Scarcity Zero: An open-source framework to solve resource scarcity and climate change.

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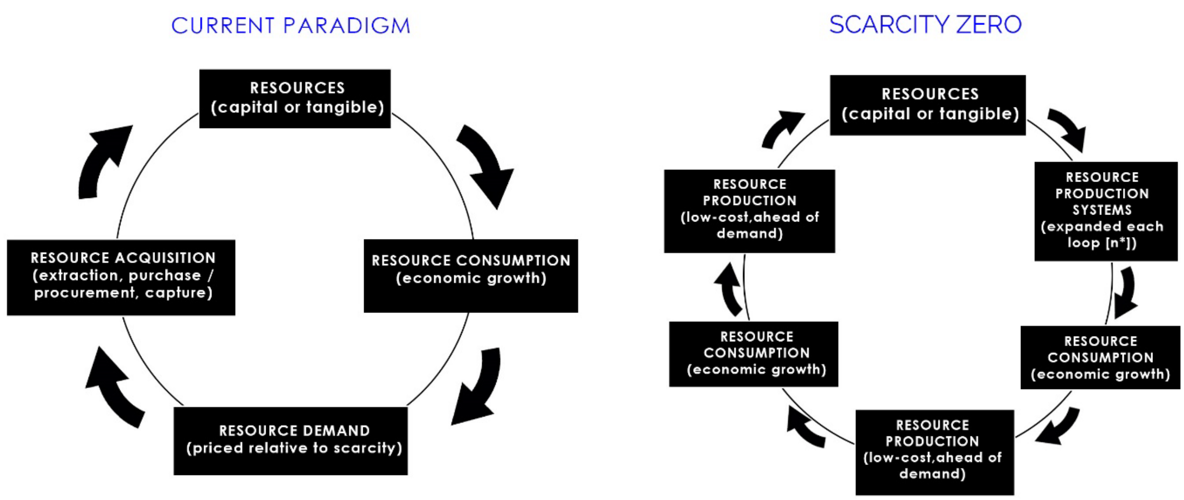
Abstract: Our world as we know it is made possible by energy and resources. As vital requirements for civilization to function, the drive to secure access to both has shaped much of human history and dominated the global order until present day. As this drive frequently occurs under a zero-sum paradigm (where each gain for one actor necessarily entails a loss for another) it spawns circumstances that present severe social and ecological impact. The insatiable demand for energy and resources are a primary cause of both environmental destruction and climate change. A lack of resources is a primary cause of economic decline, civil instability, poverty and famine. Ambitions of securing resources abroad is a primary cause of imperialism and war, along with the unquantifiable fortunes and lives they devour. Resource scarcity is a core human malady, and a curse upon our species.

We propose a system that can solve this challenge of resource scarcity. Our strategy is to deploy the most capable energy technologies we have available into an open-source framework that produces **both** energy and resources as dedicated functions that are designed to work cooperatively. Integrating modularity, standardization, cogeneration and scalability into each facet of system design allows the framework to be mass-produced and rapidly deployed. It also allows for the waste energy of one technology to be harnessed to power the functions of others at maximum efficiency. Combined, this enables a dramatic increase in energy available to society at proportionally lower cost, enabling the sustainable production of vital resources as well as dedicated systems that can capture carbon and recycle waste at scale.

We call this framework **"Scarcity Zero."**

Part I: A mindset of abundance

Every aspect of our economy and society, down to our very survival as biological organisms, is dependent on securing resources. Yet our past and present approaches to resource acquisition have proven reliably myopic: we extract whatever resources we can find, manage them unsustainably, and then seek their acquisition elsewhere – frequently by any necessary pathways. Consequently, we have historically invested in means of resource *acquisition*: extraction, trade or capture (of which imperialism and warfare are chiefly applied to facilitate).[1] The mindset of Scarcity Zero is to instead invest in resource *production:* technological methods that enable us to sustainably *produce* our most vital resources to indefinite scales – enabling a post-scarcity future spared of unsustainable extraction.



Instead of using extracted resources to power economic growth – only to be left thereafter with unsatiated resource demand – Scarcity Zero seeks to build resource production infrastructure on a nationwide scale that can continually produce resources ahead of demand as a feature by design. This, in abstract, keeps resource prices low and minimizes scarcity, which thus reduces resource cost/scarcity as an inhibitor on social and economic growth – ultimately laying the groundwork for a society where both people and enterprises can indefinitely thrive.

The Scarcity Zero framework is intended to produce five resources: **electricity, fuel, water, food and building materials** to effectively indefinite volumes – both as a dedicated effort and as a cogenerative byproduct of power generation. While the framework is designed to be modular and thus flexible in scale, its goal is to build an infrastructural capability that can expand our national energy generating capacity to 300% of annual U.S. electricity consumption (12 trillion kilowatt-hours [kWh]) at a baseline cost of 2 cents per kWh – an approximate reduction of 85% from a current average of 10.53 cents.[2] While multiple systems work together to make this goal possible, the backbone of the framework is provided by three primary functions:

Function One: Renewable Cities – Instead of deploying renewable power in disparate, ad-hoc and arbitrary locations, we advocate for integrating renewable power directly within the infrastructure of population centers – especially municipal infrastructure. Beyond rooftops, it is today both inexpensive and straightforward to install transparent solar panels within effectively any surface: the windows and cladding of buildings, the sides of bridges or overpasses, or structural canopies over roads and highway medians – the latter of which can also serve as a suitable location for wind power. This provides a nigh-infinitely scalable location to deploy renewables that offers unique advantages over traditional deployment vectors. For example:

- Integrating renewable power within city infrastructure avoids the need to purchase additional land for deployment – a massive cost factor at scale.

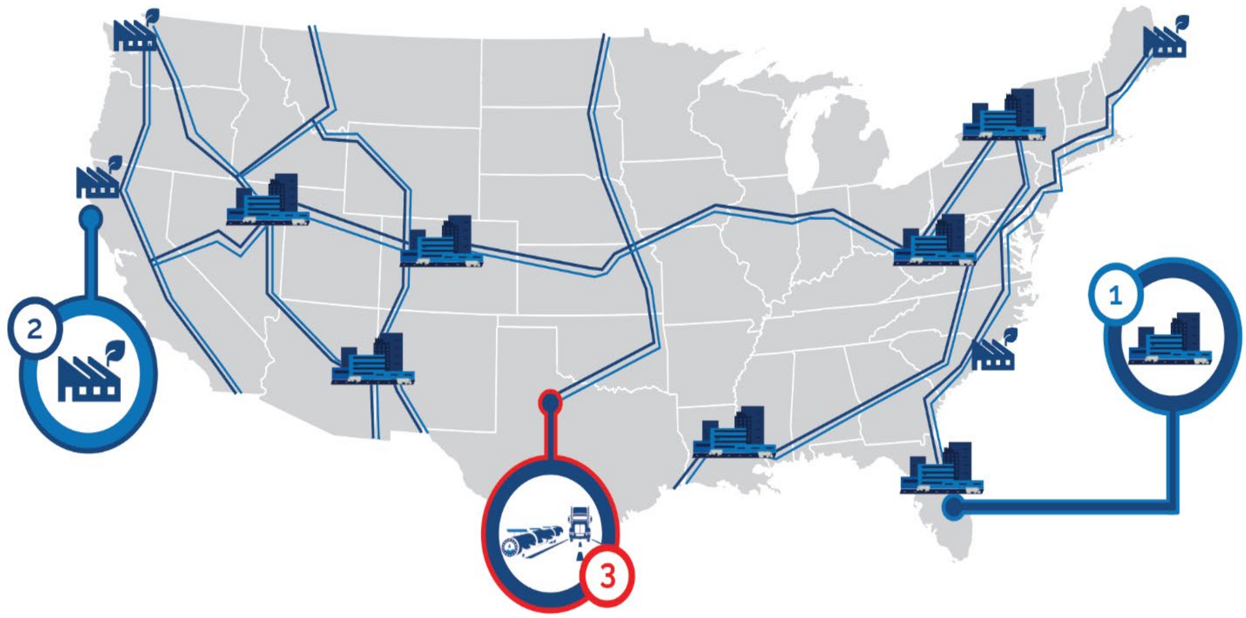
- The surface area of cities in aggregate represents trillions of square feet that is within immediate proximity of energy consumption, minimizing transmission distance.

- Operating in unison, infrastructurally integrated renewables can underwrite a smart grid that is independently and redundantly sustained, which at scale can eventually enable cities to generate net-positive energy (more power than they consume).

Function Two: Cogeneration Facilities – The concept of "cogeneration" (or "Combined Heat and Power") involves harnessing the waste heat energy of one system to power the functions of another. The role of Cogeneration Facilities is to leverage this possibility to maximum effect by pairing power-generating systems alongside resource-producing systems in the same deployment envelope. By designing and mass-manufacturing each contributing system as modular components that are standardized to both work cooperatively and install rapidly, the cogenerative potential of our most potent energy technologies can provide effective pathways to sustainably produce resources at scale. The most critical of these resources are fresh water from seawater desalination and hydrogen fuel from seawater electrolysis, but the modular nature of Cogeneration Facilities can also be extended to power systems that recycle waste, capture greenhouse gasses, grow crops in indoor farms, and synthetically produce advanced materials.

Function Three: The National Aqueduct – The National Aqueduct is water delivery network intended to transport fresh water produced by Cogeneration Facilities to provide water abundance while doubling as an immense source of power. Deployed within interstate highway and high-tension power line networks to avoid expensive land purchases, its capability to generate power is made possible by integrating hydrodynamic turbines and solar panels within modular, mass-manufactured water pipeline arrays that span the vast distances of our national landscape. This capability is extended by using excess energy to keep water at high temperature – enabling passive thermoelectric power generation that can transform the aqueduct into a nationwide "battery" to store energy generated by renewables for use off-hours.

Overview of Scarcity Zero Primary Functions:



RENEWABLE CITIES

GENERATES ACTS AS

Integrating renewable power directly within city infrastructure affords unrivaled deployment opportunities that minimize distance from generation to consumption. This avoids the need to buy expensive land and lays the groundwork to build smart electric grids. It can also transform cities into energy-generating nodes on a national network - exponentially increasing power generation capacity while minimizing external demand.

COGENERATION FACILITIES

Cogeneration Facilities are a strategic deployment of modular, mass-produced systems that are designed to work cooperatively to both generate energy, produce essential resources, capture carbon from our atmosphere and recycle waste on a large scale. With the aid of The National Aqueduct, this can provide the energy and resources for vertical farming and material synthesis.

GENERATES PRODUCES DESALINATES

CAPTURES CO_2 RECYCLES HELPS GROW

THE NATIONAL AQUEDUCT

The National Aqueduct transports desalinated water nationwide through modular pipelines, storage tanks and pumping stations deployed within the free open land of highways and power lines. By integrating solar panels and hydrodyanmic turbines within pipelines, water flow can generate immense power that can also keep water hot - turning the aqueduct into a giant thermoelectric battery to store energy generated by renwewables.

GENERATES

DELIVERS

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Function One: Renewable Cities

The first function of the Scarcity Zero framework is to deploy renewable power in the most effective and scalable methods possible. While dedicated wind and solar farms retain notable utility, we believe that the single best approach is to instead integrate renewables directly within the municipal infrastructure of population centers. In the context of solar power, municipalities present billions of square feet[3] of sun-exposed surface area nationwide that can be covered with photovoltaic panels, which are today both inexpensive and flexible in deployment. Going beyond rooftops, photovoltaic panels can be installed within the windows and siding of buildings, on the sides of bridges and overpasses, and on top of canopies over parking lots, highways, road medians and bike paths. Nearly every aspect of municipal infrastructure can today be seamlessly integrated with a means generate power from the sun.

Top-left to bottom-right: 1). Clear photovoltaic glass. 2). Green photovoltaic glass. 3). Solar-sided building. 4) + 5). Solar canopies over parking lots. 6). Highway median converted to solar-canopied bike path. 7) Solar highway canopy.

Figure 1: (Above) Concept of comprehensive solar integration with municipal infrastructure

Wind, too, can be similarly integrated. As wind power has evolved from skyscraper-sized turbines that are hallmarks of traditional wind farms, small modular turbines can today be deployed alongside solar panels within the thousands of miles of highway medians surrounding America's cities. As highway medians are flat, straight and municipally owned, they collectively present billions of additional square feet that are effectively free to deploy wind at scale – which in this context can be significantly boosted by air movement from passing vehicles.

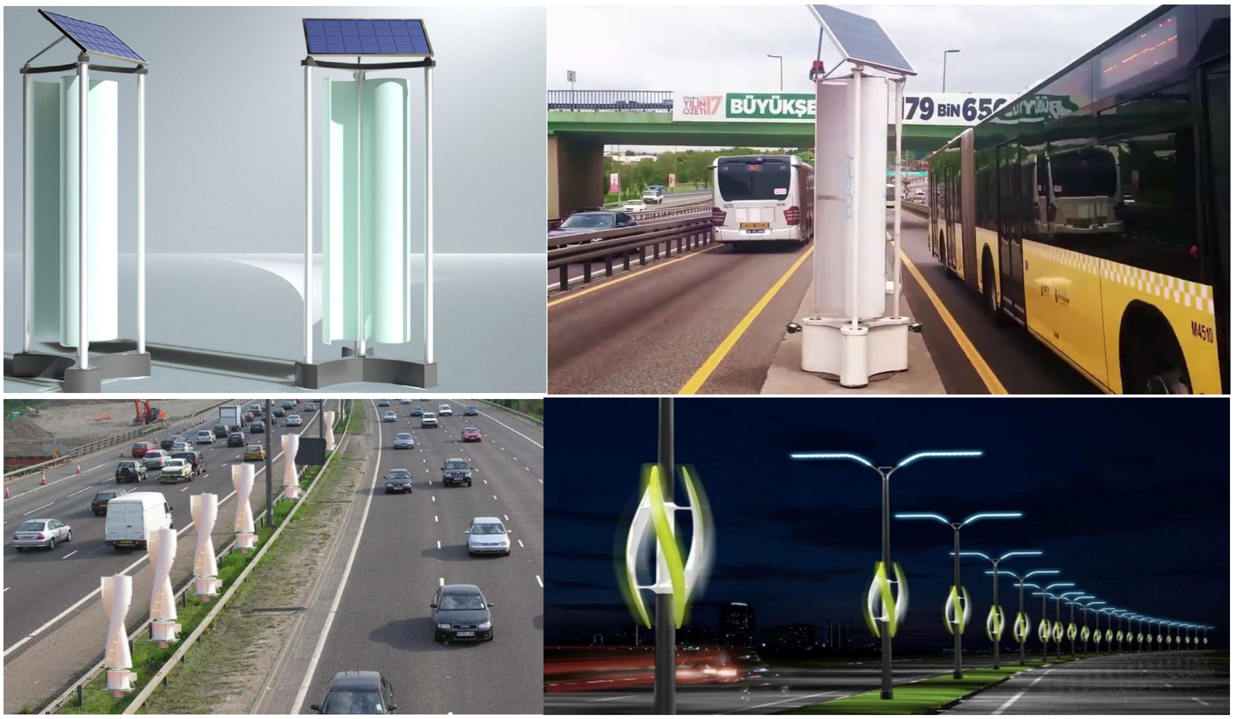


Figure 2 - Wind turbines on highway medians

It is difficult to overstate the potential scale of energy generation made possible by targeting municipal infrastructure as a deployment vector for renewable power. This is not only because it offers an unrivaled expanse of cost-free surface area and flexibility of location, but also because this approach solves most of the challenges facing large-scale renewable deployment today. *(Note: the remaining challenges of material throughput, carbon-neutral manufacturing and end-of-life recycling are dedicated roles of Scarcity Zero's second function, Cogeneration Facilities, that are detailed within the next section of this document).*

- **Location / Transmission Distance:** As a general rule, the farther electricity must travel, the more challenging it becomes to transmit due to resistance in transmission mediums (normally, power lines).[4] While the American Southwest has enough open space to power the entire planet through photovoltaic panels, electrical resistances in power lines make it unfeasible to transmit electricity over long distances.[5] Such an effort would also be cost-prohibitive, as high-tension power lines cost millions of dollars to build per-mile[6] even if capable of resistance-free transmission. This makes renewables most effective in locations close to where their generated energy is consumed, of which cities are the zenith as they consume the most energy in the most compact envelope.
- **Land Costs:** As the effectiveness of renewables is inversely proportional to transmission distance, integrating them within city infrastructure avoids the corresponding problem of

land costs. Not every state has cheap open space to deploy solar farms in the vein of California or Arizona, and as land prices tend to increase with proximity to population centers (often at six figures per-acre or greater),[7] buying the billions of acres required to implement renewables at sufficient scale would requisitely cost staggering sums.[8] Municipal integration avoids this problem because municipal governments need neither purchase land nor seek permission to install renewable power on public property. They further have the power to incentivize new construction to integrate renewable power from the design stage in both public and private development. Municipal integration can thus automatically avoid one of the most significant cost factors of large-scale renewable deployment.

- **Scalability:** Solar power today is primarily deployed in piecemeal application – on rooftops of private structures or in dedicated farms that are constrained by both the cost of land and the challenges of transmitting electricity over long distances. Integrating renewables within municipal infrastructure allows instead for standardized applications that present indefinite scalability, as each new point of generation increases aggregate generation capacity. A 50-story skyscraper, for instance, could annually generate 1.12 million kilowatt-hours of energy if outfitted with solar windows, a number that would increase to 1.38 million in Denver or 1.57 million Phoenix.[9] When applied to millions of structures across thousands of cities, the multiplier effect presents a power generating capacity that reaches into the trillions of kilowatts[10] without purchasing a single land parcel for renewable use. No other method of renewable deployment can come remotely close to matching this capability.

Figure 3 – Expanses of American cities, reflecting only a fraction of national urban landscapes

- **Intermittency:** Integrated renewables can further address the problem of intermittency (instant availability) within population centers and their surrounding regions. The present-day use of renewables requires complex networks of power systems to meet energy demand when renewables (which do not work 24 hours a day) are unable to do so.[11] This configuration contributes to a messy, failure-prone and oft-unreliable power grid that is at risk of failure in critical times of stress – or sabotage from malfeasant actors.[12] With Renewable Cities, however, the city infrastructure itself becomes the city's primary power source. In this model, a city would not need to rely on energy generated by external sources (outside of storage through The National Aqueduct), instead providing for their own needs and only consuming energy from external sources when required. This is a marked improvement from constantly relying on remote renewable farms – and then relying on carbon-emitting backup systems thereafter – if and when those farms generate insufficient power.

Beyond addressing these challenges, integrating renewables within municipal infrastructure turns each individual panel or turbine into a node that in aggregate helps underwrite a smart, redundantly reinforced electric grid. At maximum scale, every building, parking lot, highway median, bridge, overpass and all points in between become a means to both generate and transmit electricity – which, when connected, can upgrade and eventually replace the antiquated electric grids that are today struggling to keep up with our ever-advancing society.

As of this writing, our national electric grid is comprised of 7,600+ decentralized power plants[13] that are owned by 3,200+ competing utility companies[14] that transmit electricity through 450,000+ miles[15] of high voltage power lines, relay stations and transformers – effectively a convoluted mess. This arbitrary deployment of infrastructure does not operate within a cohesive, dynamic and scalable framework, nor does it utilize cooperating systems that are mass-manufactured to a modular standard for rapid installation and replacement. This contributes to the problem of power shortages and regional blackouts, which is getting worse over time as our existing electric grids decay. The currently estimated cost to upgrade them using today's technology exceeds $2 trillion.[16] Integrating renewables within municipal infrastructure can effectively solve this problem at a far superior return on investment across all relevant metrics.

Further, the combination of these aforementioned factors accomplishes two important goals:

1). It transforms cities into power-generating centers. Once cities scale renewable integration to the point where they can generate more energy than they consume, they functionally become power plants. With the ability to store energy generated by renewables within The National Aqueduct, cities can thereafter contribute to a national energy abundance instead of drawing from external power infrastructure to meet their own energy needs.

For example: Miami-Dade County in South Florida spans an area of 2,431 square miles, 1,898 of which is land.[17] It assessed a net energy consumption of 132.13 billion kilowatt-hours in 2018.[18] Using rationale explained in the following citation,[19] we assess that one square mile of solar panel surface can reliably generate 836.5 million kilowatt-hours of energy per-year. That means Miami-Dade County would only have to integrate solar panels within 159 square miles of its land area – less than 8% – to become energy independent, assuming that The National Aqueduct could provide sufficient power off-hours. At 10% integration, the county generates more energy than it consumes. At 15%, it's a power plant, one with multiplied output should integration reach beyond that – all the more so as the efficiency of renewables improves over time.

Figure 4 – Solar City in Dubai

2). It drastically increases power generation capacity. With cities powered by integrated renewables and the energy they help contribute to The National Aqueduct, any external power generation capacity thereafter enters a dynamic with drastically reduced demand. As additional power infrastructure is deployed, it increases generating capacity accordingly – at scale powering a multiplier effect where generating capacity continues to accelerate at a significantly faster rate. As the cost of energy is relational to demand, these circumstances cause the price of electricity to sharply reduce. This presents significant benefits across nearly all sectors of our economy, while also making dedicated resource production, environmental cleanup and carbon capture far less expensive.

This is where Cogeneration Facilities – Scarcity Zero's second primary function – enters the framework. As a cooperative deployment of modular, mass-produced systems that can be rapidly installed (or replaced), their intent is to eclipse our current generating capacity several times over while also powering systems that produce vital resources, extract greenhouse gasses, and recycle waste – all while providing a carbon-neutral energy source to mass-manufacture renewables.

Function Two: Cogeneration Facilities

Within the Scarcity Zero framework, Cogeneration Facilities are a flexible deployment of modular systems that function cooperatively to generate *both* energy and resources.

Primary roles of Cogeneration Facilities:

- Generate electricity
- Desalinate seawater into fresh water (Multi-Stage Flash Distillation)
- Extract hydrogen from desalinated seawater (on-site electrolysis)

Secondary roles:

- Employ Direct Air Capture to extract greenhouse gasses from our atmosphere
- Power large-scale waste disposal/recycling through plasma gasification

Tertiary roles:

- Synthesize hydrocarbons through electrolyzed hydrogen and captured CO_2 + Methane
- Expand flexibility of synthesized hydrocarbons through gasified syngas

The following illustration is a bird's eye view of a facility in concept, with descriptions noting **primary** roles that work under a cogenerative (or "Combined Heat and Power") design.

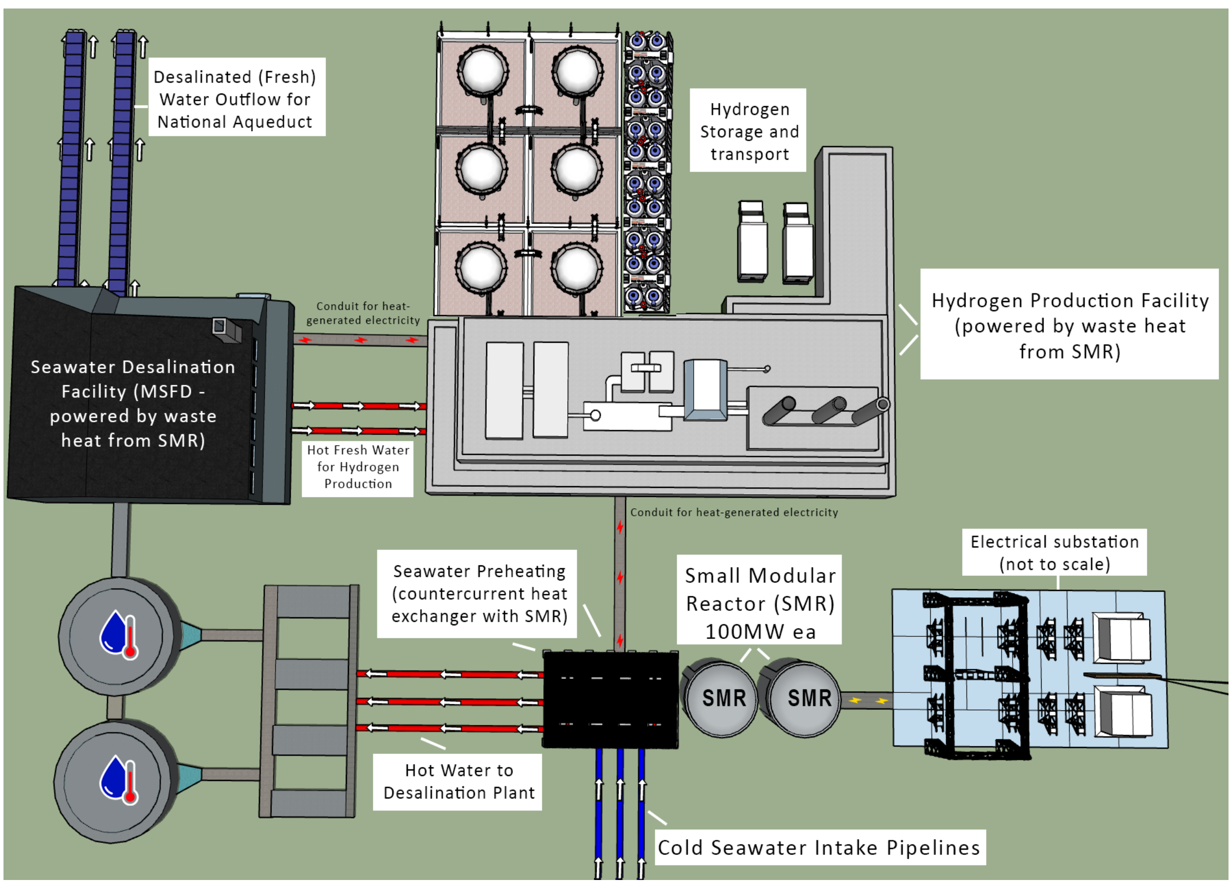


Figure 5 - SMR delivered by truck

The centerpiece of a Cogeneration Facility is the Small Modular Reactor (SMR), a potent and compact form of power generation that can be mass-manufactured and rapidly deployed as modules. As each SMR is capable of generating 20-100 megawatts of power (or greater)[20] and are small enough to be delivered by truck as completely operational units, they allow a Cogeneration Facility's power generation capacity to be rapidly scaled. Significantly increasing output can be accomplished simply through the delivery of more reactor modules that can be deployed and replaced in a fashion not conceptually dissimilar to residential batteries.

