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Sustainability & Technology

Building Innovative Solutions

Deishin Lee
Guest Editor

Cutter Business Technology Journal

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Opening Statement

by Deishin Lee, Guest Editor

> Technology is, of course, a double-edged sword. Fire can cook our food but also burn us.
>
> — Jason Silva

We all know that technology has improved many aspects of our lives; drones help farmers grow crops more efficiently, medical devices save lives, and information technology allows us to stay connected to loved ones during a global pandemic. In fact, when faced with grand challenges, we often look to technology for a solution. Some would argue that the grand challenge of our time is learning to live sustainably within the carrying capacity of the Earth. And indeed, technology — artificial intelligence (AI) and machine learning (ML), in particular — shows enormous promise in tackling the complexity inherent in sustainability problems.

One way technology can help us move toward a sustainable future is through improving the efficiency of existing processes. For example, consider the problem of managing traffic flow to reduce congestion, and hence fuel consumption and emissions. A problem like this requires a detailed model of the process (roads, traffic lights), real-time monitoring of traffic and road conditions using sensors and cameras, and sophisticated algorithms that use data to predict traffic density in the near future and change traffic lights accordingly. Today, we are at a stage of technological development where the modeling, monitoring, and optimization required for managing traffic flow and many other applications (e.g., precision agriculture, supply chain logistics, warehouse operations) are all ready for prime-time, full-scale deployment.

Technology can also enable new business models that use resources more efficiently. Often, resources are wasted when there is a mismatch in demand and supply; we can't get the right product or service to the right person at the right place at the right time. Coordination is particularly difficult in settings where timing is critical. Technology-enabled platforms, however, can solve this coordination problem. Ride-sharing platforms like Lyft and Uber match people seeking rides with people who can give rides, using the real-time location services and transparency provided by smartphone technology. Similarly, platforms for material exchanges can match buyers with sellers of excess inventory that would otherwise go to landfills. These materials could be anything from food (e.g., Spoiler Alert) to construction material (e.g., Loop Rocks). In contrast to typical supply chain relationships where buyers and sellers are in the same industry, these platforms can foster cross-industry partnerships that find innovative uses for excess inventory.

One way technology can help us move toward a sustainable future is through improving the efficiency of existing processes.

However, we all know that there is no free lunch. In the process of enabling new business models (sustainable or not) and making existing processes more efficient, technology leaves its own environmental footprint — and this can be significant. Making sensors, devices, servers, and supporting digital infrastructure requires raw material extraction, manufacturing, distribution, and installation. During the usage phase of its lifecycle, technology requires an energy source. The more complex the problem, the higher the processing power, the more data, and the higher the energy consumption of AI and ML solutions. Finally, at the end of life, electronic devices are arguably even more environmentally harmful, often ending up in landfills, resulting in an environmental double whammy: valuable material that could be recycled is wasted and becomes a pollutant.

In This Issue

The challenge is how to leverage technology to move us toward a more sustainable future, while mitigating its own impact. This issue of *Cutter Business Technology Journal* (*CBTJ*) explores the dual sides of the technology sword — the potential for environmental benefit and harm — and, in true karmic spirit, how technology can help itself be more sustainable.

> *It's inspiring to learn how FAO has co-evolved its organizational processes with technological advances to better serve its humanitarian mandate.*

In our first article, returning *CBTJ* contributor Jacek Chmiel draws attention to the increasing energy consumption by the electronic devices integrated into our daily lives. In addition to the ubiquitous mobile devices we all carry around, there are billions of devices (employing the Internet of Things and the Internet of Everything), not to mention back-end servers, all of which consume energy. Exacerbating this problem are ML and distributed ledger technologies (DLTs), such as blockchain, that require intensive computing cycles, and use even more energy. The good news is that a greener software development strategy can have significant impact on energy usage of electronic devices. Chmiel explains the challenges to implementing this strategy and how organizations can overcome them.

Next, Rohit Nishant and Thompson S.H. Teo further explore the environmental impact of AI and ML.

Upcoming Topics

Sustainability & Technology II
Deishin Lee

Cyber Attacks & Strategies That Matter
Anjali Kaushik

Specifically, the applications where these technologies add the most value are those that require heterogenous data in complex settings (e.g., optimizing smart cities, modeling climate change). In the process of creating value, these large AI and ML models require energy-intensive computing, leaving a huge carbon footprint. To counteract these concerns, Nishant and Teo offer the "Align, Reduce, Measure" (ARM) framework for mitigating the environmental impact of AI and ML algorithms. The framework encompasses the organizational structure, addresses data heterogeneity, and measures results to create accountability.

Our third article goes beyond mitigating negative environmental impacts. Simon Schillebeeckx proposes a focus on regeneration as a way for small carbon footprint firms (e.g., consulting, financial services firms) to make a positive sustainability impact. As Schillebeeckx highlights, service industry firms can proactively contribute to the regeneration of common pool resources, such as forests and lakes, which often become neglected or overused due to the "Tragedy of the Commons"[1] effect. What makes regeneration different compared to more traditional donations to a conservation nonprofit like the World Wildlife Fund is the use of digital technology that enables an organization to lay claim to the ecosystem benefits it generates through its support. The digitization of benefits claims provides a transparent accounting system for environmental benefits, so to speak. Schillebeeckx explains how transparency and accountability can lay the foundation for firms to work together to preserve and restore common pool resources.

Next, we hear directly from a global humanitarian organization on how it is using technology to increase its social impact. Cutter Consortium conducted an interview with Dejan Jakovljevic, CIO and Director of the Digitalization and Informatics Division of the United Nations (UN) Food and Agriculture Organization (FAO), on how FAO uses technology to reduce world hunger. Jakovljevic tells us how FAO has embraced digital technologies to not only improve its own internal processes but also to develop tools for its members. He explains how FAO transformed from a traditional sequential project management process to a nimble, risk-taking process better suited to addressing the needs of our rapidly changing world. As an example, Jakovljevic highlights how FAO's digital capabilities enable the organization to adapt quickly to real-time data with cross-disciplinary "tiger teams." The organization has also invested in cutting-edge technologies, such as its geospatial platform, Hand-in-Hand. It's inspiring to learn how FAO has co-evolved its organizational processes with technological advances to better serve its humanitarian mandate.

Finally, Cutter Consortium Senior Consultant Curt Hall presents intriguing examples of how corporations and governments use AI and compatible technologies to move us toward a more sustainable world. Coming back full circle to Chmiel's piece, Hall explains how many companies are using AI to reduce the energy consumption of … AI(!) and other digital technologies. He illustrates innovative technology-based solutions being developed for tracking carbon emissions and presents a selection of companies targeting key infrastructure areas for carbon reduction initiatives (e.g., data centers, transportation, waste management).

No Silver Bullet

As the breadth of ideas presented in this issue of *CBTJ* suggests, there is no silver bullet when it comes to sustainability. Complex problems call for multifaceted solutions. We are fortunate that both hardware (devices) and software (algorithms) technologies have dramatically improved their capability and flexibility. But we need more. We need scientists, engineers, entrepreneurs, and citizens to bring their different perspectives to bear on the sustainability problem — to creatively apply the power of technology — without burning ourselves on the technological flame.

Reference

[1]Hardin, Garrett. "The Tragedy of the Commons: The Population Problem Has No Technical Solution; It Requires a Fundamental Extension in Morality." *Science*, Vol. 162, No. 3859, 13 December 1968.

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Greener Software Development Strategy:
Why, How, and Why Not?

by Jacek Chmiel

Nowadays, software is everywhere. In fact, technology drives so many aspects of our private and professional lives that it's easy to argue that software is ruling the world.

