized by picking and choosing where to book profits and where to cut jobs.

Part of the problem is that the same globalizing market forces that have led a few trans-national mega-corporations to riches are rewarding investments in areas that contribute to our coordination problems rather than incentivizing solutions. A running gag in Silicon Valley used to be that the brightest minds of

[2] It is noteworthy to mention that this tendency of free markets is well documented historically and has been studied in depth (cf., *Progress and Poverty* by Henry George).

our time work on advertising.[3] However, their tactics are not always so benign and the systematic exploitation and lobbying by mega-corporations across the globe have made intellectual property, suppression of worker rights, anti-competitive practices, retribution against whistle blowers, planned obsolescence without right to repair, software geo-locking and version lock-out, price gouging, cross-device user tracking, automated copyright enforcement, content filtering, tax-evasion schemes, and environmental cover-ups the norm.

In 1983, Royal Dutch Shell predicted values of atmospheric carbon dioxide for the year 2025 to range "from 440 to 600ppm", putting it within a 96% accuracy level.[4] In 1999, Philip Morris had to admit to knowing and intentionally hiding the fact that Tobacco naturally contains large quantities of radioactive, cancer-inducing Polonium-210 for more than 40 years, because it is their main product. In 2010, an explosion on British Petroleum's Deepwater Horizon led to the largest marine oil spill in history, later ruled to be due to gross negligence, as well as willful and reckless misconduct.

In 2014 Volkswagen was forced to admit intentionally and systematically cheating in emissions tests of their vehicles through software that detected if the car was running under test conditions, affecting millions of newly produced cars. In 2015, Turing Pharmaceuticals after obtaining the manufacturing license for an anti-malarial and parasitic drug over night raised its price by a factor of 56, from $13.50 to $750 per pill, resulting in an investigation by the FTC alleging an "elaborate anticompetitive scheme to preserve a monopoly for the life-saving drug". In 2018, the political consulting firm Cambridge Analytica became widely known for illicitly buying, collecting, and processing the data of millions of voters in the United States with the goal of influencing the results of the presidential election two years prior through targeted, highly effective social media campaigns.

In 2022, ProPublica reported that millions of American renters are subject to algorithmic rent increases through software that "helps landlords push the highest possible rents on tenants". Realpage's tool was later re-branded as *AI Revenue*

[3] Because in 1999 placing ads among search result was the main idea behind the business model of Larry Page and Sergey Brin.

[4] The global annual mean CO2 level was 417ppm in 2022 and increases at around 2.5ppm per year.

Management. In February this year, fast-food chain Wendy's announced plans to bring surge-pricing to their restaurants, a practice that is already well established within the infamous transportation services Uber and Lyft.

3 GLOBAL MARKET INCENTIVES ARE BROKEN

This list could go on, but viewing the entities and people involved as greedy, corrupt, or malicious completely misses the point. It is important to realize that such developments are the result of rational — albeit shortsighted — individual and organizational chains of decision making. For-profit corporations operate in an environment of economic pressure and their behaviors are a reflection of the incentive structures they are subjected to. Optimizing for the bottom line is rewarded by customers, business partners, and share holders alike. Increased profits represent the single biggest hallmark of success when engaging in market activity.

It should thus be unsurprising to see agents who compete in the search for solutions of the distributed optimization problem posed by a globalized economy weigh market risks against market benefits. Unfortunately, what is beneficial for individual market participants is not necessarily beneficial for the planet and so in practice we observe that dropping the bottom line diametrically opposed to society's benefits frequently presents an attractive option. It also typically does not reflect negatively on the books of the participating agent unless litigated, and so ugly truths are often hidden, suppressed, cynically disguised as innovation and progress using endless clouds of buzzwords, or straight up lied about by the human representatives of these collective intelligences. The fact that "misbehaving" entities can sometimes be held accountable after the fact is of little consequence when the damage they cause is existential.

More importantly, the time, energy, and resources spent on endeavors that are highly profitable but detrimental to our species and our planet actively take away from innovating in directions we know to be beneficial. The failure of national legislators and courts to adequately respond to this reality cannot be explained by ill intent alone. Globalization has aggravated this dilemma by creating an asymmetry between market makers and the ability of national governments to

incentivize them. Countries have a long history of supporting their own national interests through subsidies, tariffs, taxes, legislation, developmental agencies, and funding programs. The ability of big corporations to operate and conduct business internationally has tipped the balance of power in their favor and now has regulators competing against each other for the number of jobs, financial investments, tax incomes, and socio-economic standing that multi-billion dollar companies bring to the table.