SMRs are among the most powerful and efficient forms of modular energy generation we have available, and they also output a large volume of heat that can be leveraged to power additional systems. Within the Scarcity Zero framework, these systems include resource production, ecological cleanup and waste management.

The first and most important system in this context is freshwater production through seawater desalination. This process begins by counterflowing cold seawater intake pipelines with the heat exchangers of SMRs, which, depending on design and fuel cycle, can range in temperature from 400-1400°C.[21] That is more than sufficient to preheat seawater to boiling – allowing water to arrive at desalination facilities already at requisite temperature with minimal (if any) energy overhead.

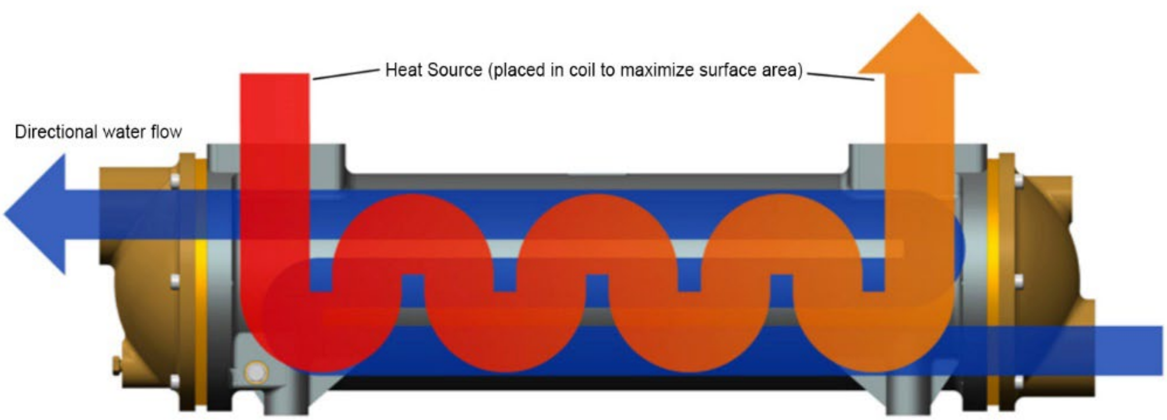
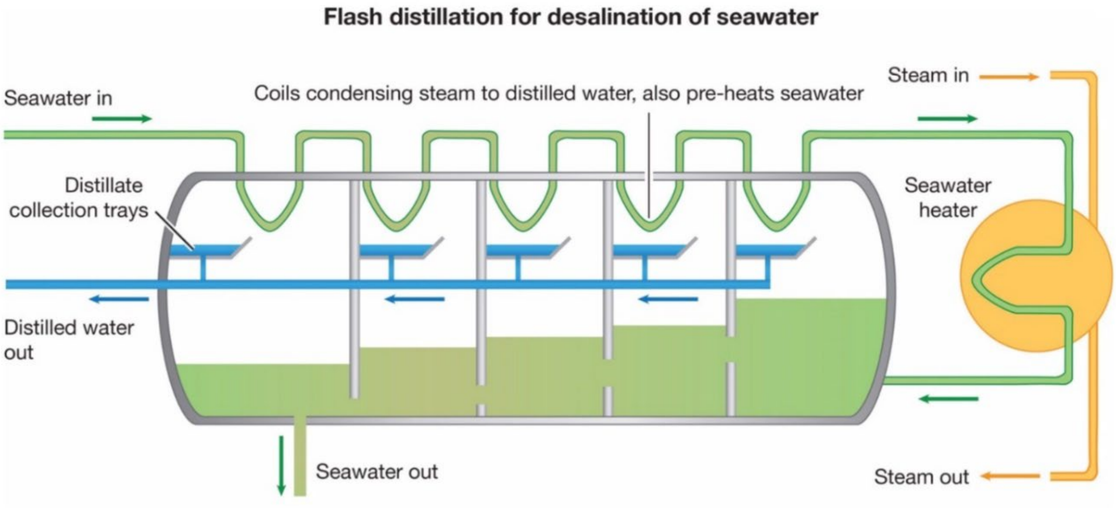


Figure 6 - Countercurrent heat exchanger for seawater preheating

At the desalination facility, preheated seawater is diverted into a Multi-Stage Flash Distillation Chamber that uses arrays of pressure chambers (relating to boiling temperatures of water) to flash-turn hot seawater into steam where it then is collected and condensed into fresh water.

Multi-stage flash is one of the most common forms of desalination today,[22] and the proven technology would be operable at fractional cost of powered purely by waste energy.



From there, desalinated fresh water is used for one of two applications:

1. It is diverted for hydrogen extraction through heat-powered electrolysis (using residual salt as an electrolyte), where it is stored and transported for external use.

2. It is pumped offsite through **The National Aqueduct** – a water delivery network that both generates power and stores energy generated by renewables. We will review The National Aqueduct in detail later in this document.

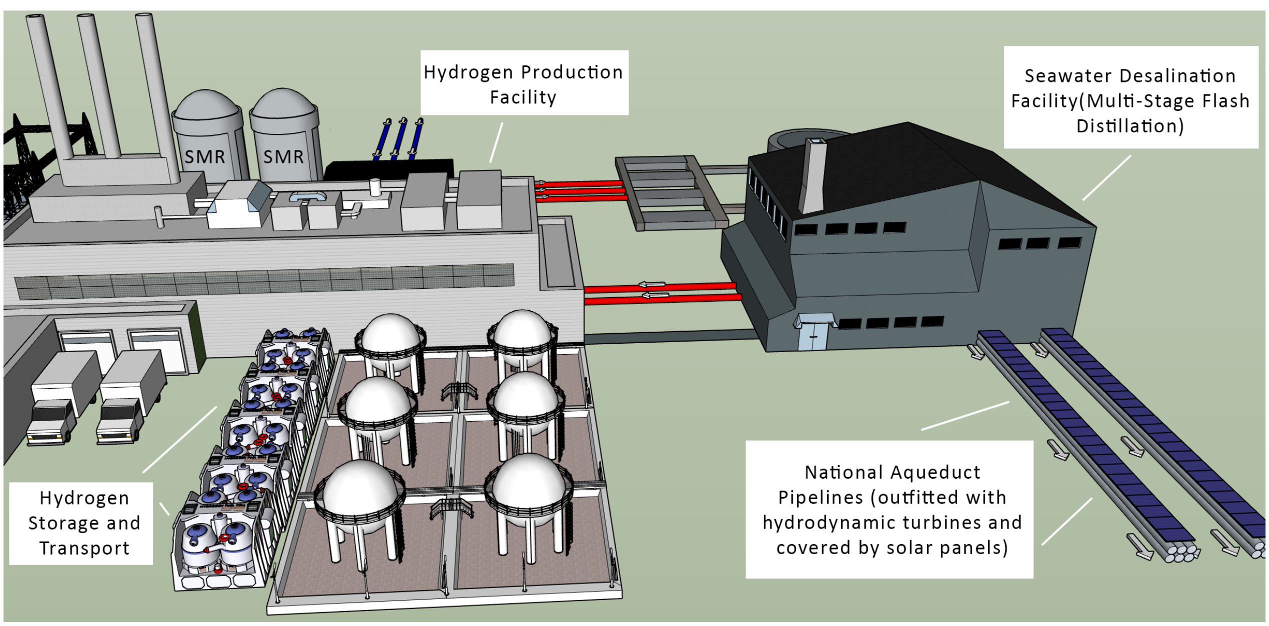


Figure 7 - Auxiliary roles of Cogeneration Facilities

This first application of hydrogen production serves the critical role of replacing petroleum (oil) with a carbon-neutral alternative in most of the applications it is used today. This includes manufacturing synthetic hydrocarbons for chemical and material engineering. It also includes powering both heavy machinery, commercial transportation and next-generation aircraft with either fuel cells or high-performance synthetic fuels.

Hydrogen is the most abundant element in our known universe with the single-highest specific energy of any conventional (non-nuclear) fuel[23] – and with perhaps the exception of synthetic hydrocarbons, every aspect of its use as fuel is carbon-neutral.[24] Hydrogen production is currently a $100+ billion industry, yet it depends on an ecologically harmful and carbon-emitting process to produce (fossil fuel steam reformation).[25] In spite of these drawbacks, it is nonetheless more cost-effective than simple electrolysis (introducing an electric current to separate water into hydrogen and oxygen), which is far cleaner and does not emit carbon. Yet this reality is due to the current cost of energy, which would change with the introduction of Renewable Cities and Cogeneration Facilities – with the latter providing sufficient energy (and potential thermoelectric charge from waste heat) to leverage electrolysis for large-scale hydrogen extraction.

Although Scarcity Zero would enable us to synthetically produce hydrogen for use in any application currently served by petroleum, we believe hydrogen's long-term affordability, safety and sustainability would be maximized by excluding its use for personal vehicles. This deviates from several schools of thought that conclude (correctly) that hydrogen is perfectly capable of powering cars and trucks. Yet hydrogen also requires complex containment systems, extensive refueling infrastructure and, as a highly explosive substance in concentrated volumes, critical safety features that present significant liability in the hands of consumers. It is simply safer and easier to power personal vehicles with electricity. Heavy machinery, commercial transport and aircraft, however, retain sufficient size to safely store large volumes of hydrogen – allowing society to regulate its use to commercialized, licensable applications that run lower risk of accidents from untrained operators. This would present less of a demand for hydrogen (keeping its cost lower) while at the same time transforming aerospace, global shipping and domestic freight into carbon-neutral industries that are no longer beholden to global fuel prices.

It is further important to note that machinery powered by either hydrogen or electricity can be substantially improved through the increased production of graphene, which Scarcity Zero seeks to extend as a core material deliverable. As we will review later in this document, graphene is a form of carbon that presents extraordinary performance implications in terms of structural strength, weight, thermal resistance and electric conductivity. Graphene sheets can be bi-woven together to create shapes that are hundreds of times stronger than equivalents made from steel, aluminum and even titanium– all at fractions of their respective mass. This makes it easier to manufacture ultra-strong lightweight tanks or fuel cells to store hydrogen at a greater density – allowing for easier integration within the fuel supply of a larger vehicle or aircraft. It also allows graphene to integrate electric storage within a structural chassis or fuselage to compliment internal batteries or wireless recharging – significantly amplifying performance at reduced mass.

This latter function presents extensive benefits to the current revolution underway with both electric vehicles *and* electrical aircraft,[26] as well as next-generation transportation,[27] which is a topic we will focus on at future points herein.

With electricity, fresh water and finally hydrogen fuel provided, the secondary roles of Cogeneration Facilities are then engaged to power systems that scrub greenhouse gasses from our atmosphere and upgrade our means of waste management/recycling.

The role of atmospheric scrubbing is performed by a technology called Direct Air Capture, which physically extracts greenhouse gasses (Carbon Dioxide and Methane) from air via a catalytic process.[28] As a byproduct of this process, any extracted gasses can be used to synthetically produce hydrocarbons that can help make next-generation materials and low-carbon fuels.[29] The following diagrams provide an overview for how Direct Air Capture works *(note: each is sourced from private companies that manufacture technology in this sector).*

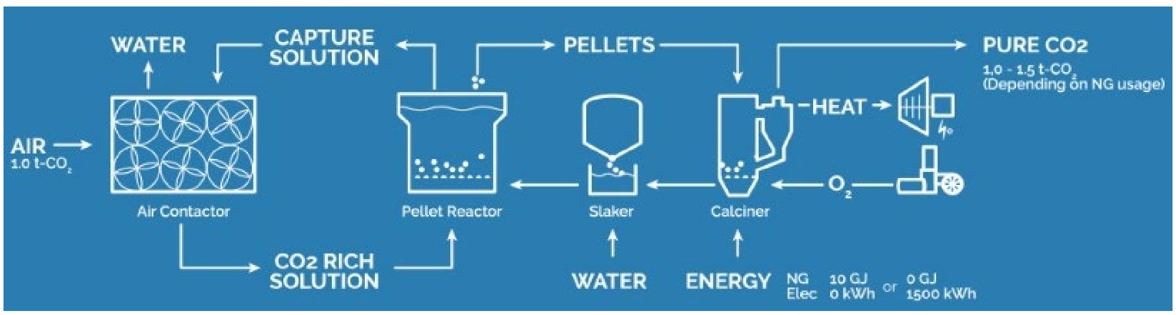


Figure 8 - Direct Air Capture conceptual overview (Source: DAC corporation)

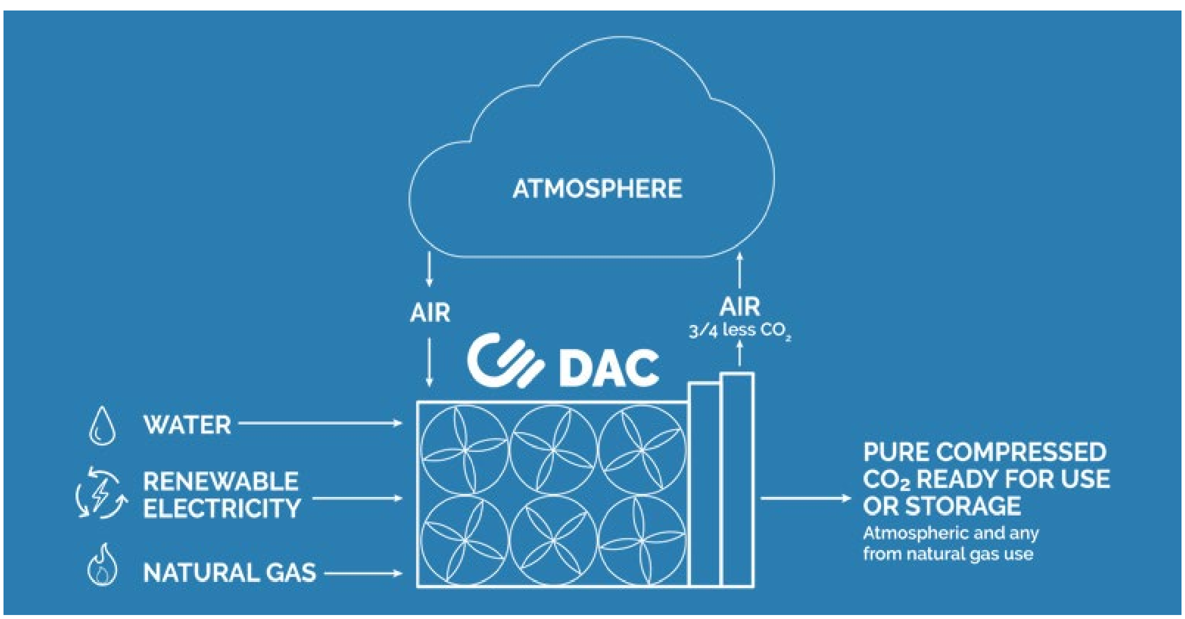


Figure 9 - Direct Air Capture conceptual overview continued (Source: DAC corporation)

As Direct Air Capture units can be installed in arrays, there are no practical limits to how many can be deployed in any given location provided there is sufficient space and electricity. While the concept image below (Fig. 11) suggests a remote location, deployment within the envelope of

Cogeneration Facilities enables access to a nigh-unlimited supply of energy generated by SMRs, either via direct current or heat/thermoelectric charge harnessed in a cogenerative capacity.


Figure 11 - DAC units assembled as larger unit (concept)

We believe Direct Air Capture to be the most effective method we have available to reverse course on climate change because it is accomplished through a *technical, mechanical means.* Unlike ideological approaches (however laudable) that require fundamental changes to human nature or the competitive nature of a global economy, Direct Air Capture simply removes the presence of greenhouse gasses as a dedicated function – one that can accomplish what forty years of principled argument has failed to.[30] On the scale of thousands to even millions, these systems enable a degree of low-level geoengineering that can solve a pressing and potent ecological threat. And they can do so as a passive byproduct of next-generation power and resource infrastructure.

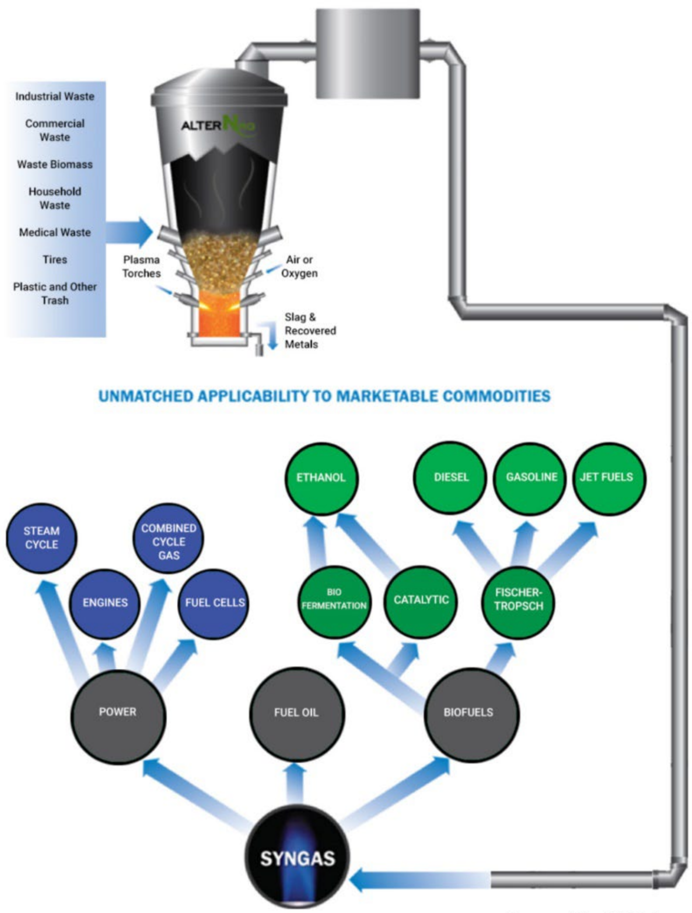


Figure 12 - Plasma Gasification Overview

The role of waste processing and recycling is performed by a technology known as plasma gasification. Powered by an ample supply of heat and electricity, a plasma gasifier is effectively a hyper-efficient means of waste incineration in a sealed environment. Exceeding temperatures of 14,000°C (~25,000°F), plasma gasifiers separate waste into base elemental compounds that can be used in a variety of applications.[31] Some are inert solids useful for paving roads ("slag"); others are fuels that can combine with electrolyzed hydrogen and extracted greenhouse gasses to provide another sustainable source for specialized fuels and lubricants.[32] Others still are raw materials and metals that can be re-integrated back into our economy for sustainable manufacturing.

Plasma gasification is itself a power-generating technology that can contribute to a nationwide abundance of clean energy.[33] As with the other functions of Cogeneration Facilities and the

Scarcity Zero framework, plasma gasification systems can be mass-produced to a modular standard, enabling rapid, turnkey deployment of yet another vital technology for our energy and resource paradigm.

By virtue of this deployment strategy, Cogeneration Facilities can both sustainably and indefinitely produce electricity, fresh water and hydrogen fuel alongside the critical roles of atmospheric decarbonization and waste management – all as part of the same parent system within the same compact footprint. Just as importantly, they can each do so as modular, pre-manufactured systems that can be scaled and replaced on demand.

This is a major departure from the way power and resource infrastructure is presently built: almost exclusively on-site as custom-designed and custom-constructed facilities that share little similarity or standardization with others like them. Consequently, our power infrastructure today is arbitrary in design, nature and operation, which drastically increases costs of construction while complicating both repairs and upgrades.

Take the Vogtle Electric Generating Plant in Georgia. Its first two power units were constructed in the late 1970s, with its third starting construction in the spring of 2013 with the fourth shortly thereafter.[34] The latter two units will not be operational until late 2021 at earliest.[35]

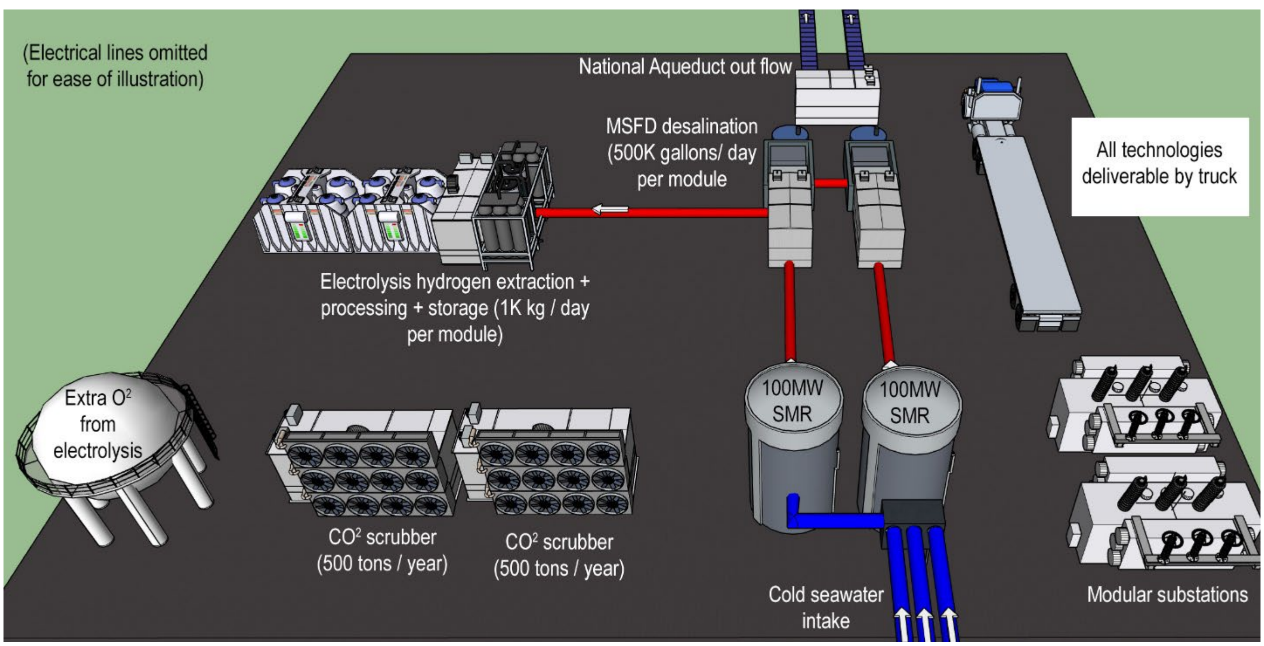
Year One: **Year Four:** **Year Eight:**

A time period of *nine years* to build two nuclear reactors is not a reflection of practical limits to manufacturing capability – the United States Navy, after all, has been building small modular reactors for decades to power warships without a single documented point of failure.[36] Rather, this dynamic is a reflection of an inefficient approach that sees complex, error-intolerant systems manufactured and deployed as unique, ad-hoc entities. It also is a stark deviation from how we manufacture technology with similarly demanding safety and performance requirements.

Commercial aerospace, for example, shares comparable degrees of precision, technical difficulty and error intolerance as nuclear engineering. Few challenges are more daunting than building systems that annually transport millions of people from rest to 570mph at 36,000 ft above the Earth[37] – with every single life underwritten by the promise that their aircraft will *never* fail. Yet today the Boeing corporation can fully assemble its flagship 787 Dreamliner jet every 17 days[38] – less time than it takes *Budweiser* to brew a bottle of beer.[39] Power and resource infrastructure can therefore be built the same way under similar performance requirements: rapid, reliable and replicable systems each mass-manufactured to a modular standard.

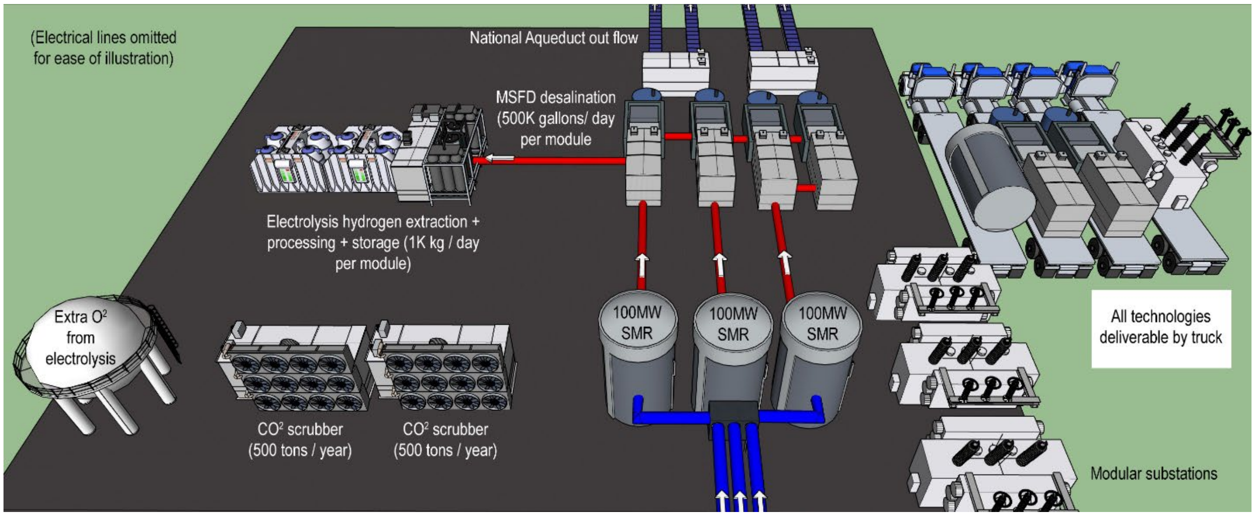
The idea is not to just build power and resource infrastructure easier, less expensively and on a larger scale. The idea is to mass-produce power and resource infrastructure like we build any complex commercial product – with the same flexibility in deployment or replacement. When a lightbulb breaks, we replace it with a new one. Same with a microwave or television. Same with a personal vehicle. Same with a city to a bus, or an airline with an aircraft. **The same can be true of a power plant.** Today, it might be a question of decades and billions of dollars to triple a power plant's generation capacity or extend functionality to desalinate seawater, dispose of waste or scrub atmospheric carbon. The goal of Cogeneration Facilities is to be able to accomplish these tasks in a matter of days if not hours. Our current state of manufacturing prowess, combined with building systems to a modular standard, can deliver this exact result.