Considering how omnipresent software is, and how much has changed because of it during the last few decades, it's pretty astonishing that when we hear the term "green computing," we often think of cloud providers running data centers or big tech companies promising carbon neutrality faster than the competition.

However, an often-overlooked aspect in the global discussion about sustainability when it comes to information and communications technology is how software can be created and deployed to mitigate a company's environmental footprint.

For this reason, let's take a look at different aspects of software development and deployment (which, as we all well know, are bound together and should not be disconnected) and see what we can do to create a more positive environmental impact.

Mobile & Web Apps

Power optimizations of computing are as old as computing itself, but here we focus on the enterprise application development perspective. Thus, we begin our discussion with the apps themselves.

Mobile Apps

Mobile developers are familiar with the requirements to design and implement applications that follow best practices for battery savings. Nobody wants their phone's battery life to deteriorate because one particular app is a battery hog. Battery life directly impacts our lives as we grow ever more dependent on mobile technology, especially when we are on the go. The more often we have to charge our phones, the more energy we use, so the benefits of long battery life are mutual for the users and the environment.

We all know the saga of battery life: a battery charged often needs to be replaced by another battery, which is produced using energy, transported using energy, and must be disposed of safely. Or users decide to replace the entire device as a result of deteriorating battery life.

Fortunately, battery life requirements are already part of the policy ecosystem enforced by the likes of Apple and Google on mobile developers. There are strict limits on what mobile apps can do — and how often they are allowed to do it. Developers must follow these requirements or risk their application being rejected from the application store.

On the plus side, mobile users can limit notifications to avoid waking apps on the phone and consuming energy. They can also disable background updates of applications to make mobile apps even more energy-efficient, at the expense of not being constantly updated.

Finally, dark modes for both entire operating systems and applications help save more than half the battery life related to the screen, which is a smartphone's most energy-consuming element. So it's disappointing that we still observe applications that fail to follow system-wide settings and display white screens during use.

Of course, there's still plenty more for designers and developers to improve upon, but enforced requirements and best practices for mobile development are a good starting point. In this case, strict requirements from mobile platform owners perfectly align with customer experience benefits. Unfortunately, this is not always the case. I'll get back to this point later.

Web Apps

Web apps are also mobile apps, but all too often, this fact is ignored by their creators. Even though more than half of users access Web pages from mobile devices, battery optimization is regularly not even in the top 10 priorities when developing Web apps.

And let's not forget that we spend much of our laptop/Mac/PC time using the browser and searching for information, as I did when writing this very article.

Whether or not laptops are connected most of the time to the wall socket, their energy consumption directly relates to CO2 consumption. In the case of mobile use, this translates to the need for extended battery life and longer remote work capabilities, so again, user experience (UX) and environmental friendliness go hand in hand.

Unnecessary animations, smooth transitions, inefficient scripts in JavaScript, and poorly implemented caching all lead to unnecessary CPU and GPU activity and network traffic. This generates several times more energy usage for questionable gains in UX. Fortunately, there are techniques and patterns in place to optimize the energy consumption of Web pages.

For starters, online energy-efficiency assessment tools analyze Web pages, applications, and resources to identify energy-consumption bottlenecks that designers and developers should address. Since it's clear energy consumption can be improved, why isn't it done? Aside from the usual set of excuses (e.g., time, money), energy optimizations can impair UX and may require hard-to-define tradeoffs.

Let's look at the example of a Web page that automatically refreshes certain information; for instance, the result of an ongoing basketball, football, or soccer match. Users would like those refreshes to come as quickly as possible, while the developers wish for them to be as rare as possible, as refreshes consume computing power and bandwidth. (Of course, there are newer techniques such as Web sockets to avoid pooling the information, but let's keep it simple for a moment.) So a tradeoff must occur between frequency of updates and performance, plus costs of Web services.

Beyond that tradeoff, the need to push information to us, the users, is not only bad for our attention spans and our ability to focus on things that matter, it also consumes more energy on our personal devices, network devices, and data centers.

Personally, I predict that when it comes to mobile apps and Web apps, reducing the number and frequency of notifications and eliminating flashy banners, annoying popups, and animations are the way to go both for our sake as users and also for energy consumption.

Unnecessary animations, smooth transitions, inefficient scripts in JavaScript, and poorly implemented caching all lead to unnecessary CPU and GPU activity and network traffic.

Devices, Devices: IoT & IoE

Billions of devices are flooding our world. One particularly negative environmental impact is caused by their short-lived design, questionable quality, and lack of repairability, which generates tons of toxic electronic waste. But let's focus on direct energy consumption and software.

Battery-operated devices are optimized by design because of business requirements. Many devices are supposed to last for months without recharging, or get recharged using tiny solar panels or wind energy. This changes everything when it comes to the software side of things as well. It means more efficient dedicated operating systems, low-level software using efficient languages such as the old but very efficient C, and more energy-efficient protocols (e.g., Zigbee instead of Wi-Fi).

Internet of Things (IoT) experts try to avoid Linux-based devices on common hardware, as they are much less efficient than dedicated devices with lower power consumption. Using more niche technologies, however, translates to difficulty in getting the right people to create those systems and applications. Still, both business and the environment benefit from energy-efficient devices.

Notifications and update frequency also matter, as network communications consume much power. So devices should be programmed to store data locally and only exchange small portions of data as rarely as possible. These are difficult design choices from a software architecture point of view, but fortunately, there's already a relatively long tradition of Internet of Everything (IoE) and good patterns to follow.

Server-Side Architecture

Data centers require lots of hardware and huge facilities with round-the-clock power and cooling to keep a single enterprise running. So let's now take a look at what can be done on the server side.

Moore's Law

In its original form, Moore's law no longer works, despite the common myth that it still does. The speed increase of silicon CPUs has not been doubling every 18 months for a long time. Physics limits the speed of development of faster chips. But there's another version of Moore's law — the green one — which says that the energy efficiency of chips is significantly improving every year.

This is great but cannot replace the efforts of engineers to create more efficient software. The energy-efficiency gains of CPU manufacturers are in the low tens of percent per generation of their chips, while software can be optimized more, and much faster. So while it's nice to have Moore's law for energy efficiency, it's just one component in a green computing effort.

> *The popular cloud-agnostic tradeoff called "cloud-native" is the most popular choice nowadays, yet not the most energy-efficient.*

ARM vs. Intel?

In 2020, we witnessed a revolutionary move from Apple when it ditched Intel CPUs and the x86-64/AMD64 architecture and instead embraced the Apple M1, an ARM-based chip. The M1 is known for its speed, but should be even more famous for its power efficiency, which is sometimes orders of magnitude better than its Intel counterparts. Nvidia and Amazon have made similar moves in the past.

In layman's terms, the same technology that has been driving our phones and tablets for years is becoming more present in our desktop computers, laptops, and data centers. What's different about these newer architectures is that they can help data centers save a lot of power; the same business applications and data processing use less energy.

Most business software is still built to target Intel and AMD processors. Changing this would enable huge energy savings. For instance, containers, which are now the key building blocks of most business software, can be created to support multiple architectures, not just x86-64. This requires changes to DevOps pipelines and deployment routines to support more efficient CPU architectures. It's happening, but very slowly.

Cloud as the Green Option

Cloud vendors promise carbon neutrality. They like to show that their energy management routines are driven by artificial intelligence (AI) — always good for marketing — and their impressive cooling systems. We cannot verify these claims, but let's assume they are true.

Developing software using building blocks delivered by public cloud vendors can accelerate cloud adoption, but greener computing is another reason to turn to the cloud faster.

