Why Nature-Based Solutions Matter for Texas and the World: Adopting Earth Rules for the Future!

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Artemis II brought attention back to the Earth from the moon, just as was the case with the Apollo spaceflight. What a beautiful sight – the blue planet rising over the moon – both in 1968 and again in 2026.

Figure 1. The Earth rising across the moon surface. Image from NASA Artemis II.

The French philosopher Rene' Descartes became famous for his phrase "I think, therefore I am." But I am mystified why no one has ever become well known for saying "The Earth is, therefore, I am." That is a true statement. Without the Earth we would not be. Yet we just don't seem to get this critical fact of our existence.

The Earth is and therefore we are. Nothing could be simpler, yet it seems at times to be incredibly complex and complicated.

"The Earth is, therefore, we are" is absolutely critical to the future of humans. We live on Earth but are out of touch with it. Consider the concept of economy. The human economy can be defined as "the production, distribution, and consumption of goods and services by rules developed in the last few centuries". The Earth also has an economy – it produces, distributes and consumes goods and services as well through the functioning of its ecological systems. However, the Earth's economy has been functioning for eons rather than just a couple of centuries.

The Earth's economy has the gravitas of eons of success when compared to our infant economy that has only been around for a relatively few centuries. And at its core are a set of principles that are referred to as Earth Rules in this paper.

Today, our human economy is at odds with Earth systems. We are changing the atmosphere with increasing levels of carbon dioxide. We are disrupting the carbon cycle and increasing the heat of the planet. We are changing the hydrologic cycle by worsening droughts and flooding. And we are destroying biological diversity in many if not all portions of the Earth. In short, our economy seems to be working against the Earth – that same Earth that is responsible for our being – our existence.

Humans have been moving away from the Earth's economy for most of human existence. In many respects, human progress was defined by and continues to be defined by our departure from nature – our independence from nature – our ability to transcend nature – our ability to ignore Earth Rules. However, we have really never been transcendent but merely dominant in ways that now threaten our future and the Earth's. And by the way, the days of fixing environmental problems at the "end of the pipe" are over.

It is worth asking "why our economy works against the Earth?" and "must it be that way?" And the answer is that it does not have to be that way, cannot remain that way, and ultimately must transition to a system that mimics nature. In order to achieve this transition, all tools must be focused on

understanding the Earth and bending and shaping our economic system to Earth rules.

Earth Rules

At this point, it is worth exploring Earth Rules. What are these Earth Rules? And why are they important to our future? And at the same time, let's explore how we might come into conformance with them.

Stated simply, Earth rules are physical truths about the operation of the Earth – the processes by which life on Earth is maintained. Earth Rules are developed by science and can be documented and described by metrics. And at their core, they will guide the changes that must occur within the human economy over the next several decades. Indeed, this transition will be the crowning achievement of the 21st Century.

A simple Earth Rule (and perhaps universe rule) is gravity. Gravity is simply a fact of existence here on Earth. If the pomegranate falls from the tree, it will go down toward the Earth rather than up and away from it. It is a fundamental truth of the operation of the Earth. Here at the surface of the Earth, gravity exists. It is real. It moves objects from the air toward the center of the Earth where the object encounters the Earth's surface. Nothing particularly hard about it and as far as I know, no one disputes that gravity is an Earth rule.