While prior illustrations of Cogeneration Facilities outlined conceptual function for ease of explanation, their envisioned deployment in practice would reflect systems that are manufactured as multiplier modules as opposed to traditionally constructed buildings. This would enable Cogeneration Facilities to rapidly change configuration and scale capacity for both energy generation and resource production in response to demand. For a practical example, the following images show sample deployments of modular technologies:



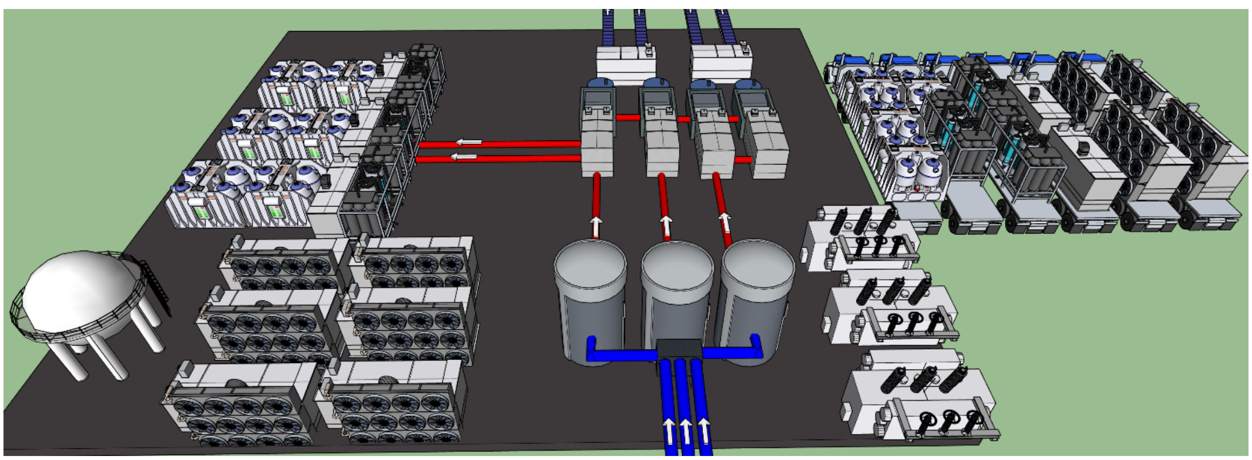
This hypothetical deployment of cogenerative technologies extends a power generation capacity of 200 megawatts, a desalination capacity of 1 million gallons (3,785m^3) per day, and an electrolysis capacity to produce 423,000 ft^2 of compressed hydrogen (1,000kg).

As with prior conceptual deployments of Cogeneration Facilities, the excess heat from SMRs is used to preheat seawater for ease of desalination and hydrogen production. Yet the nature of modular deployments along with straightforward delivery by truck, rail or helicopter enables rapid configuration changes with minimal effort. For example, let's assume that we needed to increase power generation by 100 megawatts with twice the desalination capacity.



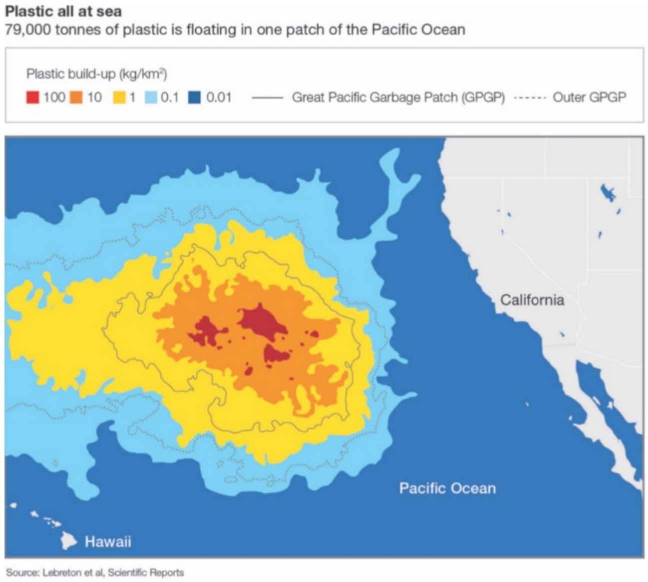
As each component can be delivered by truck, it takes all of four sorties to deliver another 100MW of power generation, two Multi-Stage Flash Distillation modules at 500K capacity each, and another modular substation to handle the load generated by the third SMR.

Let us assume thereafter that this location significantly underestimated demand for hydrogen production as well as the volume of excess energy they could devote to atmospheric scrubbing. What would it take to scale their capacity for both by 300%? In this case, six truck deliveries:

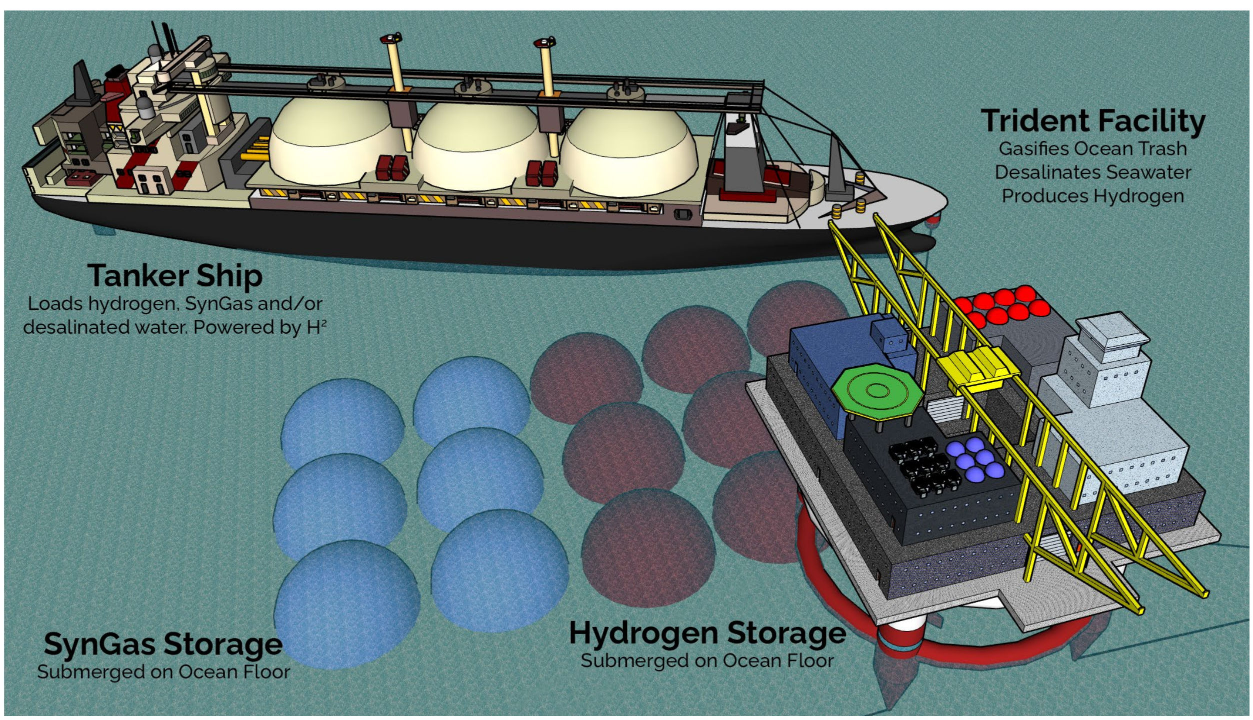


This capability is not science fiction – we already capable of building systems in this capacity. Yet in practice it reflects an unprecedented opportunity that can in no way be matched by the current approach we take today to building energy and resource infrastructure, all the more so in the face of significant changes in configuration, output and performance.

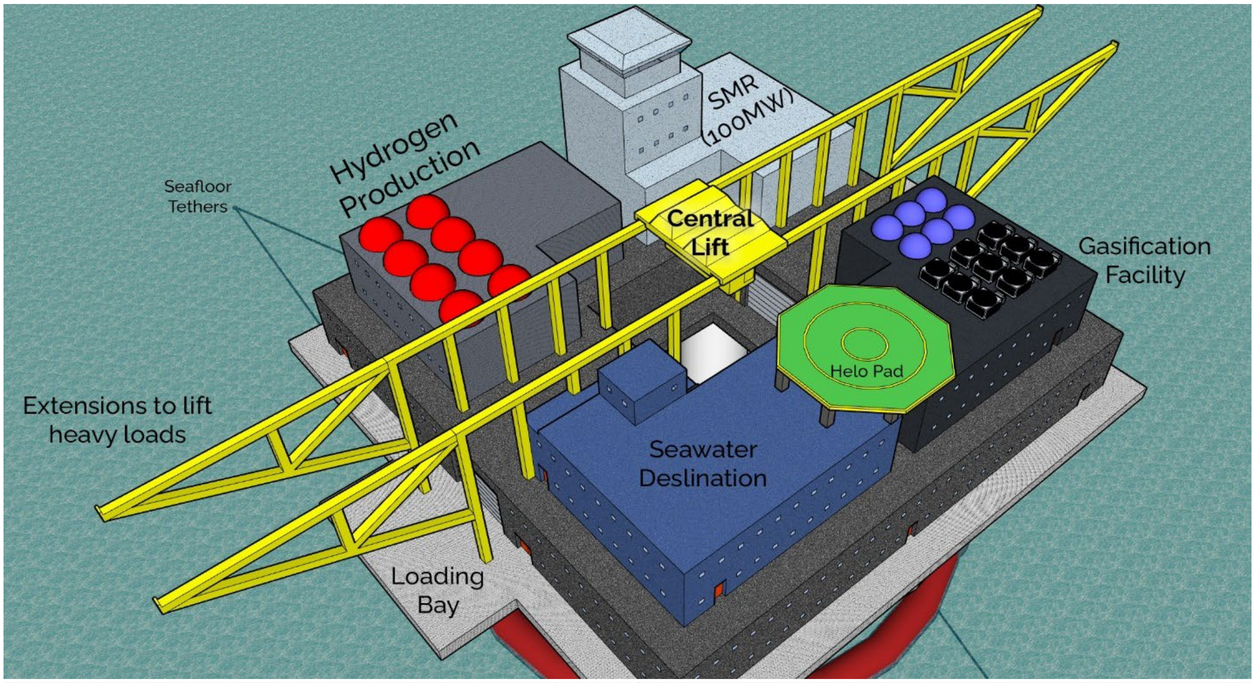
We can also accomplish this in other areas of social focus. Of the more severe ecological impacts caused by human activity, the extent of damage to our oceans ranks near the top if not at it. Besides mass overfishing, heavy-metal poisoning and vast destruction of coral reefs, billions of tons of trash float in our seas and accumulate as giant patches that can span thousands of miles.[40]

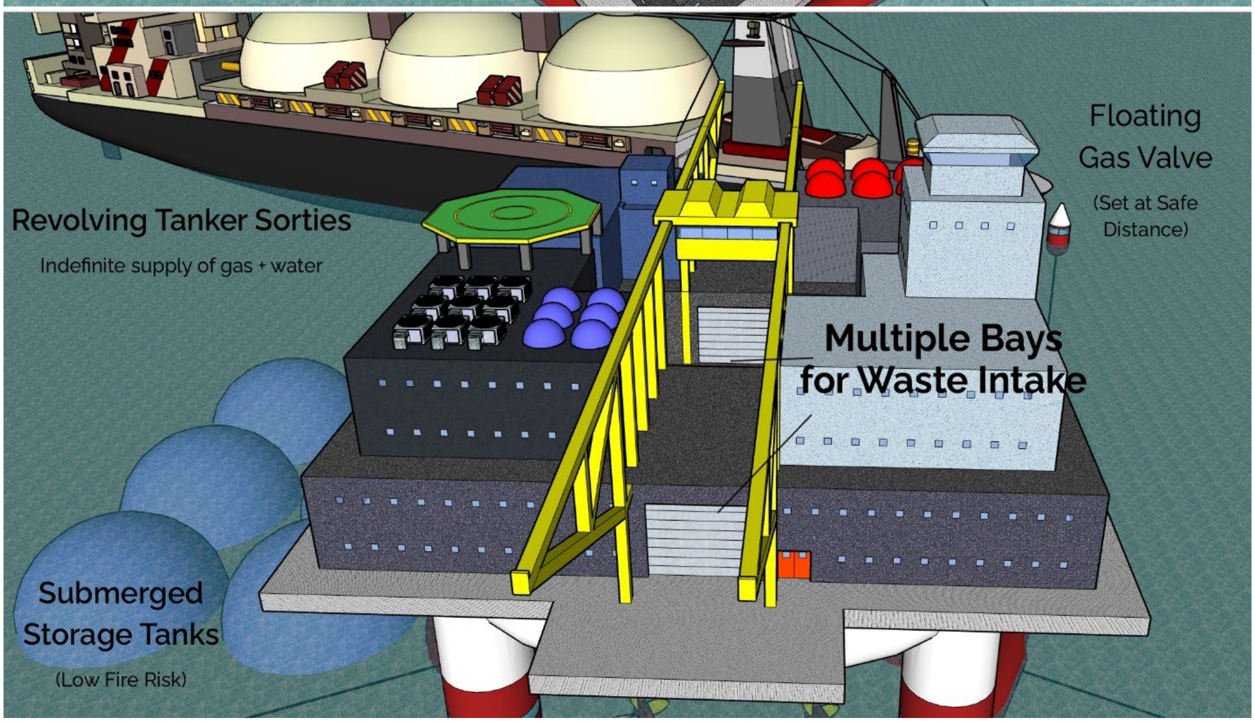


Cogenerative deployments of standardized power systems can enable to solve this problem while also manifesting resource abundance. For example, the aforementioned technologies could be deployed at sea with a unique configuration geared for ocean waste processing, seawater desalination and hydrogen production, performing these three roles as a "Trident Facility."



In this concept, Trident Facilities focus equally on mitigating waste as they do produce energy and resources. Not functioning in a dissimilar capacity to an offshore oil rig, Trident Facilities focus equally on producing resources while cleaning ocean trash. Through external waste collection systems (floating sieves for example), trash is brought to the facility where it is hoisted via crane that can lift from either end (or center) of the facility.





While a more significant infrastructural development than Cogeneration Facilities in concept, Trident Facilities demonstrate how cogenerative technology deployments can solve massive problems while serving other roles that are both socially, ecologically and economically beneficial. Thousands of oil rigs float in the oceans today; clearly, this is a system we are capable of building. There is no system currently in service that is capable of serving all of these roles, yet this deployment strategy gives us a singular vector to deploy all of them through a means that can be mass-produced. The same is true of systems that might be dedicated to capturing carbon while producing resources, or any other application where power generation, resource production, ecological cleanup or other energy-intensive task may be required.

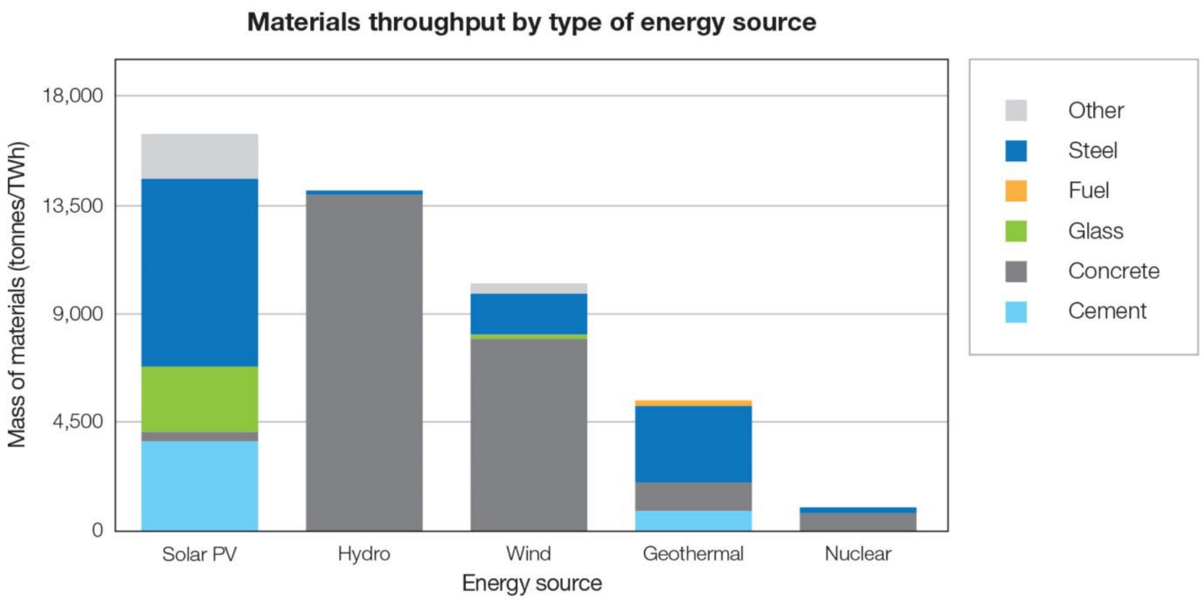
The introduction of modularity, standardization and mass-manufacturing are the critical elements that can enable sophisticated systems to be rapidly deployed in symbiotic operation, and if necessary, reconfigured on demand. Beyond improving installation time, operational flexibility and ease of replacement, the benefits of this approach also extend significant cost reductions. The Vogtle Electric plant mentioned previously will invest ~$25 billion for its third and fourth units that, after 10 years of construction, will have a generation capacity of 2,300 megawatts – some $10.87 million per megawatt.[41] SMRs cost as low as $3.4 million per megawatt[42] *at the prototype stage* – a reduction of ~70% that notably doesn't consider future cost savings through mass-manufacturing or learning curve-scaling.

While mass-producing any system to a modular standard can present similar advantages over ad-hoc design and construction, SMRs are uniquely suited to do so in the energy and resource sector. This is because they have unrivaled effectiveness for generating both heat and electricity in a compact footprint – yet it is also because they avoid most every drawback associated with past applications of atomic energy. It is necessary to emphasize this latter point given the social schism among activists between renewable and atomic energy,[43] as well as the disinformation and stigma surrounding nuclear power.[44] It is also necessary to emphasize because the inclusion of nuclear power is vital to the framework – a point warranting of special mention.

Scarcity Zero's first function of integrating renewables into municipal infrastructure performs the singular task of reducing (if not eliminating) a city's external energy demand. Not only does this drastically reduce regional power consumption from population centers, it also frees up other power sources to increase generation capacity. Cogeneration Facilities are engaged thereafter to amplify generation capacity by orders of magnitude – which critically provides the abundance of inexpensive energy required to produce essential resources at scale.

But **only** nuclear power is capable of accomplishing this task in both a cogenerative *and* carbon-neutral capacity *while also* powering seawater desalination, hydrogen production, atmospheric scrubbing and plasma gasification. The energy requirements involved with each of these tasks are immense, and nuclear is the only extant technology that can generate enough carbon-free power to perform all of them as a byproduct of generating electricity in any given location. Just as importantly, nuclear power's role in the framework additionally performs the essential task of decarbonizing the manufacture and disposal of renewables.

An inescapable reality of both solar panels and wind turbines is that they present extensive material requirements and recycling challenges.[45] Manufacturing solar panels requires 16,477 metric tons of raw material per terawatt of generating capacity, with some 10,260 tons for wind turbines.[46] Batteries present similar challenges, especially if rare-earth metals need to be sourced overseas for their manufacture.[47] The United States, alone, consumes roughly 3.8 trillion kilowatt-hours of electricity a year.[48] Building sufficient renewables to generate that volume of energy with requisite battery storage not only presents daunting material requirements, it also presents significant ecological implications.[49] Not just from the thousands of mines we would need to source such a material volume, but also because this material has to be sourced, extracted, transported, processed and used for manufacturing in a carbon-emitting supply chain.



Sources: DOE Quadrennial Technology Review, Table 10.
Murray, R.L. and Holbert, K.E. 2015. Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes (7th ed.). Elsevier.

Mining operations – especially if offshore – are rarely paragons of ecological stewardship or humanitarian practices.[50] Their scale of land destruction and use of child labor in resource-rich developing nations is well-documented and continues to be an inconvenient reality of manufacturing sophisticated products at competitive prices.[51] An ~830% increase in scale (or greater)[52] is unlikely to present mitigating effects in this context.

Even if such a feat were accomplished, it would have to be repeated in regular intervals as both solar panels and wind turbines have lifetimes between 30 and 40 years, depending on model and region of deployment.[53] Neither biodegrade well, and at present they end up in landfills[54] along with an already-extensive volume of electronic waste worldwide.[55]

Atomic energy offers a reliable means to power the entire length of renewables' manufacturing chain in a carbon-neutral capacity. It can do the same for their eventual disposal or recycling through plasma gasification.

It can also power carbon-neutral mining operations (especially through hydrogen)[56] and make it more cost-effective to mine with machinery instead of exploited human labor. The cogenerative designs of SMRs allow these benefits to occur passively while also producing resources at scale as a carbon-neutral auxiliary function. No other power source is capable of doing this.

Further, it is equally important to emphasize that modern reactor designs are different technologies than past approaches to atomic energy, and are capable of avoiding the cost, waste, safety, and proliferation concerns that were a hallmark of previous technologies.[57] We submit that it is no wiser to judge nuclear power by Soviet-era RBMK reactor designs (as built at Chernobyl) than it is to judge aeronautical engineering by *The Hindenburg*. While we recognize that some concerns with prior implementations of nuclear power were and are valid, it is categorically false to insist that modern reactors are incapable of solving the risks of their predecessors.

In fact, the majority of problems with early approaches to nuclear power stem squarely from policies that *intentionally paired* civilian energy with nuclear weapons development.[58] Our most common reactor designs operating today (Pressurized Light Water Reactor) represent 1950's-era technology that fissions enriched uranium-235 within a pressurized water core.[59] While powerful and perfectly safe if properly engineered, such designs can provide an effective pathway to reprocess spent fuel rods into weapons-grade materials.[60] If designed without extensive safety mechanisms, they can also result in ecological catastrophe (i.e. "meltdowns").[61]

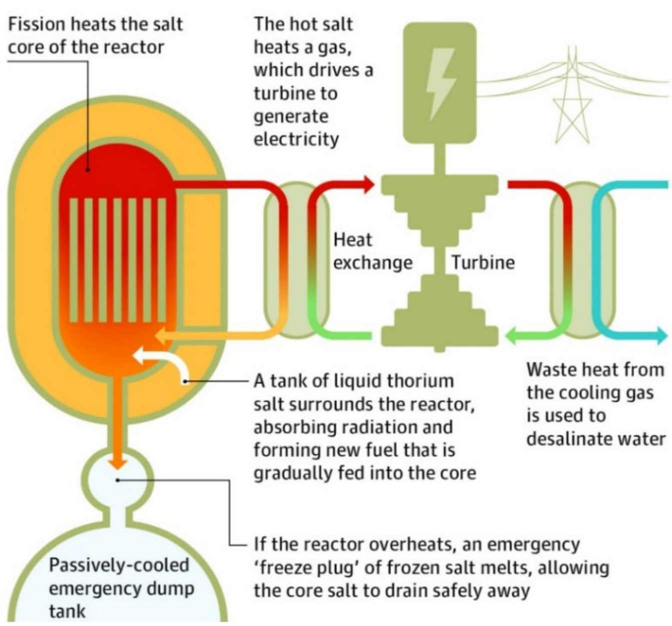


Figure 10 – Overview of thorium-fueled Molten Salt Reactor (LFTR)

While any Generation-IV SMR can be used effectively to generate power while cogeneratively producing resources (including type-certified models fueled by uranium-235), we find Molten Salt Reactors powered by thorium-232 (LFTR) to be especially attractive. This is because they operate at higher temperatures useful for cogeneration and are far more difficult to weaponize.[62] It is also because they present significantly reduced complications in terms of safety, sustainability, cost, waste volume and waste longevity. Unlike Light Water Reactors that pressurize water to 160 atmospheres to remain liquid at 400°C,[63] Molten Salt Reactors sustain fission in a molten liquid core that is not pressurized – meaning it is physically impossible for the core to "melt down" in a traditional sense (as it already operates as a molten liquid). In the event the reaction ever got too hot, a safety plug melts, and the reactant is gravity-fed into small containment tanks that lack sufficient mass to sustain a reaction – causing it to safely freeze into a solid.[64]

Molten Salt Reactors work through a concept called "breeding," where the reaction refuels itself over time by transmuting (converting) a supply of thorium-232 into uranium-233 that is then fissioned to generate heat which rotates a turbine and generates electricity.[65] Additionally, the nature of this reaction provides the capacity to consume other radioactive material as fuel – *including nuclear waste and weapons-grade material.*[66] The final waste volume is less than 1/1000[th] of older reactor designs,[67] and becomes largely inert after 68 years[68] (as opposed to millennia).[69]

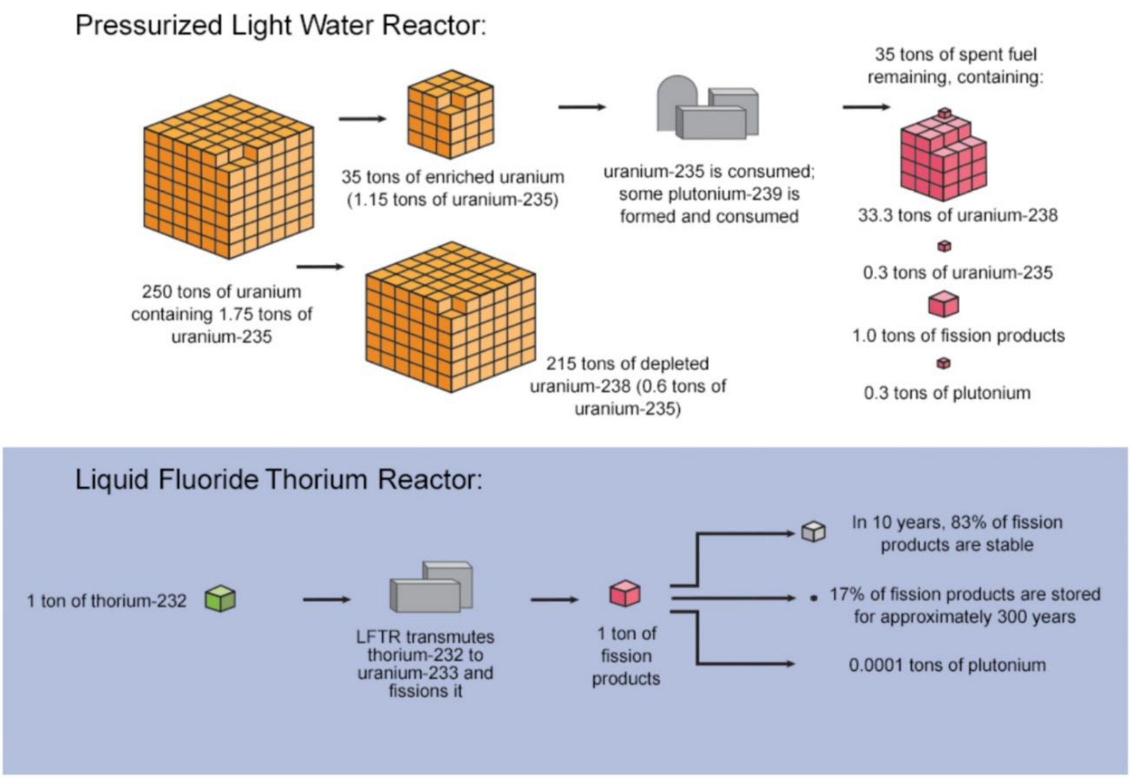


Figure 11 - Comparison of nuclear waste based on reactor design [cite]

The thorium-232 fuel cycle within LFTRs further inhibits pathways to develop uranium-235 and plutonium-239, the two most common weaponizable nuclear isotopes.[70] While it is possible for reactors to produce uranium-233 and neptunium-237 (possible proliferation risks in abstract)[71] both isotopes are significantly more radioactive than the weapons-grade materials commonly used today.[72] At sufficient mass to build a weapon, each would emit lethal doses of radiation within hours[73] – radiation that also damages the sensitive electronics required to facilitate the precise detonations of modern nuclear arms. Their use in tests was rare, and those tests performed poorly.[74] No known expertise exists to weaponize either isotope into a deployable device. The point is also largely moot – any state actor with the capability to avoid these obstacles or build a weapon with remotely operated robotic equipment can already extract uranium-235 from seawater.[75] Simply stated: if any entity has the capability to hijack a Generation-IV SMR fueled by thorium to manufacture a nuclear device, they did not need the SMR to do so in the first place.