As a result, regulatory capture is widely considered to be part of the "cost of business" in a globalized economy, illustrating a shift in momentum towards profit against all odds. This changing dynamic has been ongoing despite nation states implementing additional support structures around markets to foster research, development, and innovation. At the same time the health, reputation, and soundness of large financial institutions, as well as the retirement funds of hundreds of millions of citizens in nations all around the globe are now directly tied to the market performance of the same 50 megacap companies.

While hugely profitable for a select few[5] and implemented with broad support by western economies, globalization has impressively exposed the limits of national governance as it pertains to the regulation of international markets, mega-corporations, and industrial conglomerates. After a short period of fierce competition and brutal consolidation, global market dynamics today are utterly devoid of differentiation across sectors and have led to slowdowns in competition and innovation, exchanging societal progress for the appearance of profitability and economic growth at all costs. In 1903, the Wright brothers flew the world's first airplane, by 1927, Charles Lindbergh had crossed the Atlantic ocean, and in 1969, Apollo 11 put humans on the Moon.

In the 50 years that followed since then no human has ventured beyond the Moon's surface. In fact, we now no longer even have the capability to send humans beyond Low Earth Orbit, let alone the surface of Mars. In February, the United States' first Moon landing in over 50 years was uncrewed, literally broke a leg, and fell on its side upon touch down. Research into fusion reactors began in the 1940s

[5] Microsoft and OpenAI alone are reportedly planning to build out compute infrastructure in the 100 billion Dollar range.

and 80 years later no device has reached net power, despite the fact that fusion power would unlock immense levels of clean, safe, and industry-level energy production across the world. We possess all the necessary ingredients to replicate the physical processes powering our very Sun in abundance here on Earth, yet we choose not to seize it.

This stagnation and in some cases even regression in development as a civilization is not due to a lack of curiosity, ability, or creativity, but due to a lack of focus. While the number of papers, patents, and industry R&D spend keeps growing every year, the number of concrete, cooperative innovation projects can be counted on the fingers of one hand: the International Thermonuclear Experimental Reactor (ITER), the International Space Station, the Large Hadron Collider, or the James Webb Space Telescope represent some of the few joint projects that significantly further our understanding of and impact on the world, involving successful coordination of multiple nations and state-sponsored organizations. Why are there so few of these projects? Despite their at times sluggish execution they also represent an opportunity to reflect upon the value that such coordinated development efforts can have in providing a shared vision and purpose for the future of humankind. It is telling that compared to the staggering amounts of corporate R&D tax write-offs each year the budgets of these foundational projects are laughable.[6]

Modern markets build upon a long list of innovations and iterative advancements in communication technology, transportation and logistics, as well as international law. In this sense, just like fire, the wheel, writing, the heat engine, electricity, or the internet, international markets represent a tool with the potential to improve coordination and keep humankind's developmental cycle going. Through our Earth Observation sciences and climate modeling we have learned that the industrialization efforts that they power will also lead to environmental collapse unless we direct them towards transformational change over the course of the next few decades. While the problem is clear and we have solutions available

[6] E.g., compare https://commons.wikimedia.org/wiki/File:U.S._historical_fusion_budget_vs._1976_ERDA_plan.png and https://en.wikipedia.org/wiki/List_of_companies_by_research_and_development_spending#2022_top_20.

to us, the question that remains is whether we will be able to coordinate our global efforts towards productization and deployment of those solutions. The stakes are about as high as they can get: in man-made climate change our civilization may be confronting one of the Great Filter events that prevents our galaxy from teeming with life.

4 FUNDING THE CLEAN ENERGY TRANSITION

There are historic precedents for what successful coordination on existential matters can look like on a global scale. John von Neumann laid out the potential for nuclear energy in 1955 and indeed it has played a significant role in limiting the amounts of fossil fuel that needed to be burned since then. The International Atomic Energy Agency was established in 1957 as United Nations (UN) autonomous organization. For over half a century it has presided over the world's safe and peaceful use of nuclear energy through fission. Its UN mandate includes sending inspectors to nuclear facilities all around the globe, most recently to the Zaporizhzhia Nuclear Power Plant in Ukraine to discuss and implement measures to ensure its safety with both Ukrainian and Russian heads of state amidst the ongoing war.