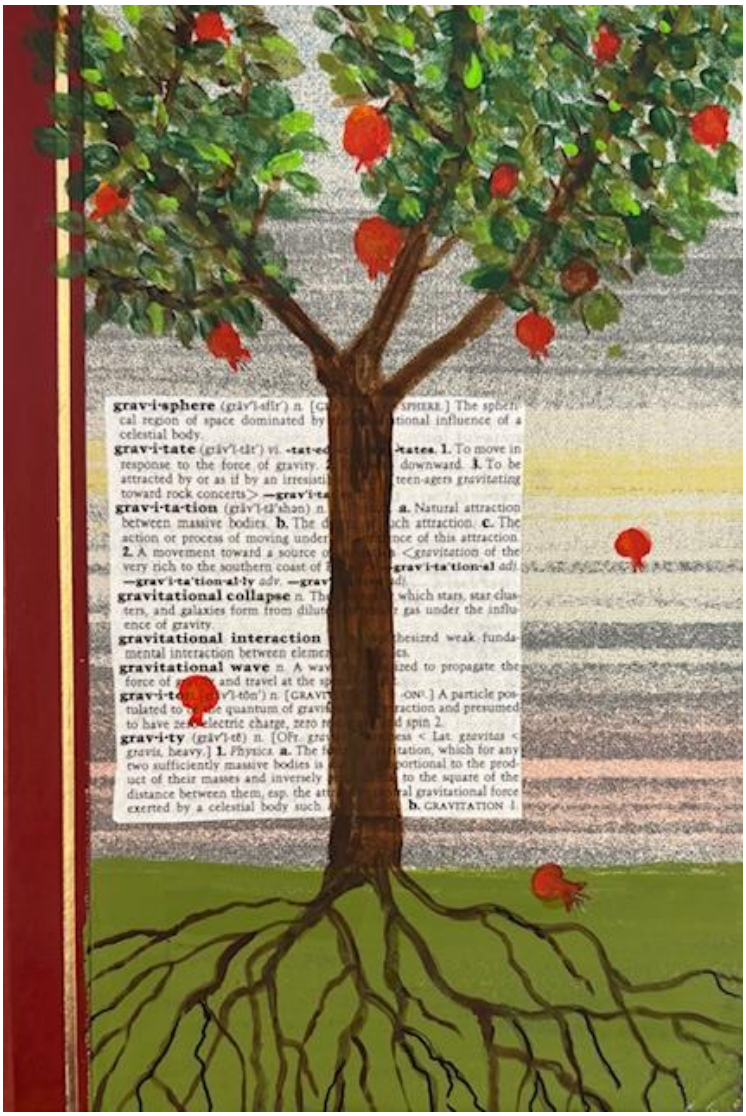

Figure 2. Illustration of gravity with the pomegranate tree as an example. Art by Isabelle Scurry Chapman.

And to be sure, there are many other Earth Rules such as the first and second laws of thermodynamics and many other concepts that are currently under development such as quantum mechanics and string theory. We have a way to go yet in fully understanding these physical boundaries, but they are real.

There are also physical rules as to how the Earth's living systems operate. These are ecological rules – rules by which life on Earth is governed. These are the rules that we respect the least yet may be of utmost importance. "The Earth is, therefore, we are" has no meaning if we destroy the life support

systems of the Earth. At least for human existence and the existence of many of the birds and plants and other organisms, these rules require conformity when the impacts of humans reach a certain scale – a scale we have reached and exceeded.

So what are these rules? Rule 1 is that there is no waste in the ecological structure of the Earth. Generally speaking, the production of vegetation becomes food for other organisms. These organisms consume resources and either expel excess as waste or eventually die and become waste themselves. However, this organic waste becomes food for other organisms until ultimately the waste becomes carbon dioxide and is returned to the atmosphere where it is cycled through photosynthesis into vegetative plant material and the cycle repeats again and again and again. All waste is used by others.

In addition to no waste, a guiding rule of the Earth is that there is a carbon cycle that takes carbon dioxide out of the atmosphere and creates biomass through photosynthesis and sends sugars into the microbial community of the subsurface. And although some carbon is retained in the soil over time, carbon dioxide also is returned from the soil to the atmosphere as well as from decomposition of organic material at the Earth's surface. The current problem related to climate impacts is that the amount of carbon dioxide being returned to the atmosphere is far exceeding the ability of the natural system to remove it as exhibited in the rise of carbon dioxide concentration in the atmosphere from about 320 ppm in 1960 to about 430 ppm by early 2026.

In this manner, our carbon cycle has become unbalanced. We have built up carbon levels in the atmosphere far beyond the norm that had existed for the last 800,000 years. This buildup of carbon dioxide is changing the temperature of the Earth to the point that human settlement patterns and human lives are threatened by this changing climate. According to the Intergovernmental Panel on Climate Change, unless our economy transitions to net zero carbon dioxide emissions by 2050, we will significantly exceed the

goal set out in the Paris Accords of keeping our rise in global temperatures to less than 2 degrees Centigrade.

This is not a fire drill. This is a bona fide emergency although we often do not appear to be responding as if it were one. We must act now to set in motion the changes to our economic system that will restore the balance in our carbon cycle. We must restore Earth order by understanding and conforming our behavior to Earth rules.