Concerns of cost are of course relevant, but as SMRs (powered by thorium or otherwise[76]) can be mass-manufactured to a modular standard they can avoid the expenses of building reactors that are designed, engineered and constructed as unique entities. Any complex product would necessarily cost orders of magnitude more if built in such capacities, which is why most – from commercial aircraft to cars to computers – are instead mass-manufactured as iterations of identical product models. Energy and resource infrastructure are anomalies in this context, which presents cost implications that reflect artificial circumstance as opposed to inexorable reality. Our economy's long-proven capability to mass-manufacture complex and error intolerant systems to an exact precision presents the same solution here as it has in most every other commercial sector.

While the examples cited here are non-exhaustive, they underline the reality that nuclear power plays an essential role in any clean energy schema that cannot be matched by any other available method. It is the only source of carbon-neutral energy that makes renewables *truly* clean, and it is the only source of carbon-neutral power that can produce indefinite volumes of vital resources as a cogenerative byproduct of power generation. A cooperative deployment of renewables and nuclear power is by far the most ideal pathway to solve our energy and resource challenges – as well as build a truly green future spared of climate change, resource conflict and the humanitarian maladies that consequently arise. Any policy that seriously seeks to further the goal of ecological activism and resource abundance must recognize this certainty, as we thus do here.

Combined with Renewable Cities, Cogeneration Facilities present the second component of Scarcity Zero that can drastically increase our capacity for energy generation and resource production. Once implemented at scale, the large volume of desalinated water produced as a dedicated resource sets up the third piece – The National Aqueduct – to complete the primary functions of the framework.

Function Three: The National Aqueduct

With Renewable Cities and Cogeneration Facilities amplifying our capacity for power generation, the primary deliverable in addition to resources is an indefinitely sustainable source of fresh water through cogenerative desalination. While a not uncommon practice today, the ability to standardize desalination technology into modules that can be mass produced allows for the multi-fold increase in scale necessary to provide an endless supply of fresh water for all of humanity's needs. Scarcity Zero's method for delivering this water is a nationwide water network called the National Aqueduct. It serves three roles:

1. Provide effectively unlimited water to any location the network services
2. Operate as a major source of power generation
3. Serve as a "battery" for renewable energy

The National Aqueduct consists of a series of water storage and pumping stations connected by a network of modular pipeline arrays that are outfitted with both solar panels and internal hydrodynamic turbines. Combined with a strong and steady flow of water kept at high temperature for auxiliary thermoelectric power, the system would be capable of generating immense energy simply through passive water delivery as a public service.

Figure 12 - Bird's eye view of the National Aqueduct in concept

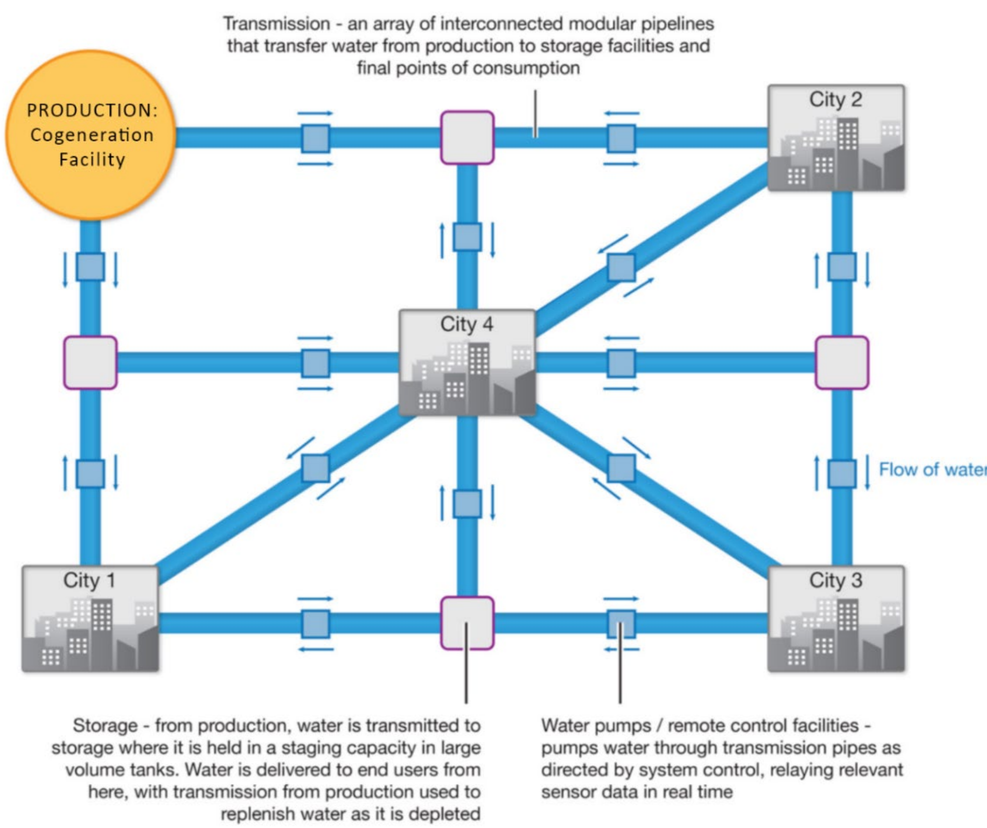
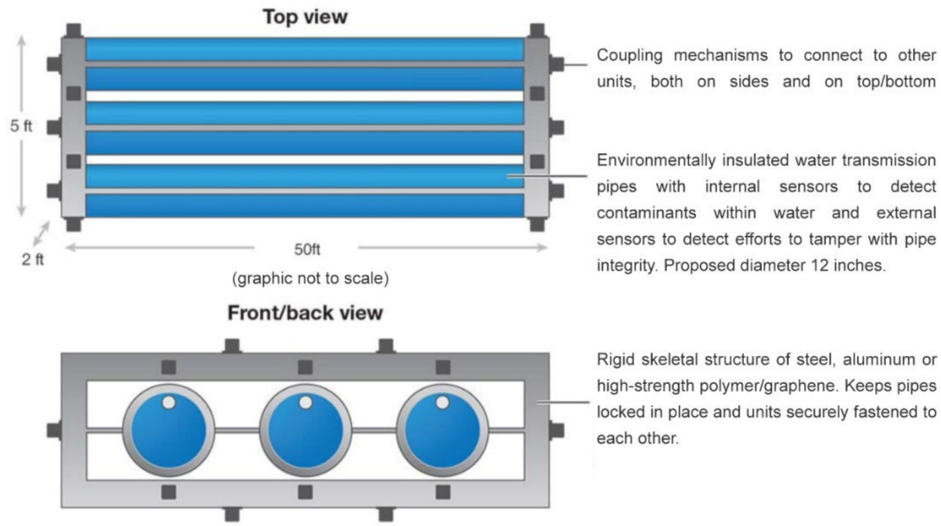
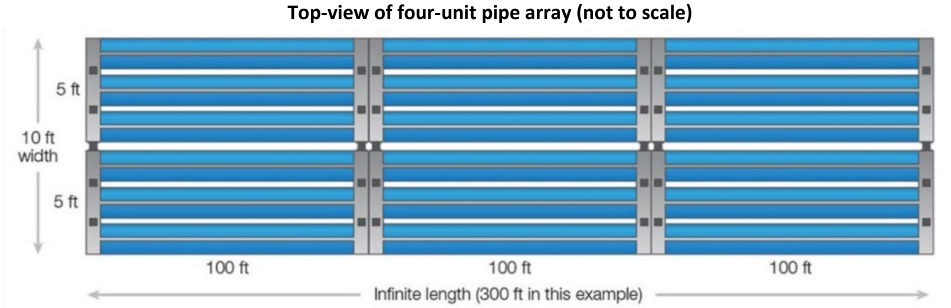


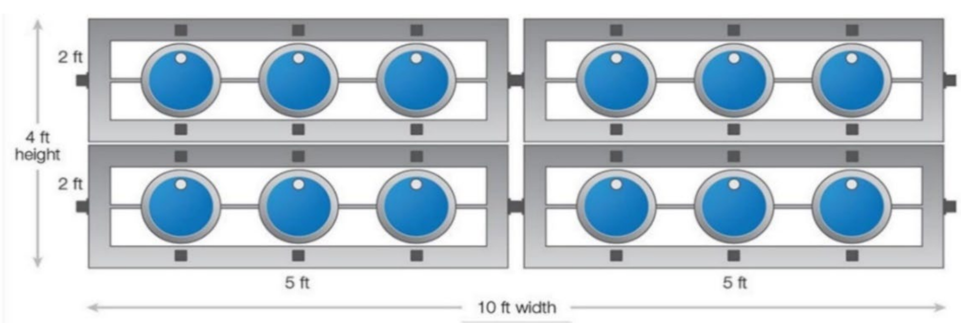
Figure 13 - Overview of National Aqueduct Pipelines



Top-view of four-unit pipe array (not to scale)



Front view of four-unit pipe array (not to scale)



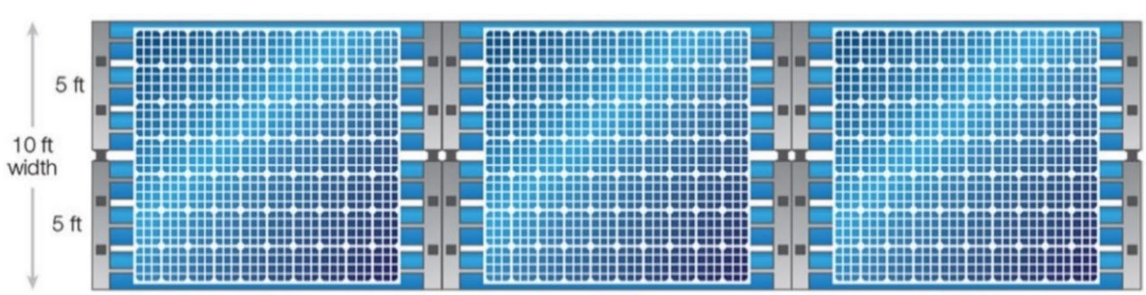
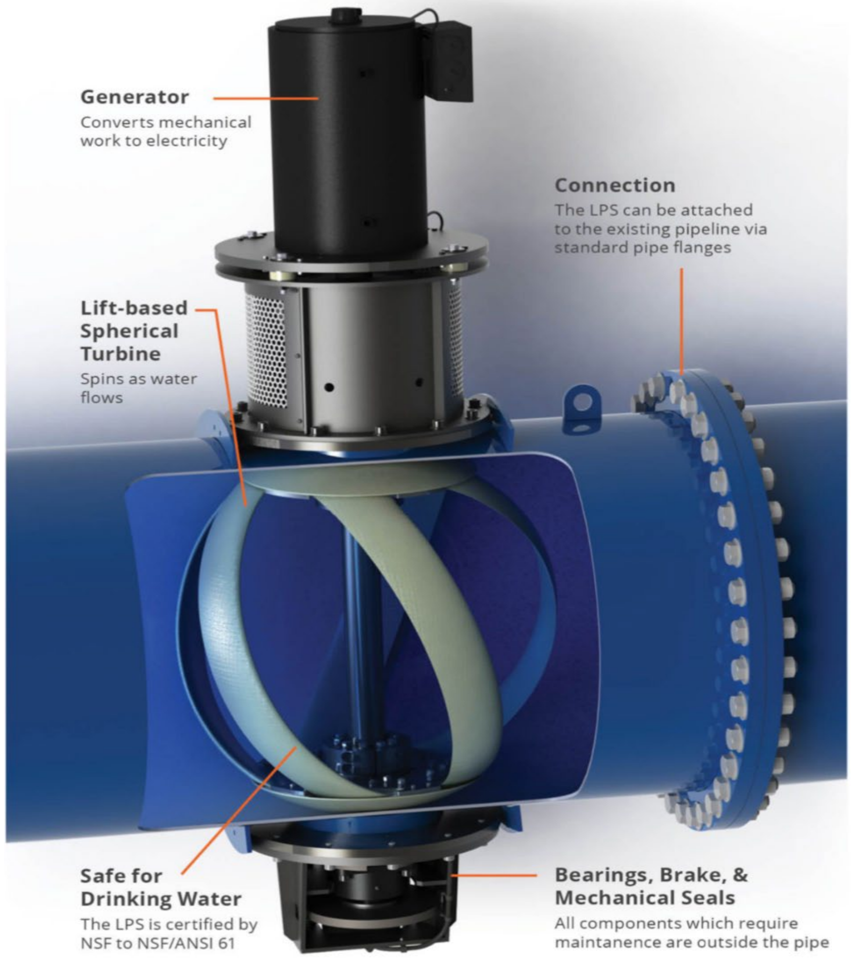


Figure 14 - National Aqueduct pipeline arrays integrated with solar panels:

Figure 15 - Hydrodynamic Turbine (Lucid Energy)



Cutaway view of pipeline:

1. Water travels through the pipe as a steady flow

2. Water rotates hydrodynamic turbines, generating electricity

3. As water pressure, volume and velocity increase, so does energy generation.

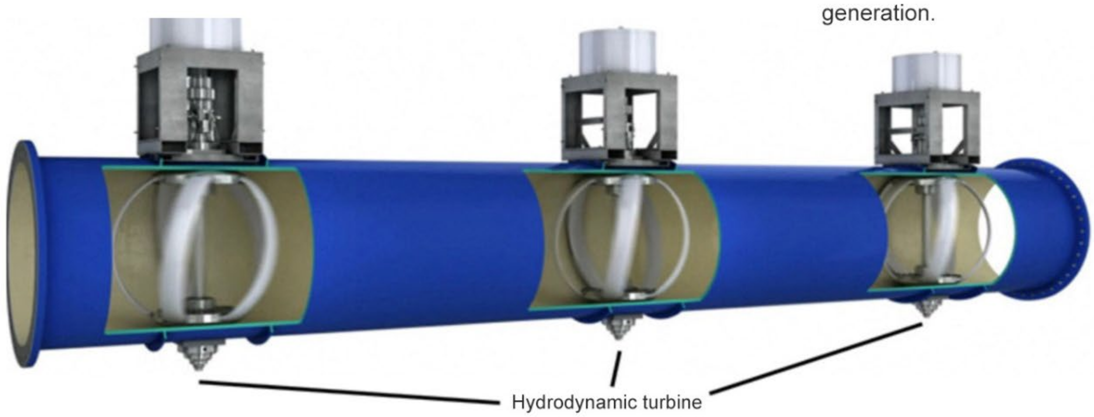
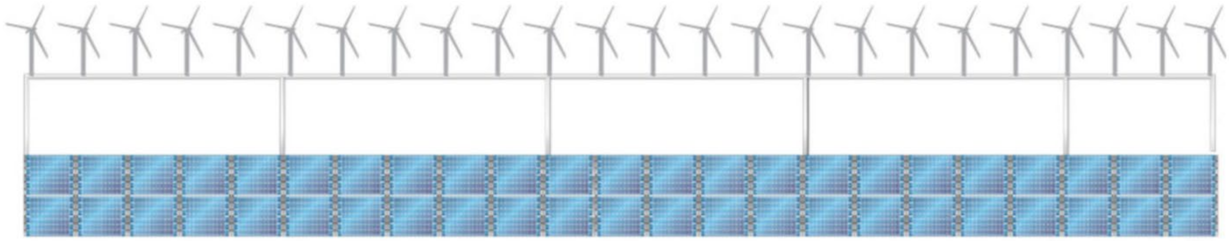


Image source: Lucid Energy, Inc.

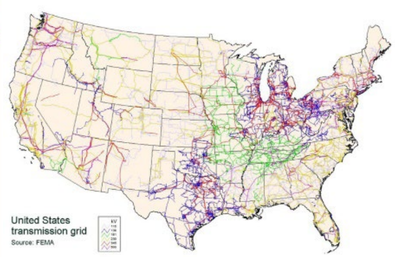
Figure 16 - Integration with wind turbines can generate power and maintain water temperature for thermoelectric functions:



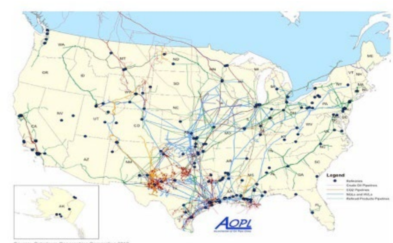
The continental United States is already well-suited to build such a network through its interstate highway system, high tension power lines and prior locations already granted easements for oil pipeline construction. Highways, for example, are flat and straight and go on for thousands of miles with little (if anything) built on the precleared sides or medians. High-tension power lines and oil pipelines reflect similar characteristics.

US Highway Network

US Power Line Network

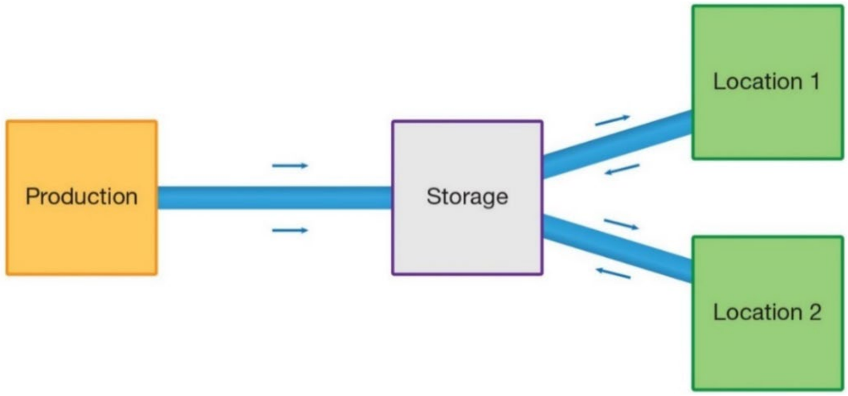


US Oil Pipeline Network

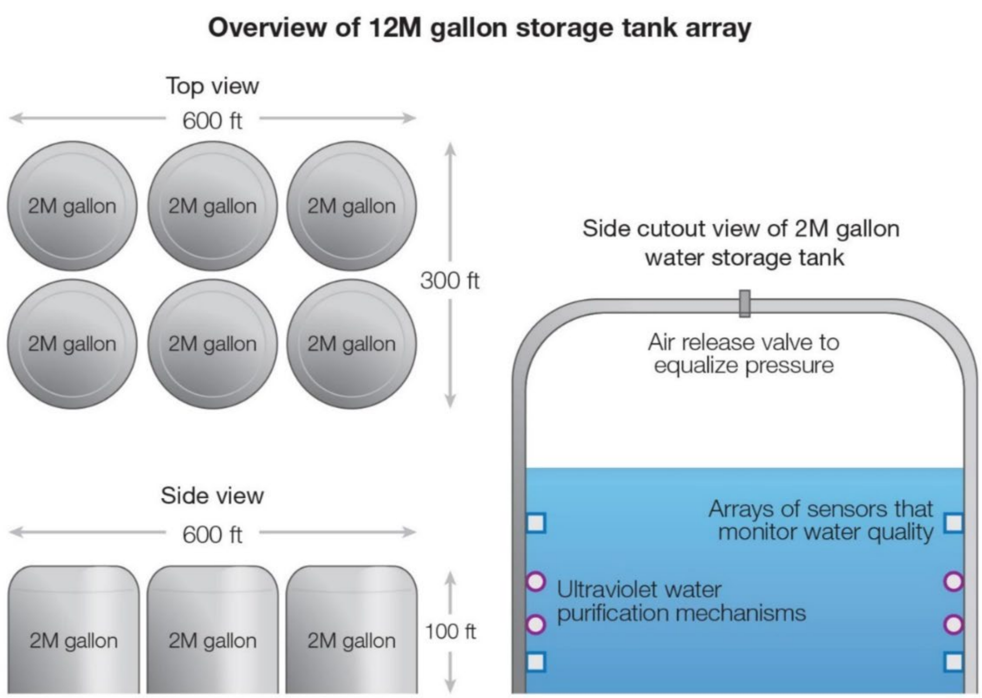


Not only does the United States have ample space to build such a water delivery network, the vast deployable area is also both precleared and either publicly owned or leased with the ability to grant access for municipal use. This means such a network could be constructed with minimal site processing and *removes the need to purchase additional private land* – allowing cost factors to be constrained to materials, installation and operation.

With pipeline arrays installed parallel to highways, power lines and oil pipelines, strategically located storage and control facilities keep The National Aqueduct constantly resupplied with fresh desalinated water. This allows the network to deliver water based on demand through a "constant staging" approach.

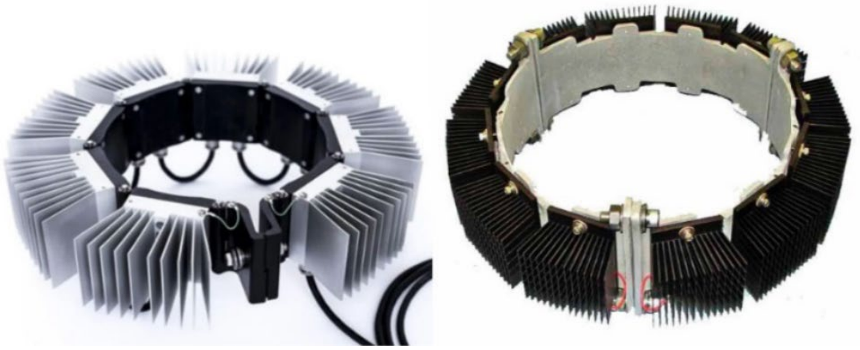


In this deployment, production (Cogeneration Facilities) transmit water to the system's storage component where it is held in large tanks, sterilized and kept at high temperature through daytime solar, hydroelectric charge and/or integration with wind turbines.



In addition to the 24/7 charge generated by hydrodynamic turbines, this component of high temperature contributes to the Aqueduct's "battery" function. In operation, any additional energy generated by solar, wind or hydroelectric turbines that is not consumed during the day would be devoted to keeping water within the Aqueduct at high temperature, which can be converted into electricity via arrays of pipeline-integrated thermocouples. While not as cost-efficient as other forms of power generation, it is a reliable method of generating an electric charge through a difference in temperature in absence of conditions for renewables to function.

Figure 16 - Commercial pipeline thermocouples (Marlow Engineering)



On a nationwide scale, The National Aqueduct would function at maximum effect with an immense volume of water – on the order of 500 billion gallons or greater. At 90 °C (195 °F), a gallon of water holds 1,707 joules (~1,618 BTU) of energy.[77] A volume of 500 billion gallons would hold ~853 trillion joules (809 trillion BTU). This is equivalent to 237 billion kilowatt-hours, approximately 1/16th of the United States' annual electricity consumption.[78] That is from heat energy alone – saying nothing of daytime solar charge or constant charge generated from pipeline-equipped turbines. While it is of course not feasible to convert the entirety of that heat to electricity without significant reductions due to entropic forces and natural system inefficiencies, it remains a vast volume of potential energy.

These functions enable The National Aqueduct to not only transport fresh water where necessary, but also to complement and support the other power-generating methods of the Scarcity Zero framework. Because fresh water in this model would be delivered to every major population and agricultural center in the United States, it presents massive implications for both our economy and our environment:

- **It would make the concept of drought irrelevant.** With limited exceptions, all irrigation, agriculture and industrial water use today is deeply dependent on natural water cycles – a reality our world is becoming increasingly aware of as we overexploit Earth's fresh water supplies.[79] By desalinating and transporting water on a nationwide scale, we have an effectively infinite supply of fresh water for social use.