Hybrid cloud, which is a combination of local and public infrastructure, is very much a limiting factor to the full adoption of cloud-specific services. The popular cloud-agnostic tradeoff called "cloud-native" is the most popular choice nowadays, yet not the most energy-efficient. The future decline of local infrastructure for many organizations will result in more environmentally friendly software architectures and the ability to embrace newer patterns. For instance, serverless paradigms for solution architecture are focused on short-lived ephemeral workloads instead of keeping the "digital engine" running all the time.

The cloud transformation traditionally has been slower than predicted, but it's inevitable. In case of any doubt, you can add the environment as another excellent reason to do it faster.

Developers Like Inefficient Languages

Languages closer to machine language and assembly language are much more energy-efficient, but they are losing popularity among developers because most business applications and even games are created using higher-level languages.

C is still very popular, but newer generations of developers prefer to learn Python, Java, and C#, instead of C. The resulting lack of developers with the needed skillset will become a serious problem for many low-level programming needs such as operating systems and, especially, devices. For business Web applications or mobile application back ends, energy inefficiency might be tolerable because the end users don't see it. But it won't work for small devices and operating systems — database systems that are expected to utilize limited resources as efficiently as possible.

Optimal Code Is Not Green Code?

Regular developers write acceptable code; the best developers write optimized code, which is code that runs as fast as possible and consumes less memory. Usually, execution time is the priority at the expense of memory usage — and energy consumption. Modern CPUs have multiple cores. Fast code uses all of them, waking them up and creating much activity to complete the operation as quickly as possible. Ironically, regular developers may create more energy-efficient code than their more ambitious colleagues. We want our apps to run as fast as possible, but ... servers sleep most of the time.

Energy-efficient code-writing techniques are lesser known than traditional code-optimization techniques. In a car driver's analogy, this is the difference between driving from point A to B in the shortest time versus consuming as little fuel as possible between those points (eco-driving). But in the case of driving, it's well known how to save a lot of fuel. In the case of software, it's much more difficult and less precisely defined.

Machine Learning (aka AI) for Business

Machine learning (ML) is all around us: our mobile phones, our laptops, our TVs. It's already doing a good job of identifying usage and energy-consumption patterns to help optimize the energy consumption of our smallest and largest devices, from smartwatches to supercomputers to data centers.

But let me remind you that ML is extremely heavy computationally, consuming a lot of power to train neural networks to recognize images, learn grammar, and detect irregularities in data. At the enterprise scale, ML requires dedicated TPUs and GPUs that consume much energy to deliver useful results for businesses.

Even worse, ML is a set of experiments, model tuning, retraining, testing, and transferring tons of data, all of which take a vast amount of energy. This is not something that we typically read about when a headline announces another AI breakthrough. There's a steep price for that progress, and it's not "just" the privacy of our data (a good topic for another time) but also the enormous CO_2 footprint of ML.

What can we do about it?

First of all, hardware and software are getting more optimal, and energy limits of computers are forcing creators to optimize watts usage in each future iteration. ML workloads, especially training, are ephemeral workloads that may not require a set infrastructure and can be run in the cloud.

When models seem to be good enough, they can be trained less often using subsets of data to minimize training time and to train at full scale only from time to time. This helps save a lot of costs (e.g., data scientists' time, computing resources) but also helps a great deal by reducing the carbon footprint by an order of magnitude.

Blockchain (aka DLTs) for Business

Digital ledger technologies (DLTs), better known as blockchain nowadays, failed to gain as much attention and interest as anticipated a few years ago. Yet numerous new projects use blockchain technologies. Unfortunately, power consumption is one of the biggest disadvantages of the most popular blockchain technologies. They require far more energy than business transactions that don't use them — by an order of hundreds or even thousands. This means projects should seek out blockchain technologies that consume less energy instead of the most popular, but inefficient, ones.

In the recent past, it was quite common to see blockchain overused. Now it seems to be used only when it helps significantly to deliver business value. But it's worth considering blockchain's environmental impact as another factor when making architectural decisions about whether or not to use DLTs in the digital solution.

Why Don't We Embrace Green Software Development?

Software developers are busy. Changing requirements, ambitious goals, and constant changes in technology make the resource shortage more painful than ever. Pressure for faster digitalization and resilience creates a lot of work in software architecture design, coding, testing, DevOps, and data processing, including ML.

Software development is hard enough already, even without considering the requirements of green computing. And it's not getting any easier ... or cheaper. Staying competitive in business means delivering better digital experiences faster and making them more resilient. Adding green computing goals on top of all that may seem like overload on a developer's plate. But ... "the times they are a-changin'."

Let's not forget that what works for the environment may very well work for your business efficiency. This has been proven already in the case of mobile apps and IoT devices, and to some extent in cloud computing. Web apps, their back-end services, and the entire data processing universe with its jewel in the crown, ML (a subset of AI), are expected to join this green computing movement slowly but surely.

Even though energy-efficient software development sometimes means functional and performance tradeoffs, it's still worth trying to add an IT component to our global efforts to save humanity from humans. Everyone has a role to play. Software rules the world — let it rule a greener world for us and for generations to come.

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A Framework for Environmentally Friendly AI

by Rohit Nishant and Thompson S.H. Teo

Artificial intelligence (AI) and machine learning (ML) are increasingly touted as technologies that can be used to tackle environmental challenges arising from global warming and climate change. Indeed, many in the field view AI and ML as powerful tools that can help humanity reduce its carbon footprint. But as AI becomes more prevalent in business and society, concerns are increasing about its environmental impact. If AI itself is not environmentally friendly, the proposition that it can facilitate environmental sustainability becomes less convincing.

While using AI/ML to combat climate change is a relatively novel phenomenon, climate change has been occupying our attention for a while. Although AI can be the source of adverse environmental consequences, we propose the "Align, Reduce, Measure" (ARM) framework as a plausible solution to ensure that the use of AI/ML is environmentally friendly. In this article, we discuss how AI/ML can have a negative environmental impact — and how to effectively counter that concern.

Heterogeneous Data: The Key to Environmentally Sustainable AI

As AI and ML gain attention for their potential to tackle the environmental challenges posed by climate change, their requirement of heterogeneous data takes center stage.

Najat Ali et al. define heterogeneous data as a mix of numerical, categorical, and other types of data.[1] They argue that real-world data is increasingly heterogeneous. For example, in climate change–related projects, ML can leverage heterogeneous data for different objectives such as forecasting electricity supply and demand, which could reduce the carbon footprint. Electricity is energy-intensive and generates 0.92 pounds of CO_2 emissions per kWh.[2] Thus, effective supply and demand management could reduce energy consumption and, consequently, the carbon footprint.

Similarly, other projects focused on fighting climate change, such as smart cities, require heterogeneous data. Emerging technologies like the Internet of Things contribute to building heterogeneous data. Such projects can help cities and society prepare for climate change adaptation as well as mitigation through actions like reducing the carbon footprint of technology infrastructure and accurately predicting weather events.

A group of AI and ML experts called on the ML community to leverage ML to fight climate change and conceptualized different strategies to leverage ML for climate change mitigation and adaptation.[3] They divided areas where ML can be adopted into high-leverage (i.e., bottlenecks well-suited for ML tools), long-term (i.e., those with potential impact after 2040), and uncertain impact (i.e., where impact on emissions is speculative). In many areas, particularly in high-leverage types, various unstructured data (e.g., text) and structured data (e.g., numbers) can be leveraged together for ML. Thus, data is heterogeneous from diverse sources.