We all must recognize that restructuring our human economy is no small or easy feat. It will take time to implement incremental changes that will take us to 2050 and beyond. Damage will occur in the future as we make this transition but transition we must.

And there is at least one more Earth Rule of note and that is that we have a hydrologic cycle that also must be maintained. Water is evaporated from the Atlantic, the Pacific and the Gulf and comes inland where it falls as rain. Rain percolates into the soil, moves downward into underground aquifers and runs off into streams and rivers. Water then flows by force of gravity back toward the oceans where it returns and repeats the pattern. Along the way, water is added from springs, taken away by users, returned and reused all the way down to the sea.

The hydrologic cycle is another cycle that has been substantially disrupted by the human economy. We have both increased the extent of flooding rainfall and increased the frequency of droughts through climate change. We have over pumped groundwater and decreased spring flow if not dried up our springs and groundwater sources. We have diverted excellent quality water and returned contaminated water. We have decreased river flow and lowered inflows to the coast where freshwater creates the ecological systems known as estuaries which are the nurseries for much of our fish and shellfish.

Additionally, there are other cycles that have been disrupted. Nitrogen is recycled, yet our use of nitrogen fertilizer has unbalanced our nitrogen cycle. In this manner, groundwater has become contaminated with nitrates and algal blooms frequently occur at the outlets of major rivers. Additionally, the

greenhouse gas nitrous oxide has been released at increased volumes over the planet. And similar disruptions occur with the phosphorus cycle.

The bottom line is that our economic system is out of sync with the cycles that form the core of life on Earth – the rules by which the Earth functions. The mandate for the rest of the 21st Century will be to bring the human economy back into sync with Earth Rules.

The Tools For Implementing Earth Rules

As a general proposition, we must redesign our economy to come into compliance with Earth rules. By necessity, these steps to compliance with Earth Rules will require incorporation of key aspects of the Earth's economy within the human economy.

As such, we will rely upon a well-known design process called biomimicry as we move forward. Humans often have taken ideas from the natural world. As shown in Figure 3, there is the bill of the kingfisher that is used for fast train engine design, the feet of the gecko for adhesive design and the fin of the whale for wind turbine design. And in this case, we are mimicking the functional aspects of the Earth in our economic system.

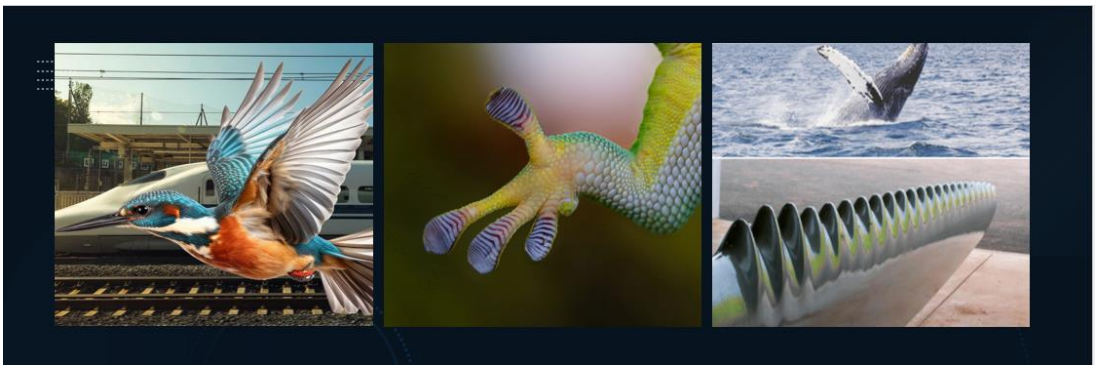

Figure 3. Examples of biomimicry showing the bill of the kingfisher used for design of the engine of ultra-fast trains, the foot of the gecko used to design adhesives and the fine of the whale used to design wind turbine blades. Image from Jim Blackburn collection.

Restoring the Carbon Cycle

One example of the changes to come is to expedite the transition from carbon dioxide emission to carbon dioxide removal by increasing the amount of global vegetative coverage. There is no better technology for carbon dioxide removal from the atmosphere than photosynthesis. It outperforms human technology at the part per million concentrations of the atmosphere. There is certainly a role for technology in this transition, but it is mainly at the end of the manufacturing stack where concentrations are higher. In the case of removal of carbon dioxide from the atmosphere, which must happen, the key will be to increase the coverage of native grasslands, forests and coastal blue carbon ecosystems that pull down and store carbon dioxide in the soil and woody plant material.