- **It allows natural freshwater supplies to stabilize.** Because fresh water could be sourced from The National Aqueduct in large volumes, it reduces stress on natural water supplies. Over time, this would provide a net positive benefit for our natural environment.

- **It enables irrigation (and agriculture) in any location.** The United States has a centralized farming model where agriculture is based in large swaths of our interior. Food is then harvested, processed and exported as a large-scale commercial enterprise. The National Aqueduct would make these ventures more fruitful and less expensive. Yet it would also do the same for effectively any location in the country – including locations where it has traditionally been challenging to farm.

The National Aqueduct is capable of providing these elements of resource abundance only because it is a component of a greater framework. Without Renewable Cities working to reduce national energy demand – and without Cogeneration Facilities desalinating immense volumes of fresh water as a byproduct of power – The National Aqueduct could not exist. Yet by working together, these aspects of Scarcity Zero can sustainably produce an effectively unlimited supply of three of our most vital resources: water, electricity and fuel (hydrogen).

While these provisions alone would revolutionize our way of life, they would also allow us to accomplish two new goals that are equally vital: sustainably cultivating agriculture within indoor urban farms, and thereafter harnessing the aggregate abundance of resources to synthesize advanced materials that we can use to build next-generation technology and infrastructure.

Food, Materials, Technology and Infrastructure

Establishing a method to sustainably produce water, electricity and fuel to effectively any scale is the chief deliverable of the Scarcity Zero framework. This is because these resources are critical for modern civilization to function, and also because their cost as commodities are dominating factors for our society and economy. Yet if such costs (and forces of scarcity) were significantly mitigated or removed outright, the limitations they place on our capabilities would accordingly follow suit. We could make things we could not make before. We could build things we could not build before. We could solve problems that were previously unsolvable.

One of the most impactful examples in this context is vertical farming, which converts warehouses into modular agricultural centers. Vertical farms can reliably produce upwards of 130x as much produce per acre of land with only 1% of the associated water usage[80] — with figures exceeding 300x not unheard of.[81] As vertical farms operate year-round under an ideal light cycle with minimal pesticide use, they are also far more productive at lower cost than current agricultural practices.

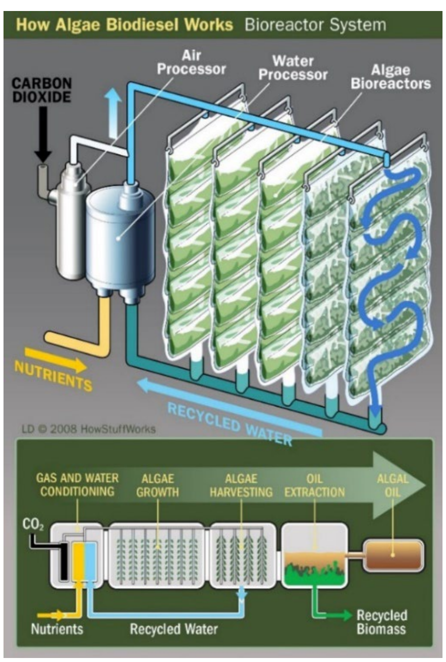
Figure 17 - Current deployments of vertical farms (real-world)

Vertical farms are particularly useful in high-population metropolitan areas. As leafy greens currently travel an average of 2,000 miles from farm to plate in the United States,[82] urban vertical farms enable a closer connection between population centers and their food supply by reducing the distance produce must travel from cultivation to consumption. These areas not only see higher food security — a buffer against climate change, external resource scarcities, and greater ecological strife — but also a corresponding increase in nutritional value of local food supplies.[83]

While a shift to indoor urban agriculture would necessarily reduce demand on traditional commercial farming, an abundant supply of water, electricity and fuel enables expanded agricultural opportunities within other commercial sectors, of which algae is perhaps the strongest candidate. Depending on varietal, algae is useful both as a nutrient-rich food supplement as well as a source of hydrocarbons that can be used to make specialized fuels and manufacture next-generation synthetic materials.

Figure 18 – Current deployments of algae farms (real-world)

In the context of food supplements, a high-yielding algae known as chlorella is comprised of 45% protein, 20% lipids, 20% carbohydrates, 10% vitamins/minerals and 5% fiber.[84] Combined with a strong photosynthetic efficiency in controlled environments, large volumes can be sustainably cultivated and dried for inclusion in effectively any processed food product.[85]



In the context of biofuels, algae varietals that produce fatty esters are reliable sources of hydrocarbons that are already produced on a considerable scale today.[86] However, synthetic hydrocarbons produced by algae do not necessarily need to be devoted for fuels in roles that would be better served by electric vehicles and switching to a national hydrogen standard. Hydrocarbons are also excellent base chemicals to make polymers and other synthetic materials.

With targeted genetic engineering of specific algae varietals, we can cultivate more specialized hydrocarbon chains[87] that we can use to make more advanced polymers.[88] We can extend this effort further through an abundant supply of hydrogen produced by Cogeneration Facilities, as well as an abundant supply of carbon extracted from Direct Air Capture arrays.[89] We can perform both in a capacity that is long-term sustainable and ultimately carbon neutral.[90]

Even today, high-performing synthetic materials can already rival hardened steel or aluminum in performance – with superior chemical resistance and insulating properties.[91] Impact-resistant polyurethane, nanocomposite plastics, specialized thermoplastics and glass-reinforced epoxies have helped build our modern world. Each can be manufactured to greater and more sustainable scales in this dynamic. The same is also true with other synthetic materials that have not yet reached commercial viability due to current costs (plastic wood, for example).

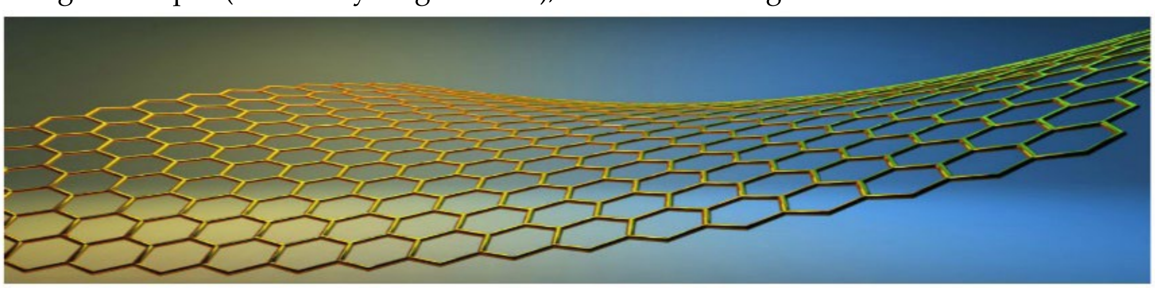
Considering that Cogeneration Facilities allow any material (plastic or otherwise) to be disposed of via plasma gasification at negligible ecological impact (including ocean trash), exponentially increasing our capability to manufacture sophisticated synthetic materials at proportionally lower costs presents unprecedented opportunities for both our society and economy.

If they were inexpensive deliverables of a positive-sum resource paradigm, sustainable production of synthetic wood and polystyrene insulation could allow us to build housing at a fraction of the cost (especially modular, prefabricated houses).[92] Synthetic concrete made of plastic can be mixed or precast into any form desired at the same level of performance as traditional concrete[93] (the sand of which is our most widely used building material after water). The synthetic materials that make clothing, consumer electronics, appliances, vehicles, aircraft and even the dimensional components of civil infrastructure would be less expensive and perform as well as, if not better than, commercial materials used today.[94] All of it could happen in in a sustainable, carbon-neutral supply chain from start to finish.

A similar trajectory is also true of graphene, which is an ultra-thin carbon lattice well-known to science and industry for its extraordinary material properties:

1. **Extreme strength.** Graphene is one of the strongest and lightest materials known.[95] It is also highly resistant to both corrosion and heat (melting point of 4,500°C (8,132°F)).[96]

2. **Flexibility.** As graphene is formed by thin sheets of carbon it can retain a rigid structure or be as flexible as a sheet of paper. It can further function at full strength when assuming a range of shapes (such as hydrogen tanks), even when designed to bend or stretch.[97]



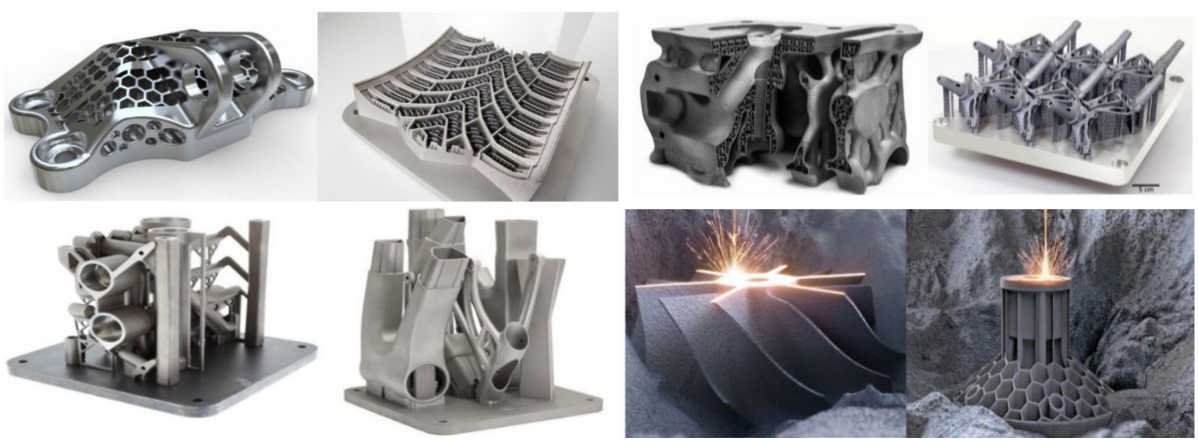
3. **Conductivity.** Graphene is an excellent conductor of electricity. This enables graphene to lend its strength and flexibility to anything electrical – as a function of either transmission, structure or direct energy storage via capacitance.[98]

The combination of these traits makes graphene uniquely suited for a wide array of applications within consumer electronics and computing, medicine and bionics,[99] structural components and manufacturing – effectively anything where high performance is demanded alongside material strength, electrical conduction, electrical storage, flexibility of form, or resistance to heat, chemicals, impact or radiation. However, graphene has thus-far been expensive to produce at scale.[100] Scarcity Zero's abundance of energy, water, fuel and extracted carbon can reduce these factors, improving graphene's potential to become a mainstay commercial resource.

Graphene, combined with the array of synthetic materials we can produce at greater scales under Scarcity Zero's resource abundance, can further pair with next-generation additive manufacturing to increase the sophistication and scale of what we are capable of building. Extant systems today already enable metal 3D printing,[101] allowing for turnkey production of aerospace-grade parts made from solid metal/high-performance synthetic materials.[102] Adding a multiplier effect to this capability improves both the scale and performance of such methods while also reducing costs. Consequently, a manufacturing expertise that once seemed out of reach can become a new normal within the in-house operations of cutting-edge industries.

Figure 19 - 3D-printed metal parts (MarkForged)

Figure 20 - Metal parts made from Selective Laser Melting



Each of the images above reflect parts that were autonomously fabricated through additive manufacturing – each to the micron order of precision.[103] Manufacturing these items in such a capacity would have been all but impossible even decades prior, yet today they can be made at the push of a button. Twenty years ago, simply testing to the micron layer of precision required highly sensitive equipment that cost millions to procure, operate and maintain. Today, parts such as these can be made in a matter of hours by commercial 3D printers or additive fabricators that in many cases can cost less than a new luxury car.

However, scalability is a present challenge to their large-scale deployment. A next-generation fabricator might be able to produce a finished piece every two hours, but how can that be scaled to the order of thousands? Further, how can accomplishing this goal be made easier through Scarcity Zero's resource abundance? Simply stated: by lowering the cost of energy and base materials, it makes it more affordable to procure more fabricators over time to incrementally scale production in a perpetually expanding cycle. An individual fabricator that can produce 12 items over a 24-hour period may not be able to scale higher than this threshold, but an array of 100 printers could produce 1,200 pieces a day (or 438,000 a year). At $100K per fabricator, a $10 million investment in a dynamic assembly line that can autonomously produce a wide array of aerospace-grade parts to a micron tolerance or better is not a tall order for a commercial manufacturing operation – especially since such parts can exceed the capabilities of what we can presently make.

The material performance made possible by these advances can integrate to positive effect within the supply and manufacturing chains of most every sector of our economy. In turn, this allows us to improve how we mass-manufacture highly sophisticated systems – including systems that generate energy, produce resources, capture carbon and dispose of waste. But it also allows us to apply these advancements to mainstays of civil infrastructure. Our current state of technology is already capable of prefabricating bridges, tunnels, highway ramps and even skyscrapers, but this is limited – often significantly – by resource and energy costs.

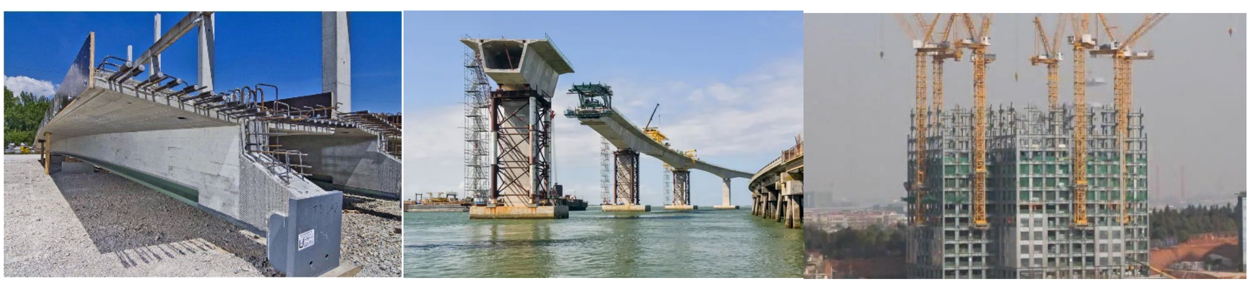


Figure 21 – (in order of left to right) – Prefabricated Road, Prefabricated Bridge, Prefabricated Skyscraper. The start to finish construction time of the 57-story skyscraper at the right was 19 days.[104]

The combination of advancements made possible by overhauling our means, volume, performance and precision of synthetic materials remove some of the most significant obstacles to mass-manufacturing larger and more sophisticated systems at scale. Combined with an abundance of inexpensive energy and resources, it also enables us to build them at lower cost:

- Megabridges or megatunnels that break the 100-mile-long (161km) threshold
- A dedicated shift to prefabrication for urban construction, allowing city towers and multi-unit housing complexes to be rapidly assembled (weeks instead of years)
- Electric cars and small-scale VTOL aircraft (especially if energy storage leverages capacitance interwoven into a graphene chassis or fuselage)[105]

- Maglev rail networks and high-speed vacuum-tube transport (Hyperloop)
- Next-generation aircraft fueled by hydrogen (including scramjets and SSTO)[106]
- Orbital delivery structures (earth/space elevators)[107]

This the infrastructure of abundance – science fiction made science possible through deliverables of technology. The final step to a new paradigm, and the next step to a new frontier.

From here, the primary functions of the framework complete a circle. Strategic deployments of systems that generate electricity and heat can power systems that produce fresh water and hydrogen fuel, extract carbon from our atmosphere and recycle waste. This resource abundance powers indoor agriculture and advanced material synthesis, transforming the technology and infrastructure we are capable of building. One step leads to the other, with the final deliverables allowing us to continually re-invest in each system component to continually improve all elements therein – and the parent framework as a whole – in a world spared of scarcity and need.

Scarcity Zero meets the threshold necessary to make that world a reality. It provides for our resource needs as a collective. It solves our problems within energy, resources and climate as a collective. It enables the open-source democratization of energy and abundance. It unchains human civilization from reliance on unsustainable or hostile resource extraction in a dynamic that is increasingly prohibitive to both of those acquisition vectors. Just as importantly, it frees up the unquantifiable expanse of social resources that are perpetually devoted to mitigating the consequences of scarcity and the social maladies accordingly brought to bear. Scarcity Zero meets this threshold not as a function of optimism or ideological triumph, but rather through something more simple and empirical: practical systems design that dispassionately employs extant technologies to their greatest cooperative strengths – for no other reason than to achieve a social mission that is, at the end of the day, perfectly achievable.

It is our key to a clean and bright future. And it is a solution we can begin building today.

Part II: Implementation and Operation

We are technologists, and our mission is to build open-source strategies for abundance – "social software" that can help solve our most pressing problems and improve our way of life. Accordingly, we promote Scarcity Zero as an ideal framework to achieve that end – and seek moreover to implement the framework as a dedicated public service.

Yet we also recognize that accomplishing that goal on any scale is no small task. While we are resolutely certain that a cogenerative deployment of mass-produced systems to a modular standard stands head and shoulders above our current energy and resource schema, establishing the means to demonstrate this through a marketable solution that can be rapidly adopted is a massive challenge. At minimum, meeting it requires an entity that can not only coordinate the development, deployment and scaling of advanced technology within no fewer than five distinct economic sectors – but can also coordinate the extensive array of industries, enterprises and regulators involved with doing so. And even if accomplished, implementing the framework as proposed would rival the largest public infrastructure projects ever undertaken.

We recognize lastly that our present circumstances deprive us of a vehicle that could meet these requirements while retaining the requisite degree of social trust to spearhead paradigm-shifting upgrades to our energy and resource infrastructure. America's advanced stage of political and cultural fragmentation (with accompanying partisan theatrics) limits the public sector for primary candidacy, especially at the federal level. The private sector is equally compromised – while the innovative nature of commercial enterprise may well yield the best technologies to deploy in a dynamic energy framework, a maximized profit model is at odds with a mission to make vital resources as inexpensive as possible. This is all the more true when considering that social trust towards incorporated business (and market economies) are at historic lows.[108] Non-profits are conversely capable of extending a philanthropic public service, but few exist that possess the capability to champion large-scale infrastructure projects. Fewer still can do so with a unified sense of public support – a consequence of not-always-unjustified frustration at performance activism of high-profile "charity" organizations that lucratively fundraise at upscale soirées,[109] yet fail to manifest social improvement in a tangible, reliable capacity.

The uncompromising reality is that our society has lost faith in the institutions that would otherwise be equipped to meet the unprecedented challenges facing our future. And although we hold concrete conviction that a framework like Scarcity Zero is capable of solving them, we can identify no pathway to implement such a framework without both a significant volume of financial resources and a sterling degree of public trust. As there is no extant entity we can embrace to achieve this end, **we intend to build something that can.**

What follows is a strategic plan for how that can be accomplished, which will cover several areas of focus: how we can create an entity geared for such a mission, its operating mindset, organizational structure and revenue strategy within its overarching social goals. This starts by establishing the foundation for a novel class of operating entity that is – by design – in thrall to the public interest, reflected as such by its namesake: A Public Interest Company (PIC).

A Public Interest Company

Conceptually, a Public Interest Company (PIC) is privately owned commercial enterprise that operates not for shareholders or personal profit, **but instead exclusively as a public service for the public interest** – the latter of which would be qualified by meeting specific, non-ambiguous thresholds (explained shortly). As a selective blend of several incorporated bodies: philanthropic non-profit, institutional public service, sovereign wealth fund and commercial enterprise with a B-Corp designation, the goal of a Public Interest Company is to fund social advancement through ongoing commercial services in a given market sector. In this doing, a Public Interest Company operates under different circumstances than other organizations with similar missions:

- Unlike a Public Benefit Corporation (B-Corp) that is designed to *balance* the interests of shareholder value with a public mission (whereas a C corporation seeks to maximally profit), a Public Interest Company's exclusive goal is advancing a mission for the public interest. Any commercial services would be offered under a **managed profit model** – with caps on executive compensation – that charge only as much as needed to advance the scale and quality of services. Under a PIC designation, all net profits are re-invested into its mission, **and no shareholder wealth is earned**. Instead, a PIC leverages the functions of capitalism to generate *public wealth* (or value) for the public interest.

- As a Public Interest Company would re-invest all net profits to a social mission, it would be granted non-profit tax status as if it were a 501(c)(3) entity. This means any revenue earned by the PIC would be exempt from income or sales tax, and any non-transactional donations by either individuals or enterprises would be tax-deductible. As with non-profits today, all accounting and meeting minutes would be publicly transparent by law.

- As the notion of "public interest" is inherently subjective, the circumstances in which a Public Interest Company could form would be empirically specific and thus certifiable. In this model, a PIC status could only be granted to entities operating exclusively within any of the following economic sectors:

    - Energy / resource generation or provision
    - Public utility service
    - Software / internet / telecommunications
    - Transportation / aerospace
    - Ecological / environmental stewardship (including animal welfare)

- Education in any exclusively secular context
- Medicine / pharmaceuticals / bionics / prosthetics
- Infrastructure / construction / manufacturing
- Open-source research and development

Additionally, a Public Interest Company would have stringent restrictions on compensation – especially executive compensation. In this model, the maximum an employee or executive of a Public Interest Company could be paid is **ten times** the median household income of the state the PIC is incorporated in. As the median household income for FY2021 is estimated to be $79,900,[110] a salary cap of less than $800,000 per year is a far cry from the $24.2 million the average CEO of the top 350 American companies is paid (a ratio of 351-to-1 to the typical worker salary).

- Because a Public Interest Company's exclusive business focus is within an application that is verifiably in the public interest, this model would establish a separate financing schema with more attractive lending rates than traditional public loans. The Small Business Administration is the public lender of choice in the United States, extending upstart enterprises loans of up to $5 million with modest interest rates.[111] Our model would advocate a 0.0% APR for all loans to Public Interest Companies – and extend the cap from $5 million to $50 million through a tiered threshold (first round of financing capped at $5MM, which once repaid in full would allow a subsequent cap of $10MM, increasing stages in $10MM increments to a maximum total of $50MM), subject to operating plan review for each refinance.

- A Public Interest Company would have a unique approach to intellectual property (IP) in this model. As with any private enterprise, it would be able to develop its own IP in furtherance of its mission, or purchase rights to the same. However, all IP acquired by a PIC would automatically be licensed under a new vehicle, a *Public Interest Patent*, that would enable any U.S. citizen or U.S.-based enterprise to leverage the technology for its own ends. This would occur under specific requirements:

    1. Any derivative technology that leverages a Public Interest Patent in a materially significant capacity (50%+) would be considered public domain (for U.S. actors).

    2. A PIC that owns IP under a Public Interest Patent would have specific rights to deny individual actors from utilizing a Public Interest Patent if they did in a manner contrary to the public interest, subject to judicial review.

    3. The Public Interest Company the holds IP would have the exclusive right to license a Public Interest Patent beyond U.S. borders under TRIPS agreements.

While the unique nature, advantages and safeguards of a Public Interest Company make it an ideal vehicle for meaningful social improvement, its capabilities to do so are significantly extended through three unique opportunities:

Opportunity #1: Partnerships with Public Services. As an entity extending commercial services exclusively for the public interest, a PIC is a natural partner for any public functions charged with similar missions. While prior marriages between public and private-sector entities have at times resulted in mismanagement, crony capitalism or even outright corruption, the structure of a Public Interest Company makes it extremely difficult for a PIC to hide and thus conduct unethical behavior. Its bank statements, accounting figures and board minutes – in entirety – would be considered public record by law in this model, and any attempt to distort, omit or censor this information would be a criminal act.

This enforceable transparency helps form a foundation of social trust that can encourage public services to join forces with PICs and multiply effectiveness in advancing initiatives for the public interest. PICs would also be able to submit lower bids for public contracts than competing commercial enterprises by virtue of their reduced tax and operating overhead, adding yet another factor supporting their candidacy.

Opportunity #2: Partnerships with Commercial Enterprises. While the operating structure of a Public Interest Company is intentionally incompatible with a profit-driven business model, PICs can extend strategic partnerships with companies that are uniquely advantageous. Because any donated funds, technology, equipment, intellectual property, advertising or capitalized labor would be tax deductible, any material assistance can offset profits while also increasing public relations and the impact of future marketing campaigns.

Just as importantly, a PIC can also be an ideal vehicle to funnel research and development (R&D) expenses through. Because only the production stage of R&D costs can be capitalized under GAAP rules,[112] and R&D expenses can no longer be deducted in the year they were incurred (as of 2022), a PIC presents considerably more open avenues to deduct the financial investments in new technologies or methods than as a capitalized business expense. Every piece of equipment purchased, every hour of salaried labor devoted, every dollar donated to a PIC would be tax-deductible. Yet as all research or technology derived from a PIC is automatically entered into the American public domain, the dynamic is transformed from a tax shelter to offset R&D costs to a public research project that just so happens to benefit the entity that funded it.

That key element enables companies to expand their R&D efforts both through offsetting their own profits but also by accessing a collectively increased knowledge of technical means that becomes available to American businesses and academia that is exclusive to them under TRIPS agreements. This makes our technology more transparent while increasing our shared capabilities – leading to greater technological achievements and securing a competitive edge.

Combined, these possibilities coalesce into unrivaled opportunities for business to profit from improving society. Perhaps a company wishes to donate solar panels and capitalized labor to a PIC seeking to lower the cost and carbon emissions of municipal electricity. Maybe an electric car company wants to offset expenses for developing a next-generation battery, or an aircraft manufacturer seeks to offset the expenses for developing a next-generation engine. In each of those hypotheticals, those companies would be able to offset those costs from a tax bill and point to the effort in their marketing campaigns. Yet they nonetheless financed such efforts for the American public domain that could, in turn, leverage its findings for any purpose thereafter. They paid to make us smarter, and as a consequence, they paid to make us stronger. That both sides of the equation accordingly benefit not only isn't a negative, we'd argue that's exactly what we should be striving for in an ever-advancing society.