> *AI and ML are gaining increased attention for their potential to tackle the environmental challenges posed by climate change.*

Heterogeneity, Complexity & Environmental Footprint

While heterogeneous data plays a critical role in the use of AI and ML to combat climate change, there is a dual side that is not environmentally friendly. AI, in general, and ML, specifically, have their own carbon footprints. In large ML models, for example, a single big language model emits an estimated 300,000 kg of CO_2 just in its training phase; this is equivalent to 125 round-trip flights between New York and Beijing![4] Complex ML models, such as deep learning, can generate as much as 626,155 pounds of CO2 emissions, equivalent to the total lifetime carbon footprint of five cars.[5]

Heterogeneous data plays a key role in the carbon footprint of ML models because the combination of varied data adds to the complexity of the data set and makes it larger. Data of varied types is more complex than a single data type as it requires significantly more effort to integrate. A more complex data set would require more complex ML techniques, which are often more carbon-intensive, increasing the carbon footprint and environmental harm. This complexity of heterogeneous data arises from its nature, its structure, and the diverse sources it comes from, such as sensors, logs, geospatial, textual, and open source.

> ***The complexity in techniques used to handle heterogeneous data requires significant computational power, which increases the carbon footprint of the ML models.***

The integration, synchronization, segmentation, and indexation of data can quickly become a nightmare because of the huge variation in types. Thus, heterogeneous data requires powerful algorithms for efficient processing, which could pose two distinct risks. First, the focus on the arduous task of processing heterogeneous data may result in a shift away from the environmental sustainability goal of the project. This contrasts with the ultimate objective of using clean and sophisticated data that is useful, accurate, and solves specific business problems. Second, heterogeneous data offers the possibility of using complex algorithms, but the use of these powerful algorithms is energy-intensive and could lead to a huge carbon footprint.

Lately, technical approaches have been proposed to manage the energy and carbon footprint of AI/ML. For instance, one group of researchers has proposed a framework for accurately reporting energy and carbon footprints and suggested strategies for mitigation.[6] Their recommended strategies include running cloud jobs in low-carbon regions, moving ML training to low-carbon regions, and encouraging energy-efficient systems and configurations.

The technical recommendations in that framework, while useful, have certain limitations. For instance, while shifting carbon-intensive jobs to low-carbon regions with low-carbon footprints seems a feasible solution, it might create additional responsibilities in terms of continuously tracking the availability and ability of these grids to handle additional loads when several ML tasks are moved to them. Although this approach is grounded in the assumption that the environmental sustainability issues are solely characterized by emissions, this approach does not reduce energy consumption.

These details allude to the possibility that AI for environmental sustainability could itself be harmful to environmental sustainability. If the efforts invested in implementing powerful heterogeneous data-processing algorithms do not result in addressing the needs of the project, it suggests that the focus of the project has been misdirected. However, this does not mean that we should avoid heterogeneous data; rather, we should optimize the data so it can be managed with relatively less effort, be efficient and effective, and does not become a source of environmental pollution.

Optimizing Heterogeneity, Minimizing Environmental Footprint: The ARM Framework

The complexity in techniques used to handle heterogeneous data requires significant computational power, which increases the carbon footprint of the ML models. The ARM framework takes a proactive approach to minimize the environmental impact of AI/ML while still achieving a project's objectives. It answers the question of how to manage this dual role of AI/ML, where its positive role is enhanced and its negative impact on the environment is reduced.

Align Goals & Objectives

Various parties are involved in sustainability and the use of AI/ML, so it is crucial that they do not work in silos. Rather, there should be interdisciplinary collaboration and alignment of goals and objectives to address climate change issues. It is important to involve top leaders in the organization as their support is crucial for ensuring the availability of resources and the viability of projects to mitigate climate change.

This collaborative approach can be achieved through an organizational structure, where traditional CxO positions, such as chief information officer (CIO), chief marketing officer (CMO), and chief financial officer

(CFO), join together to form a strategically orientated steering committee that sets the agenda for using AI/ML for sustainability. Increasingly, roles such as chief sustainability officer (CSO), chief data/digital officer (CDO), and chief technology officer (CTO) have emerged in various organizational settings. A recent addition to this growing list of C-suite executives is the chief AI officer (CAIO). These positions can form an interdisciplinary team at the operational level; such a group can be effective in bringing different experts together to examine and resolve disagreements and other issues.

Specifically, we could include the CSO, CDO/CTO/CIO, CAIO, sustainability experts, and AI/ML experts on the interdisciplinary sustainability team with the CSO and CDO/CIO as joint leaders. This team will be more operational in nature, with a specific focus on the execution of AI/ML. As the leader of the interdisciplinary team, the CSO could help the team retain focus on the bigger picture relating to environmental performance. The CDO/CIO as the joint leader would provide a bigger picture of where data and AI/ML fit in the grand scheme of environmental issues. Also, as the CDO and CSO will share the leadership, they will have the opportunity to interact with each other and arrive at a shared understanding of using AI/ML for environmental sustainability.

Reduce Data Dimensionality to Reduce Data Heterogeneity

Over the last few decades, there has been increasing adoption of environmental management systems (EMS) and various environmental initiatives, some of which were effective, whereas others were not. Mozaffar Khan et al. identified specific sustainability investments as material or relevant.[7] A path to reducing heterogeneity is through materiality, where relevant data is identified based on understanding the specific problem in a specific context. For example, Bogdana Rakova and Alexander Winter discussed the need for integrating traditional ecological knowledge of indigenous peoples and local communities.[8] Similarly, Theobald Frank Theodory provided testimony for the effectiveness of indigenous knowledge in climate change adaptation.[9] Consequently, if AI is used for climate change adaptation in a specific region, traditional knowledge about weather and climate can be used by AI/ML engineers to identify a limited set of variables rather than utilizing all available variables, which could make the AI/ML model energy- and carbon-intensive.

The AI/ML engineers can reduce the dimensionality of the variables by identifying a limited number of variables to introduce in the algorithms. Grouping together those variables that bring us the same information can reduce the time spent during the training phase of the algorithms.[10] Dimensionality reduction for heterogeneous data, which can be different from that for standard data, can be addressed in different ways, such as through use of a clustering algorithm[11] or use of different techniques that not only reduce dimensions but also manage missing data to improve the performance of the analysis algorithms.[12] However, these approaches are still technical in nature, and using these techniques would still engender some carbon footprint.

> *Over the last few decades, there has been increasing adoption of EMS and various environmental initiatives.*

Reducing complexity from the beginning is a better approach to creating environmentally friendly AI. As mentioned earlier, we need an interdisciplinary team below the steering committee, comprised of sustainability and AI/ML experts. The sustainability domain experts can identify different issues that are material or relevant for the specific context and different variables. In the above examples, teams leveraged traditional knowledge from indigenous communities, their own explicit and tacit knowledge, and the existing knowledge base, built from past environmental sustainability initiatives and technology implementation, such as EMS. The AI/ML experts can then select relevant variables (feature selection) from this list and suggest new variables, if necessary, based on their understanding of the data. Finally, these experts would assemble to prepare the final list of variables for ML (see Figure 1).

Such a collaborative approach will ensure that AI/ML does not remain a mere technical exercise in which the bigger picture of resolving issues related to climate change is relegated to the background.