Clearly, the use of fission power is neither sufficient nor without risks of its own, as the meltdown accidents of 1986 in Chernobyl and 2011 in Fukushima have shown. In the 1997 Kyoto Protocol as well as the 2015 Paris Climate Accords more than 190 UN member states acknowledged and agreed that the successful transition towards clean and sustainable industrialization will require concerted transformation efforts, as well as innovation and deployment of new technologies. To support a continued series of concrete, transformational projects across these different areas and sectors it would make sense to also consider developmental funding approaches within a global framework, however, to date no such framework has been found. The Green Climate Fund has been criticized for being ineffective as well as unfair in its allocations, and thus, did not find the necessary support from key members. Like all other organizations under the UN umbrella it derives its funding from member state contributions, which are voluntary.

There are justified reasons for being critical of this funding model at a global level. The National Natural Science Foundation of China reportedly had an annual budget of 31 billion Yuan in 2019. In the United States the Defense Advanced Research Projects Agency (DARPA), the National Aeronautics and Space Administration (NASA), as well as the Department of Energy (DoE) directly support research and development by issuing grants and contracts from their multi-billion dollar budgets to third-party contractors and investigators every year. The Horizon Europe program that started in 2021 represents the ninth iteration and current installment of a recurring framework program for fostering research and development in the European Union's member states through a budget of nearly 100 billion Euros over its seven year funding period.

These regional development efforts are already substantial and also compete against each other with respect to incentivizing economic development and stimulating research and innovation within their respective economies. Diverting from these regional funding schemes towards global initiatives only serves to weaken the position of member states further, without fundamentally changing any of the incentive structures under which international for-profit corporations operate. As outlined previously trans-national mega-corporations are able to extract immense profits while national regulators and tax boards are pitted against each other. It would therefore be natural to consider a global taxation scheme to reallocate resources from the proceeds of those profits towards concrete development projects that are beneficial to humankind and planet Earth by stimulating global market dynamics in the direction of increased innovation.

An *International Advanced Research and Development Projects Agency* endowed with the power to derive an annual budget by directly taxing trans-national mega-corporations starting at a reasonable profit level such as 10 billion USD with a blanket rate of 2% regardless of their industry or registered country of business would allow for the acquisition of the necessary levels of funding to meaningfully engage in such transformational projects. This novel funding framework could be realized similarly to the already agreed upon Global Minimum Corporate

Tax which was laid out for domestic implementation by the Organization for Economic Cooperation and Development (OECD) in 2021.[7,8]

Once implemented, UN members could regularly identify and vote on key areas towards which research and development should be refocused while the proposed agency could provide direct funding for dedicated projects through Innovation and Deployment Grants of varying sizes. Grants could be issued through global Calls for Proposals, similar to how DARPA, NASA, and the DoE operate as contracting and funding agencies on the national level in the United States. This also ensures that *all* of the proceeds generated from this global taxation scheme are fed back into the respective economies to fund innovation and sustainability, through reallocation of resources towards goals that benefit all of humankind and creating an incentive for internationally operating corporations to compete for such funds.

Some of those key areas could be (i) energy production and storage, (ii) housing, food, and transportation, (iii) industrial processing and heavy industries, as well as (iv) space exploration and natural sciences. Crucially, these calls would be open to businesses around the world and have sustainability as their primary goal, including contractually binding agreements for commissioning. Deployment Grants could be prioritized based on the impact towards concrete technological development of our species and an initial heavy focus on replacing fossil fuel power stations with clean and renewable energy infrastructure to combat global warming. Innovation Grants could by awarded by panels of international subject-matter experts and used towards fundamental research, advancement and implementation of experimental prototypes, with the goal of leading up to productization and industrial-scale spin-outs.

There are many examples for concrete projects that could immediately be launched under such a program. One obvious candidate would be the build out and deployment of power plants and storage facilities for renewable energy

[7] See https://web-archive.oecd.org/2021-12-20/620119-oecd-releases-pillar-two-model-rules-for-domestic-implementation-of-15-percent-global-minimum-tax.htm.

[8] Incidentally, a draft for a tax corporation framework is already scheduled for the 79th UN session: https://financing.desa.un.org/document/promotion-inclusive-and-effective-international-tax-cooperation-united-nations-ares78230.

sources like solar and wind all over the world. While ITER is on track to generate first plasma by the end of next year, it was designed as a research facility only, and therefore, it will not be able to generate excess power or feed generated energy back to the grid. For that, the international partners have laid out a separate concept demonstration power plant called DEMO, with its own, dedicated roadmap and unclear funding to date. DEMO build-out could be accelerated significantly by starting construction and manufacturing in parallel to ITER's operation.