Opportunity #3: Rebuilt Foundations of Public Trust. The very reason a Public Interest Company is proposed as a vehicle to implement Scarcity Zero or any large-scale project for social benefit is because the public has largely lost faith in the institutions that would otherwise be qualified to perform this role. And while we take strides to avoid drawing lines in political or cultural disputes, we ourselves struggle to disagree that our once trusted social institutions have not lived up to the trust we placed in them. It is not our intent to air laundry lists of ideological grievances, yet we also cannot ignore the evidence in support of this charge that, even from a high-level view, is frankly staggering.

America's legislatures are dominated by a two-party system that elects members based on their ability to fundraise – forcing lawmakers to cater primarily to the interests of wealthy donors[113] and placing both the nature of legislation and the tempo of legislative agendas up for sale.[114] Beyond the fact that this reflects legalized bribery in effect, it has consequently resulted in a massive misdirection of public funds at poor social value. Although the Federal Government has approved tax-funded outlays eclipsing *some $77 trillion* since fiscal year 2000[115] – with state governments paying tens of trillions in addition[116] – by few empirical metrics has the average American's life improved.[117] Of developed nations, the United States ranks among the highest in poverty rates,[118] income inequality,[119] per-capita cost of healthcare,[120] cost of higher education and student loan debt,[121] the ratio of average worker salary to executive compensation[122] and the rate of death from childbirth.[123] Our increasingly for-profit[124] legal system incarcerates more prisoners than any other nation – including authoritarian regimes like Russia, China, Iran and North Korea.[125] Our infrastructure is collapsing due to decades of decay and mismanagement.[126] We are the only country in the developed world where the average life expectancy is decreasing.[127]

Plainly speaking: America has not invested in Americans. It has not invested in the future we told ourselves we were building. It has not invested in hope for that future. It has not invested in a collective ascendence towards that future. It has instead put a price on those things – and auctioned them off for the benefit of a rarified few at the expense of our society writ large. Our society didn't get here by chance. Our system simply failed.

Determining what blame exists for this is not a role we will undertake. Yet we nonetheless must emphasize how virulently toxic these circumstances are to our society. None of this reflects healthy social homeostasis in any sense. On its face, it instead reflects a myopic indifference where our social institutions – be it media, politics, public administration, healthcare, education, housing, justice, finance or security – consistently fail to responsibly operate in furtherance of social wealth, social unity and social faith. It has become a cancer, and it is killing us.

We must thus ask sincerely, both as an organization and as individuals: if our society has so thoroughly forsaken the faith we once held in our institutional frameworks, how can people be expected to have faith in *anything* hereafter? These circumstances have left us divided, tribalist, cynical and bitter. By what right can people now be asked to place trust in something new without dismissing it as yet another sales pitch for what ultimately amounts to snake oil?

By no illusions do we believe this question can be answered today. But a Public Interest Company, through repeated action transparently demonstrating a sincere purpose for the public interest, can answer that question tomorrow by operating in deference to a fundamental civilizational tenet: **people deserve to have their faith rewarded.**

We sincerely believe that people deserve to see their society working for them, for their interests, for their future – not through empty talk or performative theatrics, nor for profiteering or ulterior motives – but specifically because we share this rock in space together and it should be advanced *collectively* for that reason alone. The ethos of a Public Interest Company is designed to perform that exact role because routine, replicable action is precisely what is needed to demonstrate to the public that the words underlining that ethos legitimately carry weight. Public trust will not be regained overnight. But action after action, deliverable after deliverable, and promise kept after promise kept will eventually establish a foundation on which it can be rebuilt. And, once rebuilt, that foundation can serve as a platform to build bigger and better things thereafter – and consolidate the necessary social, financial *and* political capital to champion large-scale projects for the public interests as a dedicated objective while attenuating the otherwise deafening noise.

Adding Things Up

The unique structure, financing pathways, reduced overhead and enforceable transparency of a Public Interest Company, alongside its inherent attractiveness for public/private partnerships and the vital element of re-establishing social trust, completes an equation that can enable a PIC to operate outside of the limitations of our social status quo. In addition to standard revenue streams, its peerless funding model affords multiple pathways to access public grants, public contracts, tax-deductible donations or corporate sponsorship without compromise or fealty.

As a PIC accepts funds and transparently leverages those resources in furtherance of its mission, it can accomplish goals other entities cannot. It does not need to ask permission from a legislature beholden to special interests to invest in a next-generation technology, or fear the political consequences of defying political power brokers who oppose the deployment of low-cost energy within a municipal authority. It does not have to answer to shareholders who would question the value of constructing vertical farms, desalination facilities, algae farms or social infrastructure. It can simply arrive to the fray, identify a social problem and begin working to remediate its symptoms and build solutions that provide for core human needs and demonstrably improve our social basis. In few other circumstances could an entity seek to do this today without deep public controversy. Yet a PIC can by its own volition, and it can do so with crystal-clear transparency the body politic can verify fidelity to.

In fact, most all of the structural elements of a Public Interest Company can already be met by any 501(c)(3) nonprofit that commits to operating in this capacity – meaning no significant legislative or tax code changes need to occur for a PIC to be founded in furtherance of a social mission. All that needs to occur is the voluntary adherence to these new standards. It can happen tomorrow, as a matter of choice. And as we are ourselves are a nonprofit, that is the choice we will make here. We intend to create the first Public Interest Company with a mission dedicated to implementing Scarcity Zero on any scale we are able, thereafter leveraging technology to heal our environment, repair our social foundations and advance our way of life. In light of the goals this effort is intended to accomplish, we will found its brand on our mission: **Scarcity Zero.**

Scarcity Zero, PIC

Scarcity Zero is a proposed Public Interest Company that is intended to accomplish our nonprofit's mission of solving resource scarcity and climate change. Intended to market energy and resources (as well as energy and resource technologies) as a commercial service under a managed profit model, Scarcity Zero seeks to provide resources to society at the lowest possible cost – or alternatively fund efforts to maximally scale their social provision. As a Public Interest Company, Scarcity Zero does not have shareholders and forsakes intent to generate private wealth. It seeks instead to exclusively generate public wealth, devoted for the public interest, which necessarily includes the long-term health of Earth's ecology. Scarcity Zero is an instrument in the form of a corporation that is designed to manifest resource abundance in perpetuity, and it intends to leverage every available method of capitalism to achieve that goal.

Operating under the rationale, structure and limitations of any Public Interest Company as previously established, this effort will begin by deploying elements of a standardized energy framework that is mass-manufacturable and modularly scalable, either as a commercial service or philanthropic effort. Scarcity Zero intends to accomplish this according to a prospective business plan that will cover several proceeding sections: mindset, operating structure, financing strategy, target projects and revenue + growth strategy, as well as known obstacles and potential challenges. What follows hereafter will cover each of those areas in detail, starting first by establishing our mindset of social mission.

Mindset of Social Mission

Scarcity Zero's mission is to eradicate resource scarcity and build carbon-neutral systems of abundance. Resource scarcity is the core social malady – one that climate change, itself, is both spawned and perpetuated by. It is the root of drought, famine, ecological destruction, economic and humanitarian crises, and it has dominated humanity since the dawn of civilization. Resource scarcity gives form to the ether in which our darkest natures strengthen and flow, thus powering the machinery of war that throughout the ages has wrought unquantifiable anguish – and devoured unquantifiable potential – that could otherwise have worked to build a better world. It is a curse upon our species that week seek to extinguish with prejudice. In this effort, our approach and actions will be governed by a mindset of **five core principles.**

One: Universal Basic Resources. We believe in a world where the abundance of critical resources is underwritten as a dedicated public function. Our technology has reached an inflection point where it can bypass the limitations of zero-sum resource paradigms and instead provide a legitimately inexhaustible resource supply by investing in a technological means to establish this capability with quantifiable certainty. We therefore consider it our duty to extend this capability and abundance to all persons regardless of their wealth, class or stature as a public extension of the social contract.

Two: Collective Capitalism. As capitalism has an unrivaled effectiveness to incentivize innovation that powers social advancement, this capability has maximum effect – and presents maximal social returns – when it is universally accessible by all socioeconomic classes. The wealth and income inequality that has become a hallmark of our present day forces people to devote their limited income to life's necessities (if even that) rather than empowering the body politic to invest in society and also their own innovative capabilities to improve the status quo. This is a needless flaw in system design, one that fundamentally robs our society of the ability to realize the economic potential of a collectively empowered labor force.

We believe the strength of capitalism and the economy it powers is measured by *collective wealth*. Yet as opposed to economic models that seek this end through greater state control of the economy to "limit the ceiling," we instead believe in leveraging technology to **raise the floor**. This means reducing the cost of necessities (such as critical resources) as much as possible, freeing up capital for both individuals and businesses to make social investments. This also means leveraging resource abundance to establish mechanisms that can protect Americans (and American enterprise) from economic headwinds or the costs of failure – keeping **all** social actors empowered to engage our economic levers with a confidence they will succeed through persistence and perseverance.

Three: Circular Economies. We conclude that a linear economic model ([acquire => use => dispose]) is as flawed for powering our consumerist economy as it is for acquiring resources. We believe in *circular* economic and consumption models that revolve steps of [make => use => re-use

=> recycle => remake] which thereafter involve as few resources as possible to maintain perpetual momentum. This means instead of making products designed to be discarded in landfills, we incentivize the continual re-use and upgrade of manufactured goods to maximize resource efficiency and the longevity of what we produce. It also means integrating modularity and standardization throughout all areas of our economy so that mass-manufactured products can be as intelligently deconstructed as they can be upgraded – enabling the regenerative extraction and recycling of substances for use in manufacturing elsewhere. The end goal of a Circular Economy is not just shared prosperity, but also a means to power consumerism through systems that are as closed-loop as possible, reducing both costs of production, aggregate material throughput and overall waste footprint.

Four: Social Investment. As a system, the health of our society is dependent on core social pillars of not just energy and resources, but also the integrity of infrastructure, effectiveness of state institutions, strength of economy, distribution of wealth, ease of trade and the cultural dynamics that ebb and flow based on the state of each. If those pillars weaken, so does our society. This reality has bound most every civilization that has ever existed or ultimately ceased to, as it in turn binds our own. At the end of the day, **we get the society we invest in**, and we believe in investing and upgrading our core social pillars as *individual systems within a greater parent framework* to help ensure our society *as a collective* can both provide a high quality of life for everyone and remain capable of rising to the occasion to overcome future challenges.

Five: Social Advancement. Although humanity has existed on Earth for ~200,000 years, 96% of that time was within prehistoric hunter-gatherer tribes. It was only within the last 12,000 years that humans discovered agriculture, with organized civilization emerging only within the last 6,000 years. From the dawn of mankind until the mid-1800's, the fastest a person could travel was on horseback. Yet by the start of the 20th century, we had invented the locomotive, automobile and aircraft, themselves mere decades behind microcircuitry, computer processing, global communication and space exploration. Achieving these paradigm-shifting breakthroughs in the last 0.04% of our history was not through stroke of luck, but rather through the drive to continue building on the advancements made by those who came before us.

We believe in accelerating that ascendant course with this knowledge of our past as the driving vision for our future – holding sacrosanct that not only do we get the society we invest in, **what good things we build end up building us.** We seek to advance society in meaningful ways to improve our collective quality of life, to instill hope in others as to what we are capable of building, discovering and solving – and to provide a testament for those who may come after that these goals are achievable with dedicated effort.

Operating Structure

As Scarcity Zero is mission-driven as opposed to profit-driven, its operating structure differs from traditional corporations that that are run in a top-down capacity with degrees of separation between executive leadership and ground-level employees. Completing our mission is a complex, multifaceted and highly challenging affair, far beyond that of the capability of one individual to execute by their own volition – and easily compromised by the pitfalls of wishful thinking, personal ambition or institutional sycophancy. In light of this, Scarcity Zero is intended to be governed by a **Stewardship Council** that is comprised of the heads of each of the PIC's eight primary departments, the nature of which are described as follows:

Mission Control is the central nervous system of the PIC as an operating entity, and is responsible for managing the overarching mission Scarcity Zero seeks to achieve. It coordinates all other departments and helps ensure that the organization is operating towards its social mission and achieving its goals as intended. Mission Control serves primarily in an *executive management* role, and the department is helmed by the **Director of Operations** who serves as the chair of Scarcity Zero's stewardship council.

Public Projects spearheads the social deliverables Scarcity Zero intends to render as a PIC, namely implementing the systems inherent to the Scarcity Zero framework: public-facing energy systems, resource-producing systems, prefabricated / modular housing, indoor agriculture / vertical farms, public infrastructure, next-generation material synthesis, waste management / recycling, and any efficiency-improving methods therein. Public Projects serves primarily in a *project management* role, and is helmed by the **Director of Public Projects.**

Applied Technology deploys the systems inherent to Scarcity Zero's social deliverables, retains expertise on how they can be best utilized to achieve specific objectives, and helps establish engineering specifications for new technology acquisitions. Applied Technology works in tandem with Public Projects and Research & Development to establish the nature of what systems are best suited to achieve specific goals, and is responsible for determining how they can do so with maximum efficiency and cost-effectiveness. Applied Technology serves the roles of *systems engineering* for the PIC and is helmed by the **Director of Technology.**

Research & Development is the brain trust of the PIC, and is responsible for researching new technologies and the potential capabilities they can present to Scarcity Zero's social mission. In addition to establishing possible acquisitions for Applied Technology to deploy within initiatives championed by Public Projects, this department actively researches new possible technologies in coordination with public, educational and private entities. The fruits of this effort are published in academic journals and industry whitepapers, and if significant breakthroughs were discovered as a result, used to establish Public Interest Patents to cement the technological capabilities in the public domain. Research & Development serves the role of *innovative R&D* for the PIC, and is helmed by the **Director of Innovation.**

Social Outreach handles marketing and PR. Beyond curating public communiques that help convey the initiatives Scarcity Zero is undertaking in furtherance of our social mission, Social Outreach helps brainstorm new prospective projects in coordination with public and private partnerships. Additionally, Social Outreach helps facilitate the foreign sale of Scarcity Zero's IP abroad in coordination with the U.S. State Department. Social Outreach serves the role of *sales, marketing and public relations* for the PIC, and is helmed by the **Director of Social Outreach.**

Legal Affairs coordinates matters of law and regulatory compliance. Beyond defending the PIC in any potential legal disputes, Legal Affairs civilly enforces the public interest requirement of any Public Interest Patents. Additionally, Legal Affairs helps the PIC resolve any local permitting/zoning issues, and helps Public Projects, tangible deliverables or the PIC as an entity remain compliant with relevant regulations. Legal Affairs serves the role of *corporate consul* for the PIC, and is helmed by the **Director of Legal Affairs.**

Finance coordinates matters of internal finance, bookkeeping, taxes, accounts receivable and accounts payable. As all financial matters of a PIC are open to the public, Finance also ensures that all accounting data is publicly accessible in a GAAP-standardized format. Finance serves the role of *corporate controller* for the PIC, and is helmed by the **Director of Finance.**

Fidelity ensures that we are keeping our promises as an organization. Did we accomplish what we said we accomplished? Did we build what we said we were going to build? Did our efforts meet the expectations we set for ourselves? The answers to these questions may vary both in context and scale, but the root of their answer is fundamentally Boolean: true or false. Yet if the answer does not resolve Boolean true, it must be a PIC-wide effort to determine why – not to lay blame, but rather to tell hard truths, and establish a doctrine of continual improvement to not repeat past mistakes. In the context of what we seek to achieve, social trust is paramount as an understatement. We must perpetually – and actively – ensure that our efforts reward the faith people place in us. Fidelity serves the role of *QA* and internal *Red Team*, and is helmed by the **Director of Fidelity.**

In operation, each department retains the autonomy needed to improve their internal functions, maintain their own team, and advance internal goals in light of the larger objectives Scarcity Zero sets as an organization. These larger objectives are established by Scarcity Zero's **Stewardship Council** that meets on a recurring basis to discuss what projects, initiatives or partnerships we should undertake – and pathways we should undertake them – to advance our social mission. Determinations on these matters is held by majority vote, with each Department having one vote with the Director of Operations having the ability to break ties.

In this structure, whether our PIC does or does not do something it will be as a result of consensus. This is not to institute design by committee, but rather to ensure our steps are steady under organizational accord. We recognize that this deprives us of the bold unilateral leadership of commercial enterprises that have succeeded wildly in our time, yet it also insulates us from the many more instances of failure derived from that same unilateral action. As an organization, we are accepting public money and stepping up to the plate to offer the public a sincerely made promise that we will substantiate the faith they once held that society is moving forward. We cannot offer that promise in good faith if we do not build safeguards to protect our mission from our own shortcomings, and to ensure that our actions – to success or to failure – are undertaken by the sincere agreement that the decision was the right call.

Overview of Scarcity Zero's Stewardship Council

Case Studies

Before illustrating our growth roadmap, target projects, revenue strategy and potential challenges, it is important to first emphasize some of the industries and organizations that inspired our operational structure, social mindset and social mission. Each of them has changed the world in profound ways, the nature of which helps fabricate the blueprints for how we intend to do so in the energy and resource sector. We'll briefly review the most noteworthy standouts to both see why, and how their demonstrated successes can translate to our mission.

Inspirations of Public Interest *Mindset*

Open-Source Software created the modern internet and empowers billions of people to communicate in ways that were unthinkable throughout all but the last twenty years of human existence. When modern computing emerged, all software was closed-source, which is another way of saying it was *proprietary*. Any use of proprietary software – or proprietary programming language – is governed by a license agreement that legally establishes the developer of the software as its ultimate gatekeeper of use. This gave early tech companies effective monopolies over software, some of which still persist.[128] Generally speaking, this is how our relationship to energy and power exists today – usually obtainable only through monopolized gatekeepers.

Yet by gifting itself to the public domain, open-sourcing changed this for software: anyone could use, share or upgrade it as they saw fit. Not only did this democratize accessibility to software worldwide, it led to massive adoption among users that continued improving it to be more performant, more secure, more effective and more adaptable. Instead of pursuing greater profits, the acolytes of open-source software pursued a *better system* – transforming it into a $33 billion industry[129] that built most of the technologies that our world today relies heavily on:

- 73% of the smartphone/tablet market is controlled by Android, an open-source operating system maintained by Google.[130]
- 100% of the top 500 most powerful supercomputers in the world run a distribution of Linux,[131] an open-source operating system that is unrivaled in security and performance.
- Linux also powers the servers of 23 of the top 25 websites in the world, 90% of global cloud infrastructure, and 96.3% of the world's top 1 million websites.[132]
- The software languages that power databases are also overwhelmingly open-source.[133]

Wikipedia is one of the greatest collections of human knowledge ever assembled. Itself a shining example of open-source software, its 58 million articles available in 326 languages comprise a modern-day Library of Alexandria that is instantly accessible to anyone with an uncensored internet connection. As a free-to-use tool that is 100% nonprofit and donation-driven, Wikipedia represents a wealth of knowledge that the world's governments, universities and corporations **combined** did not have when *The Simpsons* first aired. Wikipedia accomplished this feat the same way open-sourcing transformed software – by extending a free framework that could function as a centralized knowledge repository. This induced and inspired the global community of netizens to curate not only knowledge they held or could source, but also to form editing and categorization standards that could index this knowledge into a standardized format within an easily navigable taxonomy. As this index automatically links other articles based on keywords, the repository provides contextual cross-referencing on all information Wikipedia holds – enabling the comprehensive overview of concepts, systems, technologies, languages, ideologies, histories and all points in between. In short, Wikipedia made the aggregate knowledge of humanity accessible at the click of a button.

Google Scholar is a free-to-access repository of scientific journals, industry whitepapers, technical reports, court opinions and general academic works, performing to scholarly research what Wikipedia performed to general knowledge. As of this writing, it has indexed approximately 90% of all academic works published in English,[134] totaling more than 100 million articles that the public can access free of charge to review, cite and build upon in pursuit of their own studies. Whereas prior researchers needed to scour proprietary journals, pay-to-play repositories and locally held print works, Google Scholar digitized the nigh aggregate span of academia into a virtual index that can be instantly queried anywhere in the world.

LF Energy is an extension of The Linux Foundation that develops open-source software serving roles within the energy sector, specifically power and control systems, automation, cybersecurity and supply/demand management. They directly share many of our goals as an organization, yet are directly focused on the software side of the problem – a vital component to the standardization and modularity of mass-manufacturable hardware. Their efforts to digitize electricity and assign it indexable metadata that can be used to analyze facets of energy consumption presents significant advances in efficiency of use, transmission and storage. It also does the same to increasing the effectiveness and scalability of micro-grids, mitigating problems of transmission loss, intermittency and battery degradation. Providing society with data to grasp the minutia of energy use allows us to target inefficiencies, choke points, loss and/or risk factors with granularity – clearing the way to deploy scalable, next-generation power systems that can avoid presently limiting obstacles.

Inspirations of Public Interest *Enterprise*

Newman's Own is a renowned producer of foodstuffs, but surprisingly less well-known is that the highly successful enterprise is not a business but instead one of the most effective charities in history. From the moment it was founded by famed actor Paul Newman, every cent it has earned beyond operating costs have been gifted to charity, a total sum of which exceeds $570 million as of this writing.[135] As a nationally successful commercial enterprise that could be wealthy on its own merits, yet gears its operations exclusively to either fund charitable causes or scale its capability to do so, Newman's Own is one of the greatest inspirations for our concept of a Public Interest Company. It makes a high-quality product, it sells this product under a managed profit model, and it invests all profits into either scaling its operations or devoting the proceeds for a social mission – exactly what we ourselves seek to do.

The Unreasonable Group is a private equity and consulting firm that performs as a commercial enterprise much of that which we seek to perform as a Public Interest Company – leveraging capitalism to drive social change and shift established paradigms. They both fund and mentor emerging businesses to tackle problems within varied economic sectors – including energy and resources – of which they have more than 250 individual organizations. According to their own internal metrics, their 327+ ventures operate in more than 180 countries and have generated at least $8 billion in revenue to positively impact the lives of more than a billion people. While it is a noteworthy distinction that they specifically seek to discover profit in solving global problems, this profit is largely re-invested in their capital reserves to in turn extend investment in subsequent ventures to perpetuate a cycle of social improvement – a strategy we ourselves intend to emulate. As many of the ventures they have funded are already cashflow-positive, their efforts prove that seeking a monetary return on capital investment is not mutually exclusive with solving difficult problems and improving the status quo both domestically and abroad.

FarmBot is a startup company that sells open-source kits for automated farming. With technology packages that can be rapidly assembled, FarmBot modifies CNC machining technology to plant, irrigate and harvest crops. As a natural counterpart to indoor/vertical farming, Farm Bot's systems can enable the large-scale automated cultivation of agriculture 24 hours a day, 365 days a year. As all of FarmBot's products are open source, anyone with an internet connection and a 3D/CAD printer can download the components needed to build machines that can automate agriculture to effectively any scale, while remaining able to modify any aspect of the application layer to meet specific use cases or objectives. Mindful of the relatively low price of both solar panels and atmospheric water generators, FarmBot's technology completes the final missing pieces to democratize agriculture (and the means in which to secure abundant food resources) most anywhere on the planet.

Inspirations of Public Interest *Philanthropy*

Habitat for Humanity is the largest not-for-profit homebuilder in the world, and as of this writing has helped more than 35 million people across 70+ countries construct or preserve homes since it was founded in 1976.[136] In addition to championing green and sustainable building practices, Habitat for Humanity also runs hundreds of nonprofit centers nationwide to donate salvaged appliances, furniture and building materials to recirculate in local economies. Their efforts have since expanded to function as an interest-free lender for low-income families that might not otherwise qualify for commercial loans, a source of education and experience for people seeking employment in construction trades and first responders to global disasters that have rebuilt the homes of thousands of people.[137]

The Bill & Melinda Gates Foundation has been instrumental in spearheading advancements within public health, agriculture and access to information technology. With an endowment approximating $50 billion, it is the second largest charity in the world by this metric and the single largest started by individual actors.[138] It is one of the global leaders in venture philanthropy and makes direct investments in emerging enterprises with missions towards improvement, and also extends billions of dollars in grant funding for public policy initiatives. The results of these efforts have been marked by significant improvements within vaccine administration, insect-borne disease eradication, public sanitation, public education and ecologically sustainable practices. And although the majority of its endowment comes from the personal wealth of high net-worth persons, it has proven to be one of the most successful and impactful charities in history.

The Big Life Foundation is an anti-poaching non-profit operating in East Africa since 2010, which our own founder helped found by serving as Director of Technology from its inception until 2014. While it performs many of the roles undertaken by other wildlife preservation organizations charged with similar missions, Big Life directly takes a hands-on approach in combatting the destruction of wildlife. Some of its novel initiatives include buying crops at top dollar from farmers whose fields are eaten by herding elephants (removing the need to defend their investment with lethal force), purchasing and donating food from abroad to remove the need for local communities to hunt animals for bush meat, and hiring destitute hunters as rangers to leverage their expertise to combat commercial poaching operations. However, Big Life's most significant distinction is direct, in-field operations where it functions as game wardens with law enforcement powers. In this role, Big Life rangers actively pursue, arrest and if necessary engage poachers not only within national wildlife preserves, but also across national borders if poachers attempt to flee. To the best of our knowledge, it is the only extant NGO with cross-border law enforcement powers. As of this writing, it has patrolled more than 3.7 million kilometers, arrested more than 3,800 poachers and seized more than 5,000 weapons.[139]

While other organizations that we have not mentioned here have inspired aspects of our social mission and the goals we seek to accomplish, each of these cited case studies have unique successes that tell a greater story. Because of Open Source Software, the means to harness the revolutionary power of modern computing became globally decentralized without barriers to access, enabling the creation of the internet as we know it. This led to projects like Wikipedia and Google Scholar that transformed our ability to curate and index knowledge that could be accessed free of charge anywhere in the world. Whereas in the past access to knowledge (especially scholarly works or academic journals) was restricted by gatekeepers that required membership in a certain class or charged fees (often exorbitant) to grant access, these projects shifted the paradigm to democratize knowledge to the point of ubiquity.