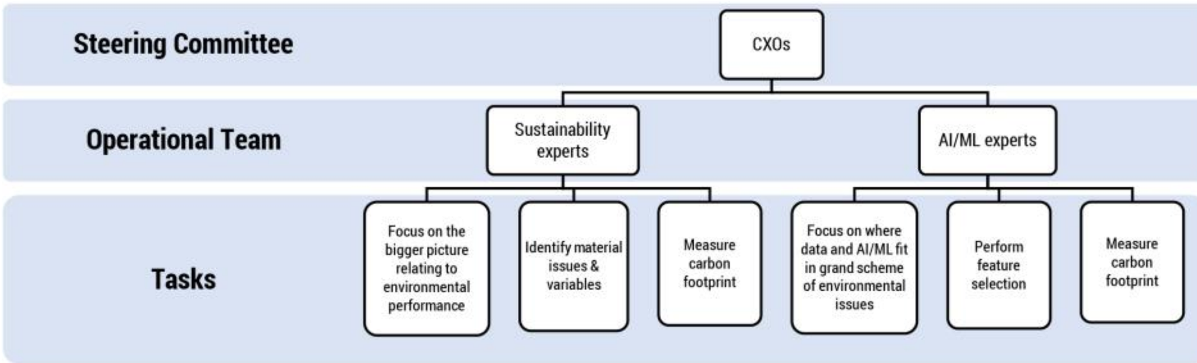

Figure 1 — Teams for environmentally friendly AI/ML.

Measure Carbon Footprint

Finally, these teams will focus on metrics to ensure that AI/ML stays environmentally friendly. Sustainability experts will prepare the carbon footprint baseline for a regular scenario when AI/ML is not used as well as measure the carbon footprint when AI/ML is used. They will prepare the baseline for different types of carbon footprints. The AI/ML experts then would use the Greenhouse Gas Protocol,[13] which comprises widely used greenhouse accounting standards to measure the carbon footprint of using AI/ML. The protocol covers carbon footprint arising from consuming energy and thus can help AI/ML experts. These experts will meet regularly and check if net carbon footprint declines after using AI/ML. If the net carbon footprint increases, they will deliberate on ways to ensure the decline of the net carbon footprint. Such ways could include reducing the number of variables or selecting a less complex AI/ML model.

Conclusion

The use of AI and ML for environmental sustainability and combating climate change will be futile if it adds to the problem. Better management of heterogenous data is a key way to address this issue because heterogeneous data increases the carbon footprint, which could negate any positive impacts from its use. ARM can help manage heterogeneity and retain the focus of AI/ML projects on addressing environmental issues and mitigating adverse environmental effects of heterogeneous data. Such an approach could help ensure that the use of AI/ML for environmental sustainability stays part of the solution rather than becoming a part of the problem.

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Corporate Sustainability Has Failed:

Digitizing Regeneration May Still Save Us

by Simon J.D. Schillebeeckx

Companies active in the making, moving, and mining of things are typically held responsible for climate change. When we consider the environmental footprint linked to their activities, this interpretation is fairly accurate. However, as I argue in this article, this perspective is not very helpful. For this attribution of responsibility to be beneficial in the face of crisis, it needs to instill a sense of agency, responsibility, and urgency. Yet, it appears that the way in which we have come to define sustainability over the last three decades has created apathy, resignation, and blame-shifting.

> *We need a new sustainability target that does not limit our collective responsibility to the boundaries of our organizations, as carbon footprinting does, but considers the boundaries of employee consumption.*

To successfully tackle climate and biodiversity crises, companies should revisit their understanding of their environmental responsibility and focus on the consumption they enable in their employees. Eventually, that end consumption drives the environmental impact on society. This is especially salient for those companies outside the making, moving, and mining of things. For them, reducing their Scope 1 (internal operations) footprint does not make much of a difference, and they often lack power to meaningfully influence their Scope 2 (electricity) and Scope 3 (supply chain, use phase, and end-of-life treatment) footprints.

Thus, in the absence of a global hierarchical power, we need to rely on the global collective action among companies, governments, and individuals. If companies start setting a different goal for environmental responsibility, we need to empower them to do so in a meaningful way that creates value. This is where digitization plays an important role. With every person connecting to the Internet, and with every piece of the natural world digitized and tokenized, protecting it becomes possible because the value of doing so increases with rising stakeholder demands for action. This new strategy for differentiation is called *regeneration*.

A New Definition of Environmental Responsibility

The old "reduce, reuse, recycle" adage, developed by Dutch politician Ad Lansink in 1979 as a hierarchy of waste treatment, has dominated our understanding of sustainability.[1] But by equating sustainability with the reduction of the negative externalities of our industrial processes, ultimately we are assigning environmental responsibility based on a company's processes. This is meaningful if you are working in the making, moving, or mining of things, but less so if you operate outside of those industries.

Thus, we need a new sustainability target that does not limit our collective responsibility to the boundaries of our organizations, as carbon footprinting does, but considers the boundaries of employee consumption. Think about the carbon footprint of a hedge fund that rents a small office, owns a few computers, and stores its data in the cloud. Getting to carbon neutrality for such a firm is very easy. Buy a few carbon credits in the open market, and you have done your duty. However, if we acknowledge the wealth such firms create for their employees and the consumption patterns this wealth enables, the picture changes drastically. This holds true for most of the service industry.

If the goal is neutrality and our responsibility is determined by carbon footprinting, what is the role of pharma, biotech, law firms, governments, marketing agencies, tech companies, digital nomads, consultancies, healthcare, PR agencies, educational institutions, banks, fintechs, the insurance industry, brokers, unions, the arts, retailers, and political parties? These sectors (which I loosely refer to as the "service industry") face much less scrutiny from environmentalists, have a low footprint, and have very little ability to meaningfully reduce that footprint.

Alternatively, by defining environmental responsibility in terms of the consumption patterns a company enables, we increase the responsibility of the vast majority of companies in the developed world. Currently, the US GDP from services is about 77%,[2] with employment in the service sector close to 79% of the working population.[3] While some of these service companies can influence their supply chains through sustainable procurement, their ability to do so is contingent on market power.

I thus propose that companies redefine their environmental responsibility as either their production footprint (including Scopes 1, 2, and 3 emissions over which they have real power) or their employees' consumption footprint, whichever is bigger.

Sustainability Beyond the Footprint

If the service industry starts defining its environmental responsibility in terms of its consumption footprint, "reduce, reuse, recycle" can no longer limit the scope of its actions. Even if the service industry somehow succeeds in reducing its production footprint to zero and achieves carbon neutrality, its environmental responsibility would be significantly higher. I suggest the service industry focus on regeneration.

According to a report from Wunderman Thompson, "Regeneration goes beyond sustainability and mitigating harm, to actively restoring and nurturing, creating conditions where ecosystems, economies, and people can flourish."[4] This view is championed by leading authorities across the world. The High Ambition Coalition for Nature and People, a group of geopolitical leaders that includes the European Commission, the UK, France, Japan, and many African and South American countries, promotes the 30x30 goal, which aims to expand the quantum of natural reserves to 30% of the world by 2030.[5]

Meeting this goal will require substantial private sector investment. Indeed, in the lead-up to the *Climate Change Conference of the Parties* (*COP26*) in Glasgow, Scotland, United Nations (UN) Secretary-General António Guterres stated that we are on track to see 2.7 degrees Celsius of warming by the end of the century.[6] The effects would be disastrous.

The "State of Finance for Nature" report from the UN Environment Programme (UNEP) concluded that we need to triple our investment in nature by 2030 and quadruple it by 2050. Currently, the private and public sectors invest respectively US $18 billion and $133 billion per year.[7] Principles for Responsible Investment (PRI) predicts that the market for forestry solutions alone will grow to $800 billion per year by 2050.[8] This may seem like a lot of money but likened to an annual investment of about $1.5 trillion in digital transformation,[9] it seems manageable, especially if doing so can create value for companies joining the regenerative economy.