To this end, the nature-based carbon credit market will provide an excellent partnership with efforts to avoid carbon dioxide emission and to minimize those emissions. For many of our industries, avoidance and minimization – the preferred pathways - will only achieve a certain level of reduction. To obtain that final step to net zero and beyond to net negative, the ecosystems of the world must be enhanced, restored and/or expanded.

Estimates vary on the amount of carbon dioxide that will need to be removed by nature, but it seems reasonable that 10% to 20% of the total carbon dioxide emission reduction will come from nature-based solutions. Given that the global total of carbon dioxide emissions exceed 40 billion tons, at least 4 to 8 billion tons of carbon dioxide will be removed from the atmosphere each year by natural sources. At a removal rate of 2 tons per acre per year, that represents 2 to 4 billion acres, or about 12% to 25% of the almost 16 billion usable acres on the Earth's surface. Such a change would be revolutionary, and that is not all.

This change in land use must work for landowners. While photosynthesis may be a "free good", photosynthesis needs land upon which to grow and function. Most land in Texas is privately owned. If the landowner does not make money from an option, they will turn to another option. So we must pay

the landowners for conforming their land use to the carbon cycle. As can be seen from Figure 4, James Clement, a rancher with lands in South Texas and west Texas, is currently receiving more income from carbon credit transactions than from cattle, and his expectation is that with the increasing price of carbon, the income from carbon will surpass income from hunting. That change will slow the loss of ranch and farmland to other uses.

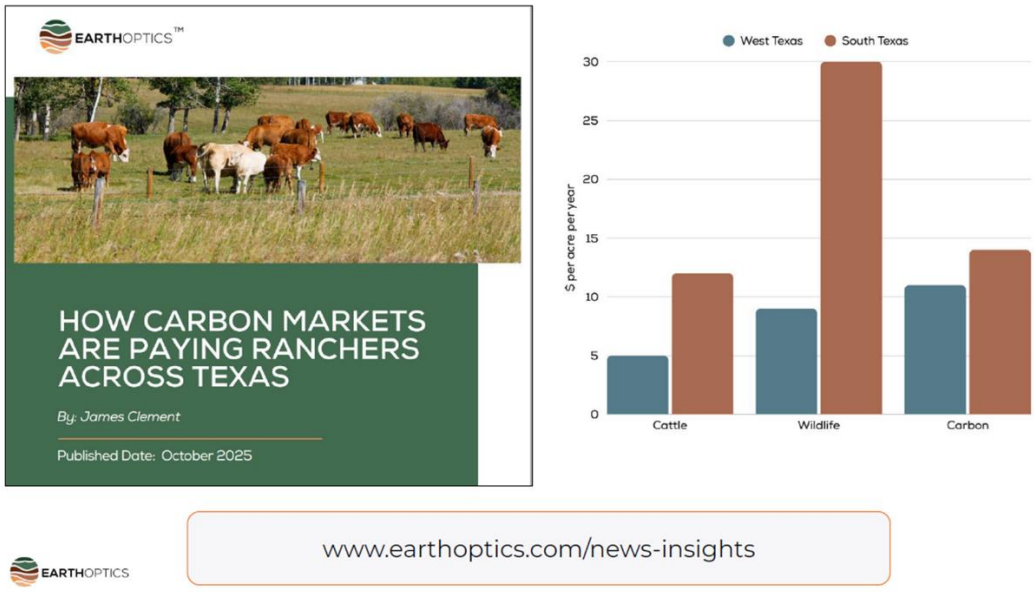

Figure 4. Chart prepared by landowner James Clement of the income from his ranches in West Texas and South Texas showing income from cattle, from hunting and from carbon. Graphic by James Clement.

Such a change also would have tremendous co-benefits. Early work at Rice University indicates that restoring native prairies upstream in the watershed can improve flooding downstream by absorbing more rainfall. At the same time, such absorption can increase springs and seeps, potentially increasing water supply. And from an ecological perspective, biological diversity will greatly increase with the restoration of native prairies, forests and coastal wetlands and sea grass meadows. But that is still not all.