Conversely in the physical world, Newman's Own demonstrated that commercial enterprise in a free market can not only be geared to exclusively fund charitable efforts, they can be highly successful in doing so even on a nationwide scale. This was seconded by the Unreasonable Group and its subsidiaries of Unreasonable Capital, which through funding and mentorship of commercial enterprises across a diverse portfolio of economic sectors, have positively impacted the lives of hundreds of millions of people across the planet. On a smaller scale, FarmBot demonstrated that a low-scale startup can achieve commercial success by democratizing its IP to enable ordinary people to sustain themselves with a relatively modest investment. Several other companies we opted not to focus on here for the interests of brevity – (Patagonia, SteriPen water filters, Warby Parker philanthropic optometry) – have done so as well to certain extents, as have others, highlighting the reality that commercial enterprise and social welfare can be congruent operational focuses.

The same is true of purely philanthropic missions. The Bill and Melinda Gates Foundation demonstrated that significantly impactful global philanthropy can derive from targeted, well-managed donations from wealthy patrons – even in highly complex social applications like vaccination and public health. Possibilities within philanthropic direct action were further demonstrated by both Habitat for Humanity and The Big Life Foundation. Habitat for Humanity has built or improved houses for more than 29 million people across 70 countries, doing more to keep people housed than any other single private, public or nonprofit actor. Habitat for Humanity also demonstrated how philanthropic finance can function as a lender of last resort when traditional capital sources are unable to do so. And although it is not as widely recognized as other wildlife organizations, The Big Life Foundation is the only known anti-poaching organization in the world that is both deputized as law enforcement within multiple countries with the ability to cross borders in direct engagement with armed poachers, demonstrating how well-run nonprofits can complement roles traditionally reserved for state actors. Alongside The Bill and Melinda Gates Foundation, both Habitat for Humanity and The Big Life Foundation further show that nonprofits can have significant impact if they operate directly in-sector as mainstay players.

Lastly, FarmBot and LF Energy demonstrate that startup organizations centered on open-source information can radically transform vital social sectors such as agriculture and energy – areas that have been traditionally vexing for organizations outside of a purely commercial model. FarmBot's technology suites democratize farming to a granular scale as small as individual, yet they can also make agriculture both location and climate-agnostic. This has extensive applications to combatting famine worldwide, and can also present significant reductions in the ecological impact of modern-day agriculture – which more often than not is quite high.[140] LF Energy harnesses advances in both system efficiency and computer processing to make all aspects of energy – from generation, to transmission, to consumption – operate intelligently within a smart, scalable and granularly managed ecosystem. Much of our own work centers on the notion that power infrastructure is incorrectly ad-hoc in both design and construction, which ultimately forsakes proven mindsets of standardization and modularity at the cost of greater obstacles to scalability, reliance on antiquated systems and exponentially increased costs. Establishing a software layer that is capable of harmonizing energy's myriad roles while providing detailed analytics for continued improvement of its open-source frameworks is a vital complement to the revolution in energy and resource infrastructure we seek to normalize.

What we see with these cases studies is a demonstrated track record of philanthropic endeavors successfully solving complex, large-scale problems within areas that society traditionally depended on government to address – and if not apparatus of state, the private sector as a commercial enterprise. And while not casting aspersions on the willingness or capability of either to perform these roles, the reality that nonprofits can develop novel solutions to complex problems and implement them on a similar scale with demonstrably effective social impact is increasingly self-evident, as is the reality that technology can accelerate these capabilities to the point where they can challenge even greater problems thereafter.

Yet with the exception of Newman's Own, each of the case studies mentioned above were able to accomplish their mission solely through external donors – especially wealthy donors as with the Bill & Melinda Gates foundation. The additional element of structuring a nonprofit as a commercial enterprise that exclusively funds a philanthropic mission is the missing force multiplier that allows such missions to truly make the largest possible impact. In the extension of a commercial service in a public market (with a nod to Unreasonable Group's ethos), it is not a practically difficult task to consider a return on investment through a lens of "what problems can we solve?" instead of "how much money we can make?" The fact that society tends to often focus on the latter at the ultimate expense of the former is a reflection of *mindset*, not of capability – and certainly not of possibility. It is a simple choice to perform business for the mission as opposed to mission for the business, and seek social returns on a social investment that prove far more valuable than what money can buy. As other organizations have proved this approach can work – and have proven so in the exact sectors we seek to operate in – we accordingly seek to do so as well, and intend to structure our operations to build off their unambiguous successes.

Growth Roadmap

Scarcity Zero's mission to tackle some of society's most vexing problems has only been made possible through novel technological achievements that only emerged in the last two decades. Yet we maintain no illusions that they alone will accomplish our goals. Even with maximum dedication and ample resources, there will be unforeseen setbacks, funding bottlenecks, operational challenges and unknown obstacles that must both be approached with a level head to competently attenuate. The best way we believe this can be performed is to grow our operations through a roadmap of five tiers that can demonstrate our capabilities and public benefit of social deliverables within a manageable scope of work – with each subsequent tier building from the one before it to solidify the foundations in which to scale higher.

Tier I: Pilot Projects. Our first tier is to build small-scale initiatives to demonstrate the capability of Scarcity Zero and the mission implementation through Scarcity Zero. This includes pilot projects for municipal solar integration, seawater desalination, hydrogen production (albeit through non-nuclear means, at least initially), National Aqueduct infrastructure and vertical farming systems. These projects will start in our headquartered city of Bellingham, Washington and surrounding Whatcom County, and will be conducted in coordination with municipal authorities, local partners and the State of Washington.

Bellingham is an eco-conscious, coastal pacific city which has several attributes that make it uniquely attractive to deploy pilot projects for Scarcity Zero. It is located directly on the waters of Puget Sound, which as an inlet of the Pacific Ocean grants easy access to an unlimited supply of seawater. It is home to a well-regarded technical college and university offering academic tracks in science and engineering. The city itself is situated between Seattle and Vancouver, both of which have world-class universities, industries and commercial enterprises that work within our areas of focus. It is also relatively close to the headquarters of NuScale power and Idaho National Labs – leaders in emergent SMR technology. This presents myriad avenues for academic, commercial and public partnerships.

Agriculture additionally plays a significant role in our local economy, and we have plenty of open space to deploy novel farming systems. As we have significantly more sun than Seattle and the lower Puget sound, solar power is also fully viable. Further, the city of Bellingham, Whatcom County and the State of Washington have each set aggressive climate goals, which makes them natural partners. Vancouver, just 40 miles north of us, is home to several of the pioneers in carbon capture and green building technologies we seek to propagate. All of this makes Bellingham an ideal location to develop and scale the systems behind Scarcity Zero. By starting our pilot projects here, in coordination with industry, academic and public-sector partners, we will demonstrate their efficacy in a way that not only improves the quality of life of the Pacific Northwest, but also generates interest to replicate this feat in other regions where resources and climate concerns are pressing.

Tier II: Multiplier Modules. After successfully completing several series of pilot projects, we will work in coordination with our partners to standardize the technologies within our areas of focus into open-source systems that can be mass-manufactured and modularly deployed. These systems will be released as "Multiplier Modules" that true to their open-source roots are updated over time through a semantic versioning scheme [model 1.0.0 (major.minor.fix)]. (Note: "Multiplier Module" is a term used internally and for this document, and final branding may tweak to remain complaint with trademarks for Westinghouse's Energy Multiplier Module prototype). At this tier, we aim to develop, manufacture and release six multiplier modules:

1. **Solar Multiplier Module** – standardized, rapidly scalable solar modules targeting housing and municipal infrastructure.

2. **Water Multiplier Module** – standardized, rapidly scalable desalination module.

3. **Hydrogen Multiplier Module** – standardized, rapidly scalable electrolysis module.

4. **Aqueduct Multiplier Module** – standardized, rapidly scalable water transmission module with integral power generation.

5. **Farming Multiplier Module** – standardized, rapidly scalable farming systems.

6. **Housing Multiplier Module** – standardized, rapidly scalable housing modules.

As these multiplier modules will be open-source and built in coordination with our partners, we aim to retain a certain volume of expertise that allows us to rapidly scale their deployment to as many cities as we are able. This will start within the Pacific Northwest and then move next to Oregon, California and Texas, as each are agricultural states that are deeply struggling with drought yet have extensive solar coverage with ample access to seawater. We will of course seek to do the same with other states on the Atlantic, but pacific and southwestern regions will be our primary focus as they have the most to immediately gain from our efforts. Although mainline construction of the National Aqueduct is intended to begin in Tier III, we will explore long-distance water transmission into inland territory of these states where capabilities allow.

Tier III: Manufactured Abundance. After successfully developing and deploying Multiplier Modules within our initial target areas, we will then seek to leverage type-certified Small Modular Reactors (Gen IV+) that can be delivered via truck, rail or rotary wing aircraft. This will begin with NuScale's recently type-certified reactor, and continue further through SMRs powered by the thorium-232 fuel cycle (LFTR) as they obtain certification – a process that we will also seek to aid as we are able. As a component of this effort, we will seek to develop open-source standards for type-certified reactors that can easily allow external systems to be cogeneratively powered from the reactor's heat emissions.

These reactors will be deployed in target projects within key demographics, namely drought-afflicted regions of Southeastern Washington, Oregon, California and Texas. Once an area is selected and the project is approved, we will begin building pilot Cogeneration Facilities that combine type-certified SMRs with other multiplier modules that either generate power or produce resources. As these deployments are modular in nature, they will change configuration to determine the most efficient use of systems based on power or resource demand – the nature of which will be used to fine-tune subsequent Cogeneration Facilities as they are deployed.

Tier IV: Indefinite Scale. We hold concrete belief that the underlying approach to Cogeneration Facilities and the mass-manufacturing of standardized modules for energy and resource production is decisively – and vastly – superior to our current approach. After these pilot deployments are operational, we accordingly believe that this will induce policymakers and industries to adopt these new methods in ways that best suit their own goals. Consequently, we will pivot operations to deploy such technology on an increased scale. This will naturally include all areas of the United States in need of the energy or resources our systems provide, but will also include international deployments in coordination with the U.S. State Department.

The case of international deployments will be a new frontier in and of itself. Whether a function of direct aid, regional economic stimulus or strengthening diplomatic ties, we expect the provision of energy and resource technologies to be a major driver of human dynamics within the next century. Building an ability to extend this provision as a purveyor of open-source energy technologies will assist greatly in allowing our organization to respond deftly to need while earning sincere goodwill along the way.

Tier V: Advanced Research and Development. Humanity has always been evolving throughout history, yet our evolution – both as individuals and as nations – has unfolded through lenses of scarcity that spark our conflicts, limit our technology and constrain our civilizational vision. Should we be successful in deploying open-source technology to solve scarcity in the ways we believe it can, the next focus thereafter will be improving our civilization writ large through open-source technology development. Some of this will include ongoing development of our core focuses of energy and resources. Others will include new frontiers and emerging technologies – including research and development of advances therein. Which areas these efforts manifest are ultimately hypothetical, as we have yet to finish even the first tier of this growth roadmap, but should we succeed in our initial aims we remain dedicated to advancing the human collective – and our long-term future – through the ongoing provision of open source technology.

Revenue Strategy

Scarcity Zero's revenue strategy is geared exclusively to expand the scale and quality of our social deliverables. We seek to offer services at a managed profit model that fund initiatives for the public interest, specifically the propagation of systems that generate energy and resource abundance. As we conduct operations, this effort will occur through four sources:

Donor Revenue concerns funds donated to Scarcity Zero or The Next Giant Leap Foundation, both of which will operate as 501(c)(3) organizations until the legal designation of a PIC is available. We will seek donations from the public, primarily through direct solicitation of larger donors who are like-minded in our goals. Once we have sufficient financial resources, we will begin Tier I of operations within the City of Bellingham and Whatcom County, and market our efforts/successes accordingly in our ambition to scale.

Public Revenue concerns funds raised by grant applications and partnerships with municipal, state and/or federal bodies. This will be raised in conjunction with donor revenue as starting capital to begin pilot projects as thus-far described.

Commercial Revenue concerns funds raised under our managed profit model through extensions of commercial services. After covering internal expenses, these profits will be invested into scaling our operations or improving the quality of our social deliverables.

Passive Revenue concerns funds raised through foreign licensing of any IP we develop and market under Public Interest Patents, which while free to use for American citizens and businesses within the United States, would carry fees if used to develop technology abroad. It would also concern revenue derived from any property investments we made for the purpose of expanding our mission or social deliverables.

As we conduct operations, this revenue strategy would engage in a cascading context. To get started we would rely more heavily on donor and public revenue to fund pilot projects, secure office space and hire a small team. As pilot projects bear fruit, donor funds would be bolstered by increasing inflows from commercial revenue, which would scale as we grow. Should we reach a scale where we have established mature relationships with overseas markets, licensing fees from Public Interest Patents would continue to be a revenue stream that we will use to extend our capabilities and improve our services.

As with much of this Implementation and Operation strategy, these revenue streams are inherently *general.* Specifics as to what projects we are capable of undertaking, what budgets we can expect to work within or volume of revenue we can raise is directly proportional to the resources readily available to us. We will start by accomplishing what we can fund as a small organization with a novel – and effective – approach to long-vexing problems. Should our financial resources increase, the scale of what we will seek to accomplish will accordingly (yet prudently) increase mindful of our reduced budgetary limitations.

Potential Challenges

While we remain confident that our mission is pressing and our approach is capable of achieving our goals, there are nonetheless obstacles we must be cognizant of. We cannot assume any of this will be easy even if we secure an ideal degree of public support and financial resources – both of which reflect significant challenges in and of themselves. Already, we have identified several external factors that will present headwinds:

- **We're attempting to undercut entrenched industries.** By virtue of our mission, we are attempting to socially democratize and make as inexpensive as possible that which currently is wildly profitable. Energy and resources are vital to social operation. Private industries make unquantifiable fortunes from extending them at extensive markup. While we believe generating an abundance of energy and resources will supercharge the economic potential (and security) of society writ large, the financial interests in the business of providing those things today will not accept a new status quo lightly. Nor will they be so easily convinced to shift their entire business strategy to investing in the means to produce abundance or the dividends such abundance provides. We must both assume and expect they will roundly oppose our efforts and wield their considerable power to ensure we fail.

- **While our business model is plainly humanitarian, institutional opposition is unknown.** There are myriad aspects to our operating strategy that requires support (or at least regulatory approval) from public sector institutions. How easily this support can be secured is unknown – especially in the context of our current pay-to-play political environment where influence (such as from established industries) can be purchased through lobbying efforts or other media campaigns.

- **Nobody has ever done this before.** We identify resource supply as the core element of the human condition because it is the most common denominator through all elements of civilizational function. Economies are dominated by it, wars are fought over it more than any other cause (if not entirely), prosperity is fueled by it and civil strife is caused in its absence. Yet it was only at this recent time that this element could even be identified as an abstract that could be met and provided through technological means, and most every entity that has come before has provided it as a for-profit commercial service. To the best of our knowledge, no organization has thus-far stepped forward with a mission to solve resource scarcity, even if they have for climate change as we also do. If they have, they have failed unknown to us, which further underlines the reality of our circumstances.

The road of history is littered with the skeletons of prior organizations that started with ample funding and good intentions, and who attempted to accomplish easier goals on smaller scales than what we intend. We believe that recognizing this as plainly as possible will help us approach the obstacles ahead with clear vision, as well as induce potential partners to support us accordingly. Because even in light of the challenges before us, we remain steadfast in our conviction that we will ultimately succeed in our mission – if for no other reason than we must.

Part III: Why We Will Succeed

While our goals have aims as high as our ideals, we are also realists. None of our efforts exist in a vacuum, nor are the obstacles before us shrouded in wishful thinking stemming from strength of conviction. We recognize the (objective) history that has led our civilization to this moment in time, the *realpolitik* of our current political dynamic, and our advanced stage of cultural fragmentation. We remain further aware of the recalcitrance our society may present towards a paradigm-shifting investment in our resource and energy infrastructure should the matter be seriously presented. We do not seek to offer solutions or even an analysis in this context without recognizing the unignorable role these elements play within our status quo.

Yet the plain truth of the matter is that the goals before us will be met – either by us or other efforts with similar aims – because our future fundamentally depends on it. It is no small source of frustration to emphasize this reality at a time when alarmism has become a common fixture of advertising, media and politics. For as the sun rises anew each day despite ubiquitous prophecies of doom, this habitual abuse of our sense of emergency results in a desensitized social ambivalence that precariously hinders necessary action in the face of threats that are *actually* existential. "The boy who cried wolf" is one of humanity's oldest fables for this reason. Back in the days of prehistoric man, an existential threat was a pack of wolves. Today, it's the collapse of the ecological and resource structures on which our civilization stands.

This goes well beyond the long-sounded alarms from most every corner of the scientific community as to the worsening state of climate change and the heatwaves, wildfires, droughts, storms and crop failures that are unambiguously accelerating in both frequency and severity. Humanity is rapidly depleting the resources of our natural world, while simultaneously destroying the natural ecology that makes such resource acquisition possible in the first place. Should current trends continue, billions of people across the globe will lack the energy, water and food to survive, especially if climate change makes entire continental regions uninhabitable. As this leads to both economic devastation and mass migration on an unprecedented scale, it will prompt states to increasingly secure resources by whatever means necessary – including war. This will both end the Long Peace, fracture the international order, and plunge humanity into global conflict. In a world rifle with histrionics and alarmism, we recognize this may strike as hyperbole. **We must insist that it is in all respects an understatement.**

2.4 billion people today lack access to clean water.[141] By 2025, the U.N. estimates that more than five billion people will live in extreme water stress,[142] meaning, specifically, that they face life-risking scarcity of most vital resource.[143] That is 70% of humanity. The U.N. further estimates that global freshwater demand between now and 2050 will increase by 55%, with demand exceeding supply by more than 30% by 2040.[144] Commercial forecasts are worse, as Goldman Sachs estimates that freshwater consumption is doubling every 20 years,[145] Data from NASA satellites show that 21 of the world's 37 aquifers have passed their sustainability tipping points,[146] meaning they will run dry if current trends continue. Aquifers supply 35% of global water use, and they are among the last reliable sources of fresh water we have left.[147] California is already tapping aquifers for up to 60% of its water supply,[148] and climate scientists expect aquifers will be relied upon to even greater extents in the future – all the more so as California breaks drought records annually.[149]

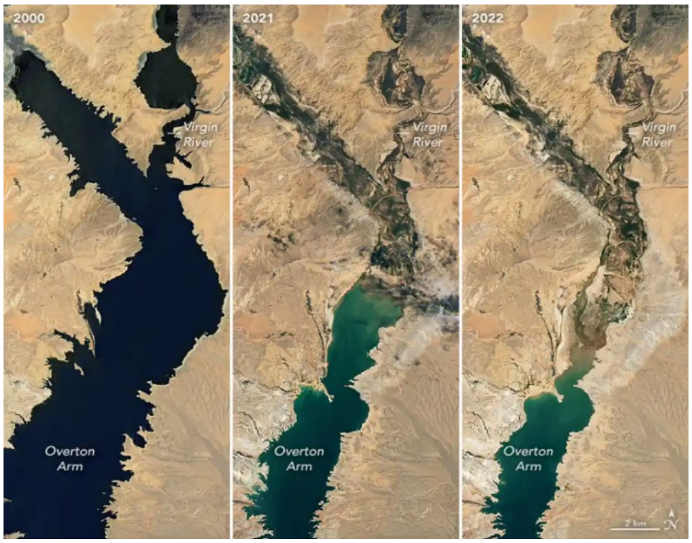


Figure 22 –Lake Mead's depletion since year 2000 (NASA)

Lake Mead is the largest reservoir in the United States by water capacity. It provides water for both agriculture and sustenance to 20 million people within Arizona, California and Nevada. At maximum capacity, Lake Mead spans 112 miles with a surface area of 250 square miles (640 km^2), holding 35 million megaliters of water. The last time it was full was in 1983. As of this writing, Lake Mead's volume has reduced by 75% - the lowest level it has ever been.

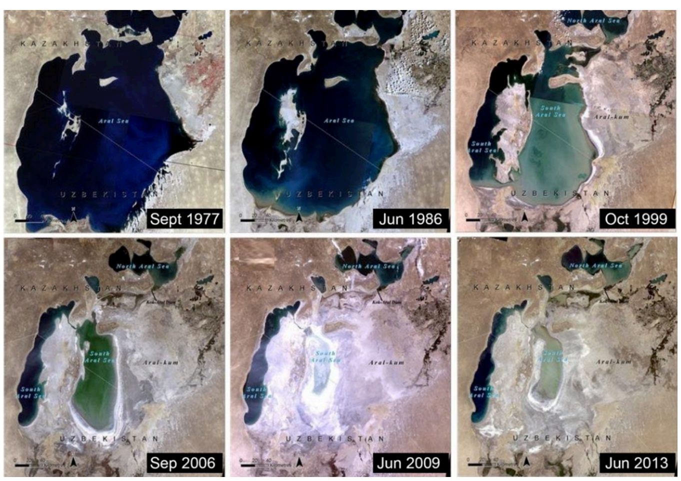


Figure 23 - Aral Sea depletion since 1977

For an even starker example, consider the Aral Sea in western Asia, which was once the 4th largest lake in the world. In 1960, the body of water had a surface area of 26,300 square miles (68,000 km^2) and a volume of 254 cubic miles (1,080 km^3).[150] For comparison, that is 4,000 square miles larger than Lake Michigan by surface area and nearly two and a half times larger than Lake Erie by total volume.[151] Yet in a timespan of just 35 years, the Aral Sea was depleted to become what is now known as the Aralkum Desert that comprises the borders of its eastern basin.[152]

Visualizing this scale of water scarcity in global terms is made possible by a recent National Center for Atmospheric Research (NCAR) study that created a single global drought model from year 2000 to year 2099 by cross-referencing 22 peer-reviewed climate models with historical drought records and indexes of prior academic research.[153] Based on current (non-increasing) rates of consumption, the results of the study reflect circumstances that would fundamentally compromise our planet's ability to support human civilization as we know it:[154]

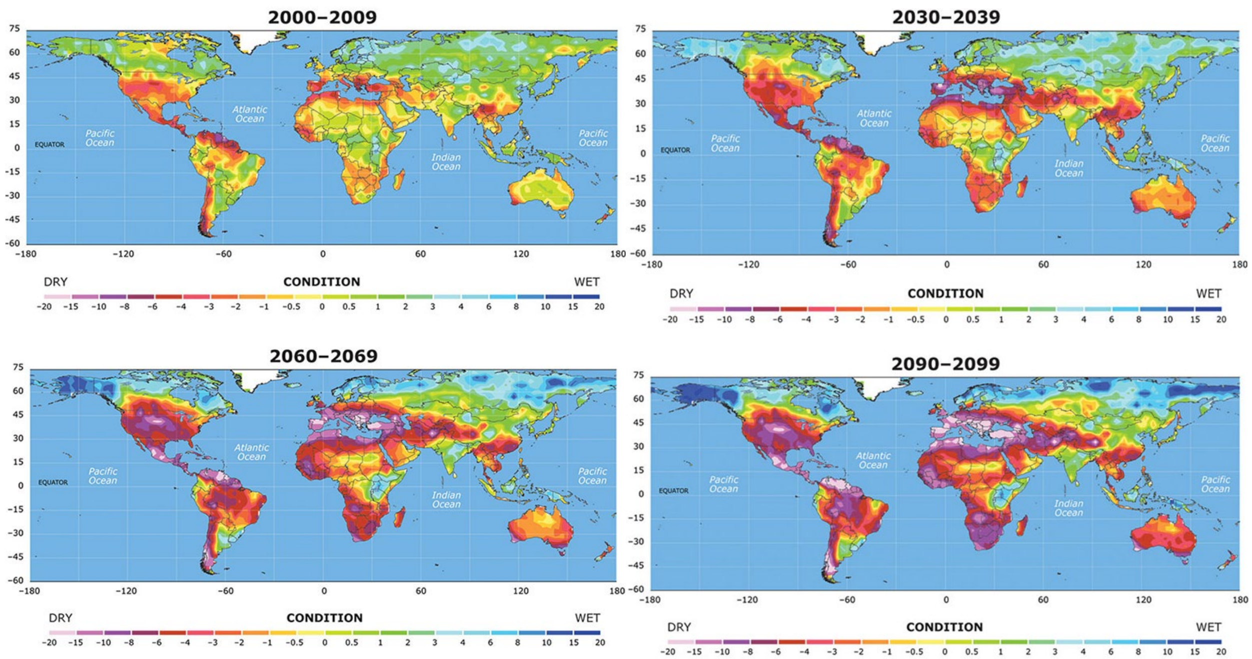
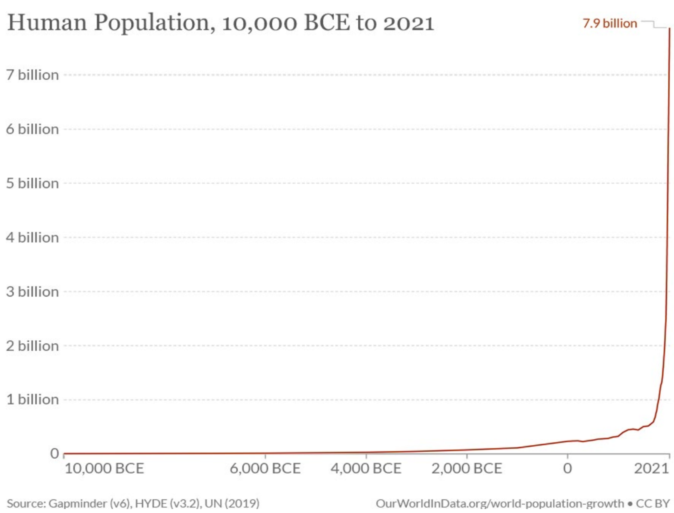


Figure 24 - NCAR Drought Model Predictions year 2020-2099 (A. Dai)

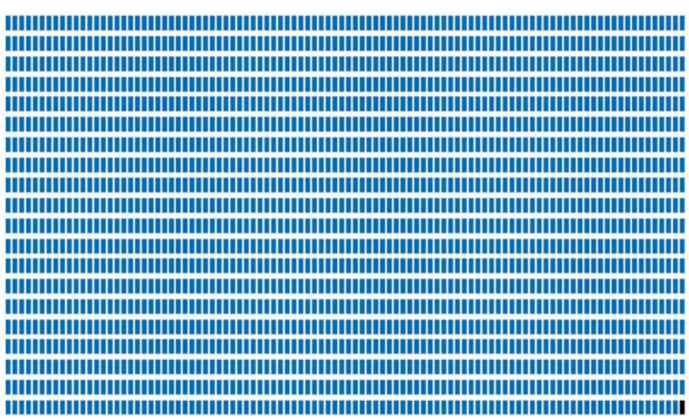
Yet water scarcity is itself only one contributing factor to our predicament. For example:

- Fish stocks are overfished by 80% globally, and ecologists fear they may collapse entirely as early as 2048.[155] Three billion people rely on seafood as a primary source of protein.[156]
- The United Nations estimates that the number of severely food insecure people has doubled in the past two years – from 135 million pre-COVID to 276 million today. More than 820 million people today (1 in 10) go hungry in some form.[157]
- Between 2006 and 2008, world average food prices rose 107% for soybeans, 136% for wheat and 217% for rice.[158] By year 2030, food prices are estimated to rise an additional 107% for rice, 120% for wheat and 177% for corn compared to their price in 2010.[159]
- Even though more than a third of Earth's land surface and nearly 75% of freshwater resources are currently consumed by agriculture,[160] the volume of food the world currently produces will feed *less than half* of humanity by 2050.[161]
- The U.S. Energy Information Agency (EIA) estimates that global energy consumption will increase 50% by 2050.[162] The demand for electricity is estimated to increase by 79% during this same time period.[163] For reference, global electricity consumption reached 22,850 Terawatt-hours in 2019.[164] A 79% increase of this figure is 18,050 Terawatt-hours – equivalent to the entire volume of electricity consumed worldwide in 2010.[165]
- Ocean acidification is occurring at a rate not seen in the last 300 million years,[166] and Earth is estimated to have lost 50% of its shallow corals in the past three decades.[167] If current trends continue, this figure is estimated to rise 90% by 2050.[168]

- Approximately 60 billion tons of renewable and non-renewable resources are globally extracted annually – twice the rate of extraction in 1980.[169] Since the start of the Industrial Revolution, humanity has cut down more than half of the world's forests.[170]
- Plastic pollution has increased tenfold since 1980, and 400+ million tons of heavy metals and toxic waste are dumped annually into global water systems.[171] China and India both face severe water contamination at 50-90% of national water supplies.[172]
- Between 1970 and 2014, Earth saw a 60% decline in its mammal, bird, fish, reptile and amphibian species — nearly all due to human activity.[173] Of Earth's remaining plant and animal species, *one in eight* are at imminent risk of extinction.[174] To date, human activities have destroyed 83% of all mammalian life on Earth.[175] Only 4% of mammals are wild.[176]



While unsustainable resource extraction and consumption naturally play into these circumstances, the simple reality is that humanity's exponential population growth is exceeding the limits of our current energy and resource paradigm. This vastly exceeds the Malthusian concerns reflected in *The Principle of Population* or *The Limits to Growth* – perhaps the two most recognizable academic works on the potential dangers of population growth exceeding natural resource supplies.[177] Humanity's population has increased 700% from Thomas Malthus' time and is today twice that of 1972, the year *The Limits to Growth* was published.[178]



To emphasize just how rapidly humanity's population has expanded, note the figure to the left where each of the 2,000 rectangles represents **one century**. In aggregate, the blue rectangles represent the entire length of time (some ~200,000 years) it took humanity to reach 1.8 billion people, which it achieved in 1914.[179] The lone black rectangle (last) represents the 100-year timespan it took humanity to grow from 1.8 billion people to 7.4 billion people.