According to recent research, increasing our natural reserves from the current 11% to 30% would not only benefit natural ecosystems tremendously but also lead to more economic growth.[10] The task is to restore natural ecosystems that have been deteriorating for decades, rewild them, and eventually remove human intervention. So, if companies redefine their environmental responsibility beyond their production footprint, taking action must go beyond "reduce, reuse, recycle." It requires contributing to regeneration.

Lessons from Michael Porter

While environmentalists like me may hope companies will simply heed this message and start financing regeneration, it will not happen without a compelling business logic. Does regeneration make strategic sense? I believe so.

Our approach to sustainability so far has been a one-sided implementation of our most important strategy lessons. Consider Harvard Business School Professor and founding father of strategic management Michael Porter's position on the two generic strategies that lead to competitive advantage: cost leadership and differentiation.[11] Companies have treated sustainability almost exclusively as a cost leadership strategy; by reducing energy consumption, waste, and resource use, companies can cut costs and gain a competitive advantage. As the policy and technological environments evolve, decarbonization becomes even more cost-efficient. Many companies have also tried to use their reductions as a differentiation strategy; however, the sustainability and environment, social, and governance (ESG) accolades companies currently espouse are weak differentiators at best and very rarely merit applause. Yet we applaud companies that do exactly that. Successful differentiation cannot be built on doing "less bad" — it requires "doing good." The strategic challenge of the next few decades, therefore, will be to turn regeneration into a differentiation strategy, and thus a value appropriation strategy.

Companies that embrace this new vision stand to benefit through improved government and investor relations; higher employee satisfaction, retention, and talent acquisition; and increased customer loyalty and willingness to pay.[12] And, it's important to consider that Millennials and Gen Z are more environmentally aware than previous generations. They want to align their career paths with their values.

Thus, the opportunities to create regenerative strategies that embed positive impacts into products and services are becoming more appealing.[13] This is the area where emerging digital technologies play a crucial role. To understand why and how, we need to revisit the Tragedy of the Commons.[14]

> *The role of digitization goes beyond enabling the creation of benefit claims.*

From Property Rights to Benefit Claims

Garrett Hardin, who coined the term "Tragedy of the Commons," explains that the lack of investment in common pool resources, like nature, happens because individual actors reap the rewards of overexploiting the commons (e.g., allowing one extra cow to graze on the pasture), while only bearing a fraction of the cost in additional environmental damage (i.e., the increased risk of turning the pasture into a desolate, arid desert). The underlying problem is the inability to assign property rights to the commons. Collectively owned resources (e.g., forests or lakes) or unowned resources (e.g., the atmosphere and the oceans) are thus overexploited.

Digital technologies in the convergence ecosystem, however, like blockchain, artificial intelligence, 5G, and the Internet of Things (IoT)[15] enable a bifurcation of property rights and benefit claims. Property rights refer to the legal ownership (or lack thereof) of a specific asset. Benefit claims capture the right to lay claim to the benefits an asset creates, irrespective of the property rights.

For example, digitization enables us to credibly attribute the benefits of a tree to a company without owning that tree. If you wonder about the benefits of a tree, consider the following design assignment: "Design something that makes oxygen, sequesters carbon, fixes nitrogen, distills water, accrues solar energy as fuel, makes complex sugars and food, creates microclimates, changes colors with the season, and self-replicates."[16] How many man-made products can you think of with such impressive features? Benefit claims accrue to the financier of the tree. A digital token proves that Company X paid for its conservation and hence can lay claim to the ecosystem benefits it creates, without being the sole beneficiary of those benefits.

Economies of Information, Value Exchange & Collective Action

The role of digitization goes beyond enabling the creation of benefit claims. Benefit claims can exist on paper. Carbon credits are a well-known form of benefit claims. What is new is the scale and speed with which these new assets can be created and the level of precision they have in terms of the ecosystem benefits they represent. Moreover, they can be layered on top of existing processes. E-commerce platforms are familiar with plug-ins that display contributions toward a positive impact at the moment of checkout. Aviation companies have often given customers the option to buy carbon credits to offset a flight's emissions. But these approaches are not very appealing because they are de facto donations to a company.

With digitization, we can change the attribution of the benefit claim. It can be co-owned by the company and the customer, hence establishing a feeling of "we are in this together." This impact integration can happen in any kind of digital transaction. Digitizing regeneration can thus underpin a powerful differentiation strategy.[17] Next, we examine three types of economies facilitated by digitization and how they are turning benefit claims into a compelling business case.

Let's assume we are indeed going to turn 30% of the earth into natural reserves. How do we make this happen? It will require a lot of data to monitor, report, and verify — what is known as MRV. Add to that a layer of visualization of the impact and you get digital MRV. This will rely on the IoT, remote sensing, machine learning, citizen science, tech platforms, and so on. As the costs of data collection, storage, and analysis have plummeted, the *economies of information* are making it possible to truly know the state of the natural world.

Yet MRV is not enough. Governments cannot finance the needed investments alone so corporations and individuals will need to step in. This is where benefit claims play a crucial role because if companies can credibly claim they are to thank for an ecosystem benefit, their reputational and brand value increases. Suddenly the economic problems around common pool resources are not that problematic anymore. The proof is in the voluntary market for carbon credits.

Blockchain is beginning to alter the *economics of value exchange*. While the Internet is great at multiplying information, blockchain enables unique, original documentation and the exchange of unique digital assets without the intermediation of a third party, creating efficiencies in many aspects of international trade. Many blockchain projects are emerging in the climate action and biodiversity space thanks to the power of tokenization of benefit claims and the ability to exchange them in a trusted and validated way, so the problems of double selling are all but eliminated, which in turn massively reduces transaction, verification, and contracting costs. Trees, plots of land, ocean segments, and even individual animals can be tagged, tokenized, and "bought" on the blockchain. This purchase does not assign property rights. It assigns benefit claims: you buy the right to claim you are to thank for the ecosystem benefits created by your financial sponsorship.

Once we have accurate and credible data, and a way to exchange benefit claims seamlessly without risk of double selling or government expropriation, an entire market for positive impact can emerge. This market is spurred by *economies of collective action*. Digitization has lowered the coordination costs of collaboration and has increased the ability to have influence beyond the resources one controls. People like Greta Thunberg wield massive influence while controlling virtually no resources. Tech giants build advantages through superior deployment of third-party resources (e.g., cars for Uber, rooms for Airbnb) and maintain their advantages through network effects, not resource ownership.

We do not need a single actor to take responsibility for every natural asset. Companies start weaving regenerative actions into their business transactions, from e-commerce and international trade to digital ads and contracting, from hiring a new person, to adding a new lead in a customer relationship management system. Every digital process can be linked to a micro-sustainability action, every transaction can be imbued with positive impact. Doing so creates micro-fundraising for positive impact, always involving at least two parties and leading to exponential involvement. It is through using these technologies that companies, especially those in the service industry with a limited production footprint, can take environmental responsibility in a way that leads to differentiation and thus superior value appropriation.

Conclusion

Most business leaders are aware of the catastrophic consequences that climate change is about to bring to bear on humanity. Yet we all excel at inaction. Why is that? Most people do not work in sectors that make, move, or mine physical objects. And most who do are not in positions of power. Therefore, our ability to combat climate change appears minimal. We lack both agency (can we act?) and responsibility (who is to blame?), so we have developed apathy to erase the nagging sense of urgency we just cannot shake. What we need is a new definition of environmental responsibility that goes beyond the production footprint and is based on the consumption patterns companies enable because, eventually, end consumption drives the economy. By shifting our understanding of corporate environmental responsibility, we empower millions of organizations to go beyond "reduce, reuse, and recycle" and start thinking seriously about regeneration.