Another example could be the electrification of planes and cargo shipments. About 90% of all traded goods are transported via shipping container, with more than 160 registered ships in the Very Large Container Ship class, each able to carry more than 10,000 Twenty-Foot Equivalent Units, and over 50 ports around the world with the ability to accommodate them. Nearly all of those container ships run on Diesel engines resulting in over one billion metric tons of carbon dioxide being emitted every year, accounting for about 3% of all global greenhouse gas emissions in total. In 2021, the Norwegian company Kongsberg Maritime delivered the world's first net-zero, battery-powered autonomous container ship, which could provide for a promising starting point for investigating improvements of its limited range and capacity.

Combining and extending satellite-based Earth Observation programs could help enforcing stricter control on industrial greenhouse gas emissions by identifying polluters and issuing fines. In 2009, space-based measurement of methane emissions began with the launch of the Greenhouse Gases Observing Satellite (GOSAT) by Japan's Aerospace Exploration Agency. Fossil fuel companies as well as government agencies already pay GHGSat, a private company based in Canada, for operating a constellation of 12 point-source satellites that helps identify facilities responsible for leaks. In 2014, the European Space Agency established the objectives for the Copernicus missions, which have begun to take operation since 2020 in making satellite-based observations of radar and super-spectral imaging for land, ocean and atmospheric monitoring. These satellites allow for a wide range of Earth Observation science, such as measurement of the polar ice caps, land and ocean surface temperatures, tracking of wild fires, and many more use cases.

5 CONCLUSION

Assuming that humankind can succeed in sourcing its energy demands from mainly clean sources by taking corrective action on all market participants in the course of the next 25 years, a number of industrial components and processes will likely remain difficult to replace. After major energy production and transportation workloads have successfully transitioned towards clean energy other large-scale heavy industry facilities such as blast furnaces, steel mills, and chemical processing plants should eventually be moved off planet. Bootstrapping a space-based economy while building out clean energy production would prepare for an eventual transition of heavily polluting industries outside the Earth's atmosphere, while allowing for sustained growth of industrial output.

Basic materials could be mined and refined entirely outside our biosphere, before being dropped down the gravity well, touching down at the destined location just in time without requiring further transport. What may sound like science fiction has already been demonstrated successfully in February this year, when Varda Space Industries returned its Winnebago-1 payload carrying space-grown ritonavir crystals for HIV/AIDS treatment drugs after more than eight months in orbit, making it a pioneer in space-based manufacturing. To achieve a sensible, large-scale economy around space-based manufacturing raw materials must be sourced from space as well. Our solar system provides an abundance of natural resources. Individual asteroids full of water ice, minerals, and precious metals have been valued at Trillions of USD.

The increased lifting capabilities of SpaceX's Starship are already planned for development of a moon base under NASA's Artemis program. But humanity cannot hope to achieve this feat without taking the next step on the technological ladder. Continued and sustainable industrialization and growth as well as the accompanied improvements of living conditions for humans on Earth necessitate bootstrapping of a space-based economy in the medium term. Manufacturing and construction hubs in orbit will not only allow us to create radiation-shielded, floating habitats with spin-gravity, but also build next-generation rockets and

spacecraft that can launch equipment and material from outside the Earth's atmosphere.

For the future of human civilization on Earth the asteroid belt represents a treasure trove of resources and economic potential not just by creating millions of jobs and new vocations, but also by propelling humanity farther into our solar system. For tens of thousands of years humans have looked up to the skies and pondered the same basic questions: where do we come from, where are we going, are we alone? Transitioning towards a sustainable, technologically developed, space-faring civilization would allow for continued, long-term development and industrialization, minimize the fallout to our biosphere, thereby improving life on Earth, while also providing a joint purpose and vision to venture out and explore our big questions together as a people. Prominent candidates for life beyond Earth are the deep, underground saltwater oceans of Europa, as well as the thick atmospheres of Venus and Titan. I hope we can succeed in building a path towards them, for the sake of our own future.

ABOUT THE AUTHOR

David Gens is a Senior Member of Technical Staff at Cerebras Systems, building compiler infrastructure and models to run on its AI accelerator called the Wafer-Scale Engine, the biggest computer chip in the world. Prior to this he was a Postdoctoral Researcher in the Computer Science department of the University of California, Irvine in the Secure Systems and Software Laboratory headed by Professor Michael Franz. David received his PhD from the Technical University of Darmstadt, as part of the Intel Collaborative Research Institute, where he was advised by Professor Ahmad-Reza Sadeghi. Before that, he developed trade-workflow and performance-analysis tools at 360 Treasury Systems AG based in Frankfurt, Germany for their OTC/FX-trading platform while studying Computer Science and Mathematics.

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