Restoring the Hydrologic Cycle

In addition to restoring the carbon cycle, the move to mimic natural systems and follow Earth Rules requires the restoration of the hydrologic cycle. By keeping the temperature increase at less than 2 degrees Centigrade, we will begin to stabilize our changing rainfall patterns although a significant further drawdown of carbon dioxide will be required to restore norms established over the last several hundred thousand years.

Additionally, we have made significant modifications to the hydrologic cycle of almost every river system in the world. That statement is certainly true in Texas where an archaic system of water rights and water use has led to the overallocation of water use on every river in the state. And perhaps more importantly, our management systems and current understandings of that water use are not great.

To this end, the first step to restoring the hydrologic cycle is to create water intelligence systems throughout Texas and the world to better understand the current problems and manage the restoration of these systems. Such a water intelligence system is currently under development by EnviroAI and the authors and is called the Watershed Intelligence Engine or WIE.

As shown in Figure 5, the WIE has real time inputs, ongoing computations and real time outputs that are designed to better manage water within Texas river systems. Among the inputs are rainfall and soil moisture data from the SMAP satellite system, spring flow information, water allocation and withdrawals, water use and return flows, stream ecology and coastal ecology. Within the engine, various programs will generate regulatory compliance analyses, physical modeling result and data fusion aspects. From these computations will come three outputs – the current state of the watershed in real time, an analysis of water use and desired outcomes and forecasting and alerts regarding upcoming problems. At this time, no such tool exists for us on Texas watersheds.

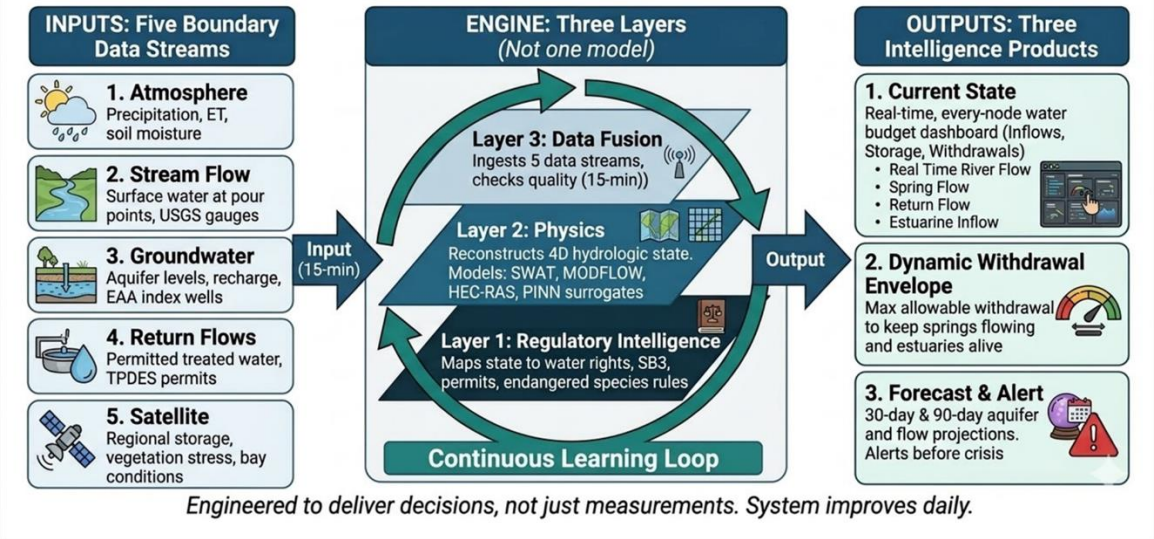

Figure 5. The concept of the Watershed Intelligence Engine (WIE) – currently under development by EnviroAI and the authors. Image from EnviroAI.

At this time, the Watershed Intelligence Engine is under construction for at least two watersheds in Texas. It must be emphasized that the WIE is a work in progress and must be verified and validated. Although this tool has great promise, expectations need to be tempered until errors can be identified and corrected (and there will be some). We do not want to overpromise to ensure that expectations can be met by reality.

Rediscovering the Circular Economy of the Earth

There is also a third level of analytics based on Earth Rules arising from the more general circular structure of the Earth's economy which essentially creates no waste. To be sure, various industries have discussed if not acted upon creation of circularity regarding product recycle and reuse, particularly in the plastics industry, but there is a far larger societal issue here, and that is the fact that our economy is linear at almost all levels.