Thus far, we have approached sustainability one-sidedly. Our focus has been on evaluating and reducing our carbon footprint, thus engaging in a cost leadership strategy focused on efficiencies. This approach has disempowered, in my estimation, about 75% of organizations in the developed world. However, companies can also excel through differentiation. Support for regeneration will be a key differentiator for the coming decades. Once we widen our understanding of corporate environmental responsibility to include the consumption patterns we enable in our employees, we will empower a whole new approach to sustainability. We have less than a decade left to prevent our children and grandchildren from growing up in a world that is a lot less livable than the one we inherited. We owe it to ourselves and our offspring to turn apathy into action. Digital regeneration shows the way.

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BE BETTER

How Tech Can Tackle Hunger: An Interview with FAO's CIO

by Cutter Consortium and Dejan Jakovljevic

The United Nations (UN) Food and Agriculture Organization (FAO) works with more than 194 member states in more than 130 countries across the globe toward the goal of achieving food security for all. Increasingly, digital tools and processes are indispensable for addressing world hunger. Cutter Consortium (CC) spoke with FAO's CIO and Director of Digitalization and Informatics Division Dejan Jakovljevic (DJ) to learn more about how technology is transforming FAO's ability to meet its goals.

CC: Tell us about FAO's mission and how it is using technology to achieve its goals.

DJ: FAO is the UN organization for food and agriculture. In the UN system, organizations have different mandates. One way to understand how FAO contributes globally is to look at the UN's Sustainable Development Goals, or SDGs. The SDGs are quite important because they also include indicators and provide a targeted focus on improving situations behind those indicators. For example, FAO is custodian to 21 indicators and contributes to a further five.

Among these indicators, FAO is, of course, a major custodian of global indicator 2: Zero Hunger. But through this overarching vision, the organization also contributes directly to No Poverty (1) and Reduced Inequalities (10), and is custodian to several other indicators that may not be as obviously connected to food and agriculture but that also support the achievement of the broader SDG agenda. These include, for example, Gender Equality (5), Clean Water and Sanitation (6), Responsible Consumption and Production (12), Life Below Water (14), and Life on Land (15) (e.g., sustainable forest management) — see Figure 1.

When it comes to employing digital toward SDGs in FAO, it is important to note FAO's new strategic framework, focused on delivering around the four "betters":

1. Better production
2. Better nutrition
3. Better environment
4. Better life

Toward achieving the four betters, FAO has four accelerators: innovation, data, technology, and the complements (normative and regulative aspects). The first three accelerators — innovation, data, and technology — or "Digital FAO" are embedded into FAO's delivery and how FAO works day to day.

From an IT perspective, CIOs often begin with a dialogue on how to secure support from the business. In FAO, Digital FAO is already embedded in everything we do. The accelerators are in motion across all of the organization to find ways that innovation, data, and technology can actively contribute to the food systems and achieve the SDGs.

CC: What led to FAO's comparatively fast adoption of technology and digital tech?

DJ: Our overarching motivation begins with a significant sense of urgency. In 2020, about 2.3 billion

Figure 1 — The UN indicators under FAO custodianship.

people — roughly 30% of the global population — lack access year-round to adequate food. And around 811 million people went undernourished last year. At the same time, due to COVID-19, we are seeing an increase in this number of about 160 million additional people.

So our sense of urgency is quite strong, and we have a couple of elements responsible for the fast adoption of new technologies. First, we have strong management support around modernizing FAO and moving toward Digital FAO. Digital FAO is a very important concept for us because it encompasses FAO as a transformed organization: agile, working in modern, digital ways.

> *We transformed from traditional, "100% functional requirements first" to embracing risk-based/low-certainty, adaptive ways of working.*

Second is around the impact and products we deliver to our members and small holders, also included in Digital FAO, with transformative digital products, DATA for Impact, and public goods to accelerate impact toward SDG objectives.

Another enabler of quick acceleration comes from IT. We take advantage of cloud solutions and emerging technologies (e.g., developments in remote sensing, geospatial, and big data/unstructured data). We can access these technologies for rapid deployment of the solutions, and cross integration and data use provide for greater impact.

This also means we had to, as IT, reorganize how we work. We transformed from traditional, "100% functional requirements first" — the usual defined and structured universe — to embracing risk-based/low-certainty, adaptive ways of working. We can start projects with just some initial idea, determine immediate principles for impact, and then adopt a strategic approach going forward (e.g., use of cloud platform, data aspects) and start building, with very quick scale-up, even if the idea from the very beginning was not 100% developed. It's more of an iterative, minimally viable product approach. We focus on which digital capabilities can help, and then we organize around those to deliver results.

It means we don't run IT by an organizational chart; instead, we identify digital capabilities needed as a common objective, so we aggregate efforts around it and assemble cross-functional, multidisciplinary tiger teams with whomever needs to be involved to enable these capabilities. Then we move forward, and adapt immediately as needed. It is a truly adaptive way of working.

As a specific example, we are building a "situation room" for one of the countries in need. First, we activate a tiger team or task force — we know we need an expert on data modeling, a cloud expert, an expert in food systems, and others, so we organize a team around these needs. Then, it is understood that everybody else must support this team to accomplish the objective. That's how we can move very fast, how we can be on target, and how we can afford to be quick to develop under uncertainty. I can also see the very positive impact of the cross-functional team reflecting into innovative approaches and increased quality as boundaries are removed between IT functions and with business embedded into the team from the very beginning.

CC: What are some examples of leading-edge technologies at FAO that you find most exciting?

DJ: One example is the FAO's Hand-in-Hand initiative: our geospatial platform. What is really interesting about Hand-in-Hand is that it allows us to take vast amounts of data and knowledge — from all across FAO, as well as external sources — and to enable new capabilities, providing unique insights to accelerate impact toward the SDGs. From a technology perspective, we are introducing new modalities, taking advantage of the geospatial platform data and numerous other layers of other data, and making specific insights for different circumstances, as some interventions may need to be focused on harvest and others need insights related to fisheries or the impact of locusts, for example.

Hand-in-Hand is our flagship platform; it allows us to provide services to our members so they can have insights into corrective measures they may need to take at the country or regional level. There is a whole set of useful tools based on this core platform.

In addition, we can take the knowledge from the platform and, out of that, produce tools for farmers in hand. For example, we can use this data and provide insights, such as providing a crop calendar, and put it in the hand of the farmer. We also produce what we call

"WaPOR" (Water Productivity through Open access of Remotely sensed derived data), which monitors water usage in near real time using satellite data, to make and share insights on water usage. WaPOR measures water productivity over continental Africa every six days, so we can see what is going on with water productivity innovations.

Another exciting initiative employs machine learning and image recognition to detect armyworm infestations. In Kenya, for example, a farmer can use a smartphone to detect what kind of infestation is happening. As another example, we have a system that helps deal with the locust crisis, assisting our members with emergencies related to locusts across many countries. These tools use a combination of satellites and drones to supply insight into what's going on where and then correlates that with other data to see the location of infestations. It's an application that a farmer can load on a mobile phone, and it enables crowdsourcing of data. We can complement the data we have from drones and satellites with the crowdsourced data. Normal usage employs statistical data that is clearly defined from collection to processing to dissemination. This introduces more real-time, dynamic, indicative data from the field.

There are other digital capabilities and tools for decision makers. For example, FAO Data Lab makes it possible to gain insights around market prices and different aspects of trade indicators. Another use case is data providing insights on the relationship between COVID-19 cases and food insecurity — and many more different insights available instantly, based on common platforms.

CC: Are there any FAO programs using technology focused on reducing food waste?

DJ: FAO maintains a food loss and waste database online that is available for all. The key benefit is that interventions can be tailored based on the area where the waste is occurring.