In another way of saying: humanity's population increased 410% in the last $1/2000^{th}$ of human history. At our current rate of population growth, humanity will reach 8 billion people by 2022 and exceed 10 billion people by 2050.[180]

It is true that population growth is estimated to plateau by year 2100.[181] It is further true that this itself may have negative implications to our long-term economic growth over the long-term, as has been argued.[182] Yet as things stand today, the entire exercise will prove moot if widespread ecological collapse causes the foundations of our civilization to run out of vital resources a half-century earlier – if not sooner – a problem that will be in no way solved by declines in western birthrates. Population growth is fastest within developing nations that seek to emulate the lifestyles and consumption habits of their western counterparts,[183] and are rapidly increasing their purchasing power to place stress on resource and commodity supplies.[184] Major pillars of our collective ecology are already at the brink of collapse as of this writing. We would consider it unrealistic to the point or irresponsibility to assume that our current paradigm will sustain a multi-fold increase in both resource consumption, resource demand and resource extraction as a matter of course.

We further consider it a dubious prospect to assume that developing nations on the cusp of rapid growth will embrace restraint and temper the resource demand western nations did not during their own rise, as the predictable behavior of states seeking to acquire resources in zero-sum paradigms is one of history's reliable constants.[185] Also constant is the presence of resource scarcity as a cause for armed conflict, either internally, regionally or globally. As the events that follow mass scarcity and/or mass conflict have reliably illustrated our darkest days as a species, we cannot place hope in a future determined by the track record of human behavior in times of acute scarcity or accompanying strife.

Recalling that the world was brought to its knees by COVID-19 – a novel respiratory virus with an approximate case fatality rate of 2.5%[186] – we consider it manifestly unlikely that the global order as we know it can withstand widespread ecological collapse in any of the aforementioned contexts – let alone all of them combined. The notion of sustained global drought and crop failures risking the survival of billions of people, or of perpetually severe heatwaves making entire nations uninhabitable, or of a billion or more climate refugees migrating in desperation are scenarios that are both catastrophic and plausible. We can envision few circumstances where this does not lead to the war, conquest and destruction that scarcity and desperation have consistently wrought throughout history.

Yet even though history may well repeat itself, the extent and sophistication of nuclear arms place us in uncharted territory. Today, some 15,000 nuclear devices call at least nine countries home[187] – more than one for every city on Earth.[188] Of them, greater than half are deployed in a first-strike capacity that can reach anywhere on the planet within an hour or less.[189] Thousands of others intended for rapid battlefield deployment lack Permissive Action Links (PALs)[190] that prevent use absent launch authority from an established Chain of Command. In a world engulfed by ecological collapse, resource scarcity and war, it is wildly optimistic to assume they will remain sidelined based on understandably wishful thinking.

Hyperbole is not necessary to emphasize how calamitous these circumstances are to the foundations of our global economy, global security and mankind's ability to support our civilization as we know it. In aggregate, they represent the single greatest threat we face as a species. Our only two options are either to develop a solution to their causes and consequences, or fail to do so. Failure in this context is not quantified by a loss of power, prestige, influence or wealth. It is quantified by the immolation of our civilization as we know it, the destruction of earth's natural beauty – and the ashes of the brighter future we could have otherwise built.

That is the uncompromising reality of our circumstances as they today stand.

It is for that reason why we will be successful. Because we have to be. There is no future without this solution, thus it is incumbent on us as individuals and as a collective to build one. **That is the duty civilization <u>requires</u> of us.** It is a duty some 200,000 years in the making, and it is our time – our time – that will determine whether or not humanity as a species is capable of rising to the occasion. There are no points for anything but success. We either do or we do not.

We therefore choose to build a future worth having, one that spares subsequent generations from knowing scarcity and need as humanity's most fundamental plights – a future that is worthy of the sacrifices made by those who came before us. At the end of the day, that's it – the core lesson to learn, the core promise to keep. We get the society we invest in. We get the world we steward. We get the future we build. And what good things we build end up building us.

We have the tools to see this goal accomplished, should we choose to use them. We have the knowledge, should we choose to apply it. We have the technical means, should we choose to engage them. We have the finances, should we choose to invest them. We have every element necessary to achieve a paradigm-shifting approach to our relationship with energy and resources and build a world of abundance – every element except the will to choose to do so.

The will to make this choice does not need to be unanimous among us as a collective. It just needs to be made collectively enough to demonstrate that we can build systems which rekindle the faith society once held in a brighter future – and that can reward such faith hereafter.

That is a choice we can make today. That is a choice we can inspire others to make tomorrow. And that is a choice that they, in turn, can inspire others to make hence.

As such, it is the choice we now ask of you.

https://nextgiantleap.org

https://scarcityzero.org

Citations and Data Reference

Please note that via our source and citation policy:

1. Specific facts of an obscure and highly technical nature are primarily sourced by commercial documents, technical whitepapers or public-sector research reports, or academic works. This may include documentation from a commercial enterprise that markets technology in the respective sector in question.

2. Supporting data on general topics is frequently sourced from nonpartisan media, commercial trade publications and other journalistic sources.

3. Wikipedia is cited for background reading on general technical concepts, characteristics of public works projects, geographical features of area and population centers. While we do not rely on it for specific facts of an obscure or highly technical nature, we believe it is the most compact and high-quality form of general information that is universally available free of charge.

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[1] While it is generally not disputed that wars are fought primarily over resources, the following two sources provide useful background material:

Klare, Michael T et al. *"The public health implications of resource wars."* American journal of public health vol. 101,9 (2011): 1615-9. doi:10.2105/AJPH.2011.300267

United States Armed Forces Joint Forces Command – "*The Joint Operating Environment 2008 - Challenges and Implications for the Future Joint Force."* https://www.jcs.mil/Portals/36/Documents/Doctrine/concepts/joe_2008.pdf

[2] Energy Information Administration. *"Average Price of Electricity to Ultimate Customers."* https://www.eia.gov/electricity/annual/html/epa_02_04.html

[3] New York City is 302.6 mi², according to its Wikipedia entry - https://en.wikipedia.org/wiki/New_York_City - which translates to ~8.44 billion square feet. We will assume that the aggregate surface area of all municipalities in America crosses the threshold of hundreds of billions, yet we estimate it is more likely past one trillion.

[4] International Electrotechnical Commission. *"Efficient Electrical Energy Transmission and Distribution."* (2007). https://basecamp.iec.ch/download/efficient-electrical-energy-transmission-and-distribution/#

[5] M. Brain, D. Roos, "How Power Grids Work." https://science.howstuffworks.com/environmental/energy/power4.htm

Union of Concerned Scientists. "How the Electricity Grid Works." 17 February, 2015. https://www.ucsusa.org/resources/how-electricity-grid-works

[6] Electric Light & Power. *"Underground vs. Overhead: Power Line Installation-Cost Comparison and Mitigation."* 2 January, 2013. http://www.elp.com/articles/powergrid_international/print/volume-18/issue-2/features/underground-vs-overhead-power-line-installation-cost-comparison-.html

[7] Bloomberg CityLab. *"The Staggering Value of Urban Land."* R. Florida. 2 November, 1917. https://www.bloomberg.com/news/articles/2017-11-02/america-s-urban-land-is-worth-a-staggering-amount

[8] Bloomberg CityLab. *"The Staggering Value of Urban Land."* R. Florida. 2 November, 1917. https://www.bloomberg.com/news/articles/2017-11-02/america-s-urban-land-is-worth-a-staggering-amount

[9] Solar Window Power Model: https://solarwindow.com/powermodel/

[10] If a single urban structure can annually generate 1.57 million kilowatt-hours annually, it would require only 637,000 buildings to generate one trillion kwh at similar generation capacity. New York City, alone, has more than one million buildings. https://lastfiascorun.com/faq/often-asked-how-many-buildings-are-in-new-york-city.html. We therefore operate under the assumption that nationwide there are many millions of buildings, thus exceeding the threshold to generate "trillions of kilowatt hours" in aggregate.

[11] Washington Post. *"Turns our wind and solar have a secret friend: Natural Gas."* C. Mooney. 11 August, 2016. https://www.washingtonpost.com/news/energy-environment/wp/2016/08/11/turns-out-wind-and-solar-have-a-secret-friend-natural-gas/

[12] United States Government Accountability Office. *"Electric Grid Cybersecurity: DOE needs to ensure its plans fully address risks to distribution systems."* 18 March, 2021. https://www.gao.gov/products/gao-21-81
[13] EIA information on power plants nationwide. https://www.eia.gov/tools/faqs/faq.php?id=65&t=2

[14] Information on the number of Energy Utilities operating in the United States. https://www.publicpower.org/system/files/documents/2018-Public-Power-Statistical-Report-Updated.pdf

[15] Energy.gov information on the number of power lines in the U.S. http://energy.gov/articles/top-9-things-you-didnt-know-about-americas-power-grid

[16] American Society of Civil Engineers. *"America's Infrastructure Grades Remain Near Failing."* 9 March, 2017. https://www.asce.org/templates/press-release-detail.aspx?id=24013

[17] Wikipedia Entry on Miami-Dade County. https://en.wikipedia.org/wiki/Miami-Dade_County,_Florida

[18] Miami-Dade County. Energy outlook assessment. Page 2. https://www.miamidade.gov/greenprint/planning/library/milestone_one/energy.pdf#p2

[19] Solar panel output varies by sophistication, size, region and efficiency. We have therefore established assumptions based on the myriad solar options available. The SunPower E20 solar panel is a solid quality solar panel available on the market today. With a nominal power output of 327 watts, it is 61.4 inches wide and 41.2 inches tall, coming to a surface area of about 17.5 square feet (as per https://us.sunpower.com/sites/default/files/sunpower-e-series-commercial-solar-panels-e20-327-com-datasheet-505701-revh.pdf). That translates to roughly 18.7 watts of power per square foot. Converting to energy, 18.7 watts of power exerted over an hour is measured as 18.7 watt-hours. Assuming five peak sun hours in a day, that totals 93.5-watt hours generated per day. Extrapolated over a calendar year, that totals 34,127.5 watt-hours.

Denoted in kilowatt-hours (the standard most energy is measured in), that comes to 34.12 kilowatt-hours of energy generated per square foot, per year. To account for anomalies, we'll reduce that figure by 10%, and estimate that one square foot of solar panel surface can reliably generate 30 kilowatt-hours per year. As there are 27.88 million square feet in one square mile, we will conclude that one square mile of solar panels would reliably generate 836.5 million kilowatt-hours in a year.

[20] American Society of Mechanical Engineers. *"Entrepreneurs Look to Small-Scale Nuclear Reactors."* M. Abrams. 2 March, 2021. https://www.asme.org/topics-resources/content/entrepreneurs-look-to-small-scale-nuclear-reactors

[21] B.M. Elsheikh. *"Safety assessment of molten salt reactors in comparison with light water reactors."* Journal of Radiation Research and Applied Sciences. Volume 6, Issue 2. October, 2013, Pages 63-70. ISSN 1687-8507. https://doi.org/10.1016/j.jrras.2013.10.008.

[22] Multistage Flash is used in ~26% of desalinated water systems, second only to reverse osmosis due to energy cost. https://en.wikipedia.org/wiki/Multi-stage_flash_distillation

[23] At 141.86 Megajoules per Kilogram (Higher Heating Value), Hydrogen has the highest specific energy of any practical chemical fuel. Energy Density Table (Chemical Reactions). https://en.wikipedia.org/wiki/Energy_density

[24] Hydrogen combustion or use in fuel cells does not emit carbon. https://en.wikipedia.org/wiki/Hydrogen_fuel

[25] Most hydrogen today is produced by steam methane reforming of fossilized gas. https://en.wikipedia.org/wiki/Hydrogen_fuel / https://en.wikipedia.org/wiki/Steam_reforming#SMR

[26] Electric Vehicles have been commercially available since the late 2000's and market share has increased significantly over time. The same is true of electric aircraft (eVTOL), of which several startups have manufactured commercial models (such as the eHang 216 - https://www.ehang.com/news/774.html)

[27] "Next Generation Transportation" in this context refers to currently in-development projects such as the Hyperloop, Reaction Engine's SABRE, and Boeing's latest iteration of a man-piloted hypersonic aircraft. The following sources are for general background reading:
https://virginhyperloop.com/
https://www.reactionengines.co.uk/beyond-possible/sabre
https://www.wired.com/story/boeing-hypersonic-mach-5-jet-concept/

[28] International Energy Agency. *"Direct Air Capture – more efforts needed."* November, 2021. https://www.iea.org/reports/direct-air-capture

[29] Carbon Engineering technical detail on diverting captured carbon to make specialized low-carbon fuels. https://carbonengineering.com/our-technology/

For academic source: Noah McQueen et al 2021 Prog. Energy 3 032001. *"A review of direct air capture (DAC): scaling up commercial technologies and innovating for the future."* 16 April, 2021. https://iopscience.iop.org/article/10.1088/2516-1083/abf1ce

[30] Scientific American. *"The Discovery of Global Warming."* S. Weart. 17 August, 2012. https://www.scientificamerican.com/article/discovery-of-global-warming/

[31] U.S. Department of Energy. National Energy Technology Laboratory (NETL). *"Plasma Gasification."* No author or date provided. https://netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/westinghouse

[32] Background reading on synthetic hydrocarbons / synthetic fuels. https://en.wikipedia.org/wiki/Synthetic_fuel
Specific reading on hydrogenation: https://en.wikipedia.org/wiki/Synthetic_fuel#Hydrogenation_processes

[33] A. Sanlisoy, M.O. Carpinlioglu. *"A review on plasma gasification for solid waste disposal."* International Journal of Hydrogen Energy. Volume 42, Issue 2, 2017. Pages 1361-1365. ISSN 0360-3199. https://doi.org/10.1016/j.ijhydene.2016.06.008.

Background reading on Plasma Gasification: https://en.wikipedia.org/wiki/Plasma_gasification
[34] Power Technology Magazine. *"Vogtle Electric Generating Plant, Burke County, Georgia."* No author or date provided. https://www.power-technology.com/projects/vogtle-electric-generating-plant-georgia/

Georgia Power. Plate Vogtle 3 and 4: Project Update. https://www.georgiapower.com/company/plant-vogtle.html

[35] Power Technology Magazine. *"Vogtle Electric Generating Plant, Burke County, Georgia."* No author or date provided. https://www.power-technology.com/projects/vogtle-electric-generating-plant-georgia/

Georgia Power. Plate Vogtle 3 and 4: Project Update. https://www.georgiapower.com/company/plant-vogtle.html

[36] The USS Guardfish suffered a coolant leak in 1973 due to human error. No other accident from U.S.N reactors have occurred to public knowledge. https://en.wikipedia.org/wiki/USS_Guardfish_(SSN-612)#1973_Reactor_Accident

[37] Commercial jets travel between 460-575mph at 36,000 feet. Flight Deck Friend. *"How fast to passenger jets fly?"* https://www.flightdeckfriend.com/ask-a-pilot/how-fast-do-commercial-aeroplanes-fly

[38] The Post and Courier. "Pace of 787 Dreamliner production quickens and Boeing's North Charlson campus." D. Wren. 1 April, 2018. https://www.postandcourier.com/business/pace-of-dreamliner-production-quickens-at-boeing-s-north-charleston/article_02b584ea-3384-11e8-a3d4-ff9ca36dc590.html

[39] According to Budweiser and several sources, it takes Anheuser-Busch approximately 30 days to brew a bottle of beer. https://www.cnbc.com/2008/07/02/Brewing-the-King-of-Beers.html /

[40] National Geographic. *"Great Pacific Garbage Patch."* https://education.nationalgeographic.org/resource/great-pacific-garbage-patch

NOAA. *"Garbage Patches: How Gyres Take Our Trash Out To Sea."* https://oceanservice.noaa.gov/podcast/mar18/nop14-ocean-garbage-patches.html

[41] Walton, Rod (9 August 2018). *"Vogtle Cost Upgrade Causes Rethinking of $25B Nuclear Plant's Future."* Power Engineering. Retrieved 16 August 2018. $25B for a 2300 MW reactor arrives at ~10.89MM per megawatt. Additional background reading here: https://en.wikipedia.org/wiki/Vogtle_Electric_Generating_Plant

[42] According to NuScale power, an SMR has an overnight cost of $3.6MM per megawatt of generating capacity. NuScale Power. *"NuScale's Affordable SMR Technology for All."* *https://www.nuscalepower.com/newsletter/nucleus-spring-2020/featured-topic-cost-competitive*

This is within range of the University of Chicago's EPIC (Energy Policy Institute at Chicago)'s paper "*Small Modular Reactors – Key to Future Nuclear Power Generation in the U.S.*", R. Rosner, S. Goldberg, November 2011 (P.9), which was an addendum to the University of Chicago's *Economic Future Of Nuclear Power* report, 2004, which estimated SMR technology to be significantly lower, some 2,000/MW.

[43] Background reading on the nuclear power debate. https://en.wikipedia.org/wiki/Nuclear_power_debate

[44] Contemporary media has significant volumes of dis/misinformation in criticism of nuclear power, specifically that it is dangerous, that radioactive waste is pervasive and/or unmanageable, and nuclear power inherently carries a proliferation risk.

Nuclear Energy Agency. *"Addressing the challenges of misinformation."* No date or author provided. https://www.oecd-nea.org/jcms/pl_58232/addressing-the-challenges-of-misinformation

Forbes magazine. "*Natural goas industry blasts nuclear power with fake news."* J. Conca. 15 June, 2017. https://www.forbes.com/sites/jamesconca/2017/06/15/natural-gas-industry-blasts-nuclear-power-with-fake-news/?sh=62bebe7f133b

See also: https://en.wikipedia.org/wiki/Anti-nuclear_movement

[45] U.S. Environmental Protection Agency. *"EPA Releases Briefing Paper on Renewable Energy Waste Management."* 6 January, 2021. https://www.epa.gov/newsreleases/epa-releases-briefing-paper-renewable-energy-waste-management

[46] U.S. Department of Energy. "Quadrennial Technology Review." Table 10.4: Range of materials requirements (fuel excluded) for various electricity generation technologies." September, 2015. Hosted directly: https://nextgiantleap.org/sites/default/files/source_files/quadrennial-technology-review-2015.pdf

[47] ARS Technica. *"Are we ready to recycle the 'rare earths' behind an energy revolution?"* S. Johnson. 21 July, 2020. https://arstechnica.com/science/2020/07/are-we-ready-to-recycle-the-rare-earths-behind-an-energy-revolution/

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[49] Nature Journal. (Editorial). *"Lithium-ion batteries need to be greener and more ethical."* 29 June, 2021. *doi: https://doi.org/10.1038/d41586-021-01735-z*

Forbes Magazine. "If Solar Panels Are So Clean, Why Do They Produce So Much Toxic Waste?" M. Shellenberger, contributor. 23 May, 2018. https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#175aff0e121c

The Verge Magazine. *"More solar panels mean more waste and there's no easy solution."* A. Chen. 25 October, 2018. https://www.theverge.com/2018/10/25/18018820/solar-panel-waste-chemicals-energy-environment-recycling

[50] Council on Foreign Relations. *"Why Cobalt Mining in the DRC Needs Urgent Attention."* J. Campbell. 29 October, 2020. https://www.cfr.org/blog/why-cobalt-mining-drc-needs-urgent-attention

New Yorker Magazine. *"The Dark Side of Congo's Cobalt Rush."* Reporter at Large. 31 May, 2021. https://www.newyorker.com/magazine/2021/05/31/the-dark-side-of-congos-cobalt-rush

[51] Massachusetts Institute of Technology. *"The Future of Strategic Natural Resources – Environmental Risks of Mining."* No date or author provided. https://web.mit.edu/12.000/www/m2016/finalwebsite/problems/mining.html

Smithsonian Magazine. *"The Environmental Disaster that is the Gold Industry."* A. Bland. 14 February 2014. https://www.smithsonianmag.com/science-nature/environmental-disaster-gold-industry-180949762/

[52] As of late 2020, 29% of global electricity generation is renewable – most of it from hydropower (16.8%), leaving 12% of global electricity generation through solar + wind. If we were to leverage renewables exclusively, we would therefore need to scale renewable manufacturing and deployment by 8.3x.

Data sourced from: Center for Climate and Energy Solutions. *"Technology Solutions – Renewable Energy."* https://www.c2es.org/content/renewable-energy/

[53] Wind turbines have a lifetime of 20 years, as per U.S. Environmental Protection Agency *"Renewable Energy Fact Sheet: Wind Turbines."* (August, 2013).

Most commercially available solar panels have a lifetime of 25-30 years. GreenBiz "*What will happen to solar panels after their useful lives are over?"* N. Berg, 11 May, 2018. https://www.greenbiz.com/article/what-will-happen-solar-panels-after-their-useful-lives-are-over

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However, successfully making a militarily deployable weapon from neptunium-237 or uranium-233 is significantly more difficult. This is due in part to their rare use in tests (where performance was considered sub-optimal), but more because both isotopes have significantly higher radioactive emissions. See: *"Neptunium 237 and Americium: World Inventories and Proliferation Concerns."* D. Albright and K. Kramer. July 10, 2005. http://isis-online.org/uploads/isis-reports/documents/np_237_and_americium.pdf#p14

The critical mass required to use either isotope in a device would quickly be lethal to humans, thus requiring nigh-exclusive use of remote/robotic equipment in most steps of assembly. The heightened radiation would also degrade the sensitive electronics necessary for precise detonation, forcing use of krytron tubes for implosion switches – which in addition to being highly controlled, would preclude miniaturization to warhead-size. In the case of uranium-233 (the superior of the two isotopes), its heightened radioactivity comes from a naturally occurring presence of uranium-232 – a strong gamma emitter. It has been theorized this U232 could be chemically removed, but beyond being an difficult process achievable only by state-level science programs, the level of purity necessary is extremely high. Even a 5PPM presence of uranium-232 within uranium-233 is hazardous. In general, most molten salt reactors carry a uranium-232 presence of ~220PPM.

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In this context, it's important to note that uranium-235 (standard weapons grade isotope) can be sourced from seawater, presenting a far easier pathway to access than weaponizing the thorium fuel cycle. (https://www.forbes.com/sites/jamesconca/2016/07/01/uranium-seawater-extraction-makes-nuclear-power-completely-renewable/). Simply stated: if a state-level entity has the capability to weaponize thorium, they could already have done so with easier methods at greater effect.

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