Today, disposal is the norm. Consider municipal garbage. Organic waste (food and yard trimmings) makes up 29%, paper products make up 27%, plastics 13%, metals 9%, rubber, leather and textiles 9%, wood 6%, glass 5% and other waste products 3%. In the future, this waste will be brought to a central processing facility where separation occurs and recovered items

become the feedstock for new item construction, representing reductions of carbon and water footprints for new items not to mention the recovered materials themselves.

Here, the scale of impact is hard to understand. Each year, the United States produces almost 300 million tons of solid waste. Of this, paper products represent 81 million tons, plastic waste represents 39 million tons and metal products represent 27 million tons thrown away each year. These items represent energy and carbon investments, water investments and raw material investments. And if they were to be recycled and reused, massive amounts of resources currently being "lost" could continue to be used instead of extracting and using more water, more petroleum and more raw materials as well as emitting more carbon dioxide.

The most ambitious recycling concept I have encountered is the Eco-Hub proposal developed by George Gitschel, a Houston-based inventor and entrepreneur. Eco-Hub will take in commingled municipal waste and separate the organics from paper, metals, plastics and other materials which will also be sorted. In the newest concept to emerge from George, he has created a concept to link a data center and power plant with the Eco-Hub and have this work together to create a net zero carbon emissions data center that uses water reclaimed from the waste processing as well as from nearby wastewater generators. This combined version is called the EcoData™ Center and is shown in Figure 6. This data center will be 100% off grid for electricity and potentially for water as well.

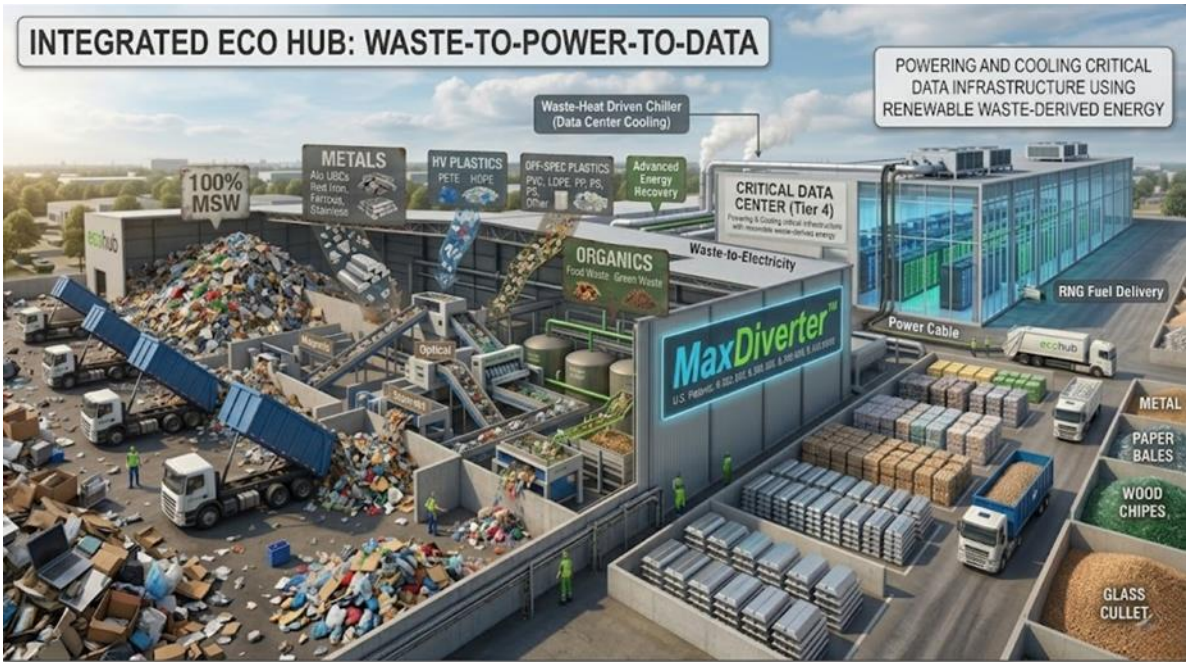

Figure 6. Integrated Eco-Hub waste to power to data center. Image from EnviroAI.

Additionally, at this time, a Material Intelligence Engine is also under design and construction by EnviroAI and the authors. This Material Intelligence Engine will quantify the life cycle impacts of new products and will compare that footprint with the footprint of recycled and reused materials. In this way, the difference between the current linear economy and an economy in sync with the Earth's economy can be directly compared and environmental attribute credits will be issued associated with the life cycle savings associated with the various products. Indeed, metrics will be the key to all of these changes that are forthcoming. And once these metrics are understood, the savings associated with these reused products as well as the dollar value of the reclaimed resources and avoided emissions can help fund the transition to the economy of the future.

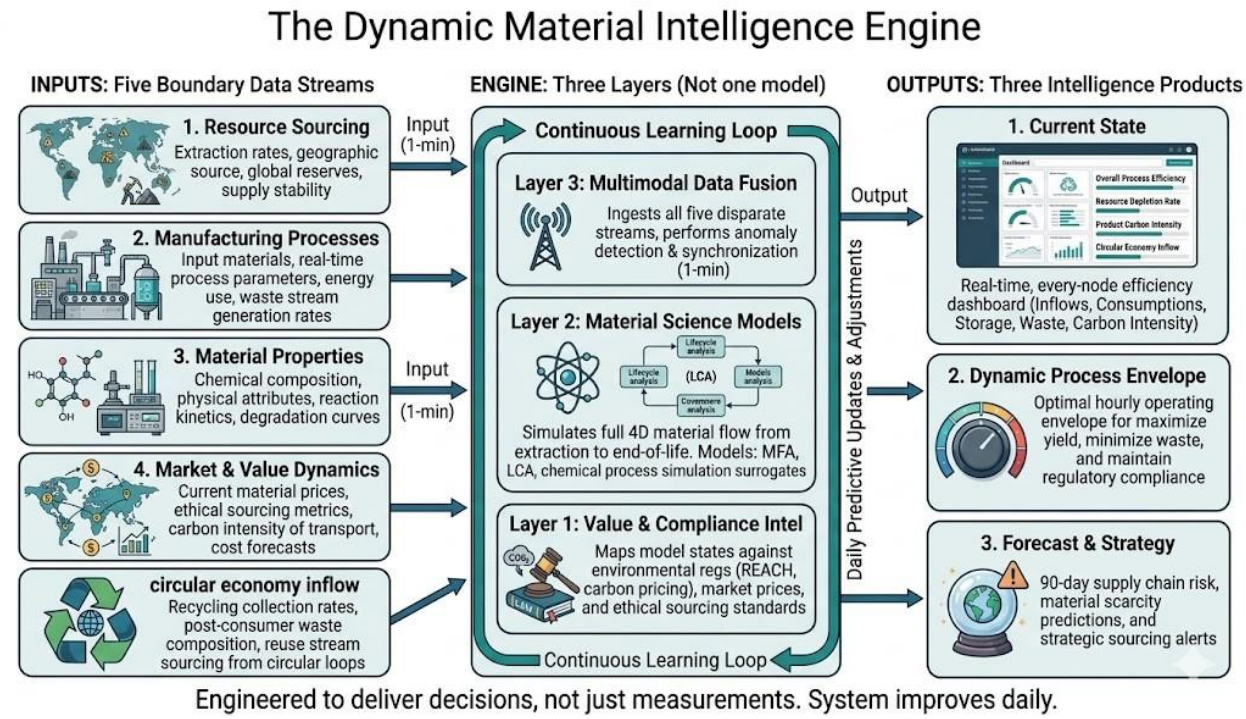

Figure 7. Diagrammatic representation of a dynamic Material Intelligence Engine. Image from EnviroAI.

The Power of Information

In considering this return to and rediscovery of nature, it is important to understand that the legal system is not leading this effort. Indeed, it has been 36 years since the passage of the 1990 Clean Air Act Amendments, the last major environmental statute enacted by the United States Congress. Yet since that time, there has been tremendous change in corporate policies, particularly since 2000 relative to sustainable development and since 2016 relative to climate change.

These changes in policies around sustainability and climate were not caused by legal requirements at the U.S. level nor at the global level. Instead, we would argue that the wide availability of high-quality information and the

realization that profitability may follow the use of this information have been the key elements for the transformative policy change that has occurred so far in the 21st century. And with the coming of AI technologies, that reality will only become increasingly evident and widespread.

Indeed, at least one company, EnviroAI, has compared the pathway to the environmental superintelligence of the future to climbing Mt. Everest. There are base camps now being established – camps like automated air permitting and the water and waste intelligence engines. What can be clearly seen here is that the future will include massive amounts of information – information about Earth systems and their conditions – information about industry and governmental compliance with Earth rules. It is arguable that the legal system will become less important relative to environmental policy and that the role of information will become the primary consideration in policymaking going forward.

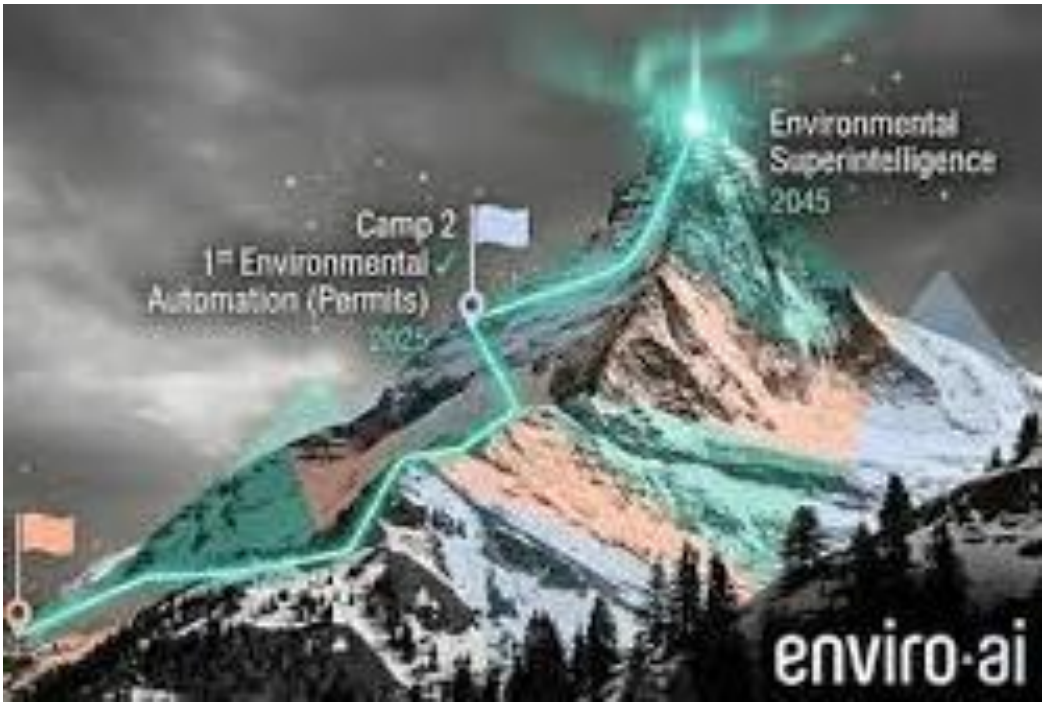

Figure 7. The environmental superintelligence summit. Image by EnviroAI.

Conclusion

Earth rules are real. They allow the Earth to support life. To date, humans have existed without reference to Earth Rules because they could exist outside of these rules without serious consequences. However, with the life support systems of the Earth beginning to fail, Earth Rules are now being recognized and will become the basis for future decision-making based upon excellent, up to date information.

Arguably, the legal system is experiencing an evolution of its own. Rather than relying on iteration upon iteration of human mandates, we are moving back to recognizing legal concepts that are fundamental, core principles. And nothing could be more fundamental than Earth Rules – the rules for keeping our planet amenable to humans and other living things.

As corporations adapt to the realities of the 21st century, more will adopt Earth rules as operating principles. Already corporations are adopting positions on restoring the carbon cycle and adopting the circular economy. And there are also corporations that have pledged to become water positive, providing more water to the system than they have withdrawn and used. But these are only the early signs of a long-term, massive transition to compliance with Earth Rules.

So have no doubt about it. Nature-based solutions will become the dominant concept of the 21st century in Texas and in the world, both by direct use of natural systems and by humans mimicking natural systems. The transition back to nature has only just begun, and we will all benefit from it.