There are many, many different elements related to where food waste and loss can occur. For example, there is food waste related to pre-harvest, harvest, grading, storage, transport, traders, processing, packaging, distribution, retail, consumer, and exports. It's not just one aspect. It is common to think of the waste that comes from markets or from food at home, but it's a much more complex undertaking.

FAO has a tool that shows a heat map of the areas where food waste or loss is happening. Based on these measurements, geographically and along the supply chain, partners can then make insights based on a graph of loss and even explore by stage.

FAO has a full program that employs technology to make an impact. For example, in mobilizing the industry, we employ different means. Sometimes we use promotional campaigns via social media platforms, but not necessarily one particular platform. FAO is global, operating in more than 30 countries, so in some places we may use WhatsApp while in others it might be Facebook or whatever platform that dominates there.

CC: Hand-in-Hand was conceived of in October 2019, and the initiative was handled very quickly from an IT project perspective. What were the critical success factors that allowed it to be accomplished so fast?

DJ: In fact, the first prototype of the Hand-in-Hand geospatial platform was developed very quickly. I recall the first request back in January 2020, and the first working version was available in March 2020. Within those two months, we had the first prototype working, utilizing quite a large subset of data (from about 11 contributors out of 20). It took two months to get the data organized and get the platform enabled with seamless data sharing, including data visualization, dissemination, on-the-fly data analysis, and more, fine-tuned and presented to our members in a full scale-up, officially launched in July 2020.

What enabled this quick development was FAO's adaptive approach in IT. We reorganized ourselves into a tiger team, including both IT and colleagues in the business areas (we call them "program areas") — because that's where the data is and it's also where the knowledge is. We did not try to centralize within IT as is usual, as we believe that our role is to provide the platform and then enable colleagues who are experts in their own areas to flourish. The objective is to enable sharing of the data and insights into data that others contribute. In this way, we also enable colleagues to go to the next level within their own specialized work with new insights not available before. So, instead of trying to centralize and in a way compete with the knowledge we have in the program areas with colleagues working on geospatial in these different segments, the objective is to enable and help accelerate our programs.

Perhaps one more key success factor from an IT perspective is that we believe very strongly that we should take a lead and inspire, and not only deliver. So IT does not wait for the customers to be able to give us the low-level detail of exactly what they want. We take an extra effort to understand the business outcome they need to achieve and, without "selling" technology, bring forward technological opportunities.

> *We are not done, and we will need to continue to keep the pace, but we have already achieved a number of transformations.*

Part of this approach includes building capacity with the customer to have better dialogue on using digital to accelerate and transform toward results. Next is quick validation of an approach and, if we are on the right track, we move immediately and go to the next step, and the next step — for incremental but immediate delivery. That has proven to work really well, and it unlocks IT and the customer from the Catch-22: "I don't do x until we get the functional requirements right and until I get the budget."

Instead, we move first, with calculated risk, and then we validate if there is a sense that what we're doing is right. Of course, we want to have a sustainable solution, so all the elements are considered, including architecture, security, support modalities, budget, and everything else that's needed.

CC: As a whole, FAO has transformed into a more digital organization. Can you describe how those advances have enabled FAO to achieve progress on its goals?

DJ: FAO transformed extremely quickly on two fronts. First (also accelerated due to COVID-19), and almost overnight, we went into remote, digital working. From an IT perspective, while having new challenges, we also noted unique opportunity. What can we do to use this opportunity to accelerate transformation toward Digital FAO?

For IT, it was not only about having a Zoom call; it was about transforming how we communicate, collaborate, and fully work in digital ways. We provided the whole set of tools, with change management elements, training with help from our HR department, communication campaigns with the comms department, and, most significant, changes with the transformation of internal processes and internal ways of working.

Digital signatures are a good example. As we are shifting into electronic processes to "digitally sign paper," it wasn't actually the signed paper that we were looking for as the end result; we were looking for what the process is about (e.g., a signature is needed as a form of approval). So, we need to transform the process into digital approval rather than something to sign. I think many organizations were tempted to introduce electronic signing of the same paper they used to sign. We still do some of that, but we will continue to transform so that we don't need that actual paper. Instead, we have introduced the required action, which is proof of approval, in this case.

The message is that we genuinely want to take the opportunity to transform. We are not done, and we will need to continue to keep the pace, but we have already achieved a number of these transformations.

Another important aspect is to provision digital capabilities for impact to quickly enable response to crisis management. We have provided completely new digital capabilities almost immediately — including DATA for Impact and Hand-in-Hand and a subset of tools, including analytics and dashboards for quick response. We used these capabilities to address the immediate needs to be solved with COVID-19. Examples include big data, structured and unstructured — organized to give insights via different dashboards and instantly available overlays of various data. The same, core platform is also used to provide in-hand tools for farmers.

From an internal "IT engine" perspective, we have activated three streams to help us move quickly. The first is the digital workplace, focusing on internal, corporate digital capabilities and FAO's ways of working. The second stream is digital capabilities for impact — focused on public goods, DATA for Impact, and rapid development of solutions toward the achievement of the SDGs. The third stream is our own internal IT stream to run adaptable internal IT, including adaptable governance and quick, ad hoc teams that are vertically and cross-team focused on digital capabilities.

CC: 3D printing has been generating a lot of hype. Any interesting examples at FAO in the 3D printing realm?

DJ: 3D printing is quite a useful technology, and it is already included in different aspects of FAO's work. An important aspect with 3D printing is our focus to democratize and to provide as public goods, for free, different elements that could be 3D printed to assist farmers.

With our 3D Warehouse, the models are free and open. So, if a smallholder farmer would like to build something — using 3D printing, if it's accessible — the model is there, so they could reproduce what they may need for the farm. In fact, the 3D Warehouse includes an entire milk plant model in 3D. It's open source, so it can be used for free.

One of FAO's founding principles is to produce public goods. Digital capabilities can also be a public good that anyone can use. The intention is to democratize access to knowledge and tools FAO can offer. We provide open source models of different elements that could be useful for farmers or agricultural production.

As another example, if there is a piece of machinery and a part is broken, there's a model for that. Or, if the farmer wants to build a water irrigation system, there's documentation for that as well. It could be anything from a little pump to more complex elements for milk production. If we can democratize and provide easy, free access to these models, there is no need to reinvent and face time or investment barriers.

Another area where FAO aims to help is to influence access to 3D printing. FAO works with partners in the industry to enable an environment where 3D printing can be used on the scene in a cost-effective way so a farmer wouldn't have to buy a particular part but instead could search a database and source the missing part via technology.

CC: COVID-19 is pushing so many more people into hunger, making it harder to achieve the already ambitious SDGs. You've talked a lot about how tech is helping FAO. How is tech helping to close the gaps caused by COVID-19?

DJ: Yes, of course, the stress to food systems and technology impact, and the SDGs — it's all related. If we look at COVID-19 and the digital capabilities we are producing for response, and using technology, our DATA for Impact efforts to transform the sector toward the four betters, and the SDGs — it's all one story. We want to make sure that FAO has the digital capabilities that accelerate impact toward the goal of Zero Hunger.

COVID-19 prompted us to innovate and to introduce new digital capabilities quickly, particularly for small farm holders. For example, we started assisting with producing tools to transform how they work. Even before COVID-19, FAO provided assistance with traditional food production practices and respective ecosystems, including transportation, access to markets, and so on. But now, through the transformative power of technologies, we can provide such capabilities straight into the hand of the farmer, with direct knowledge products, match making, and other advisory services.

> *One of FAO's founding principles is to produce public goods. Digital capabilities can also be a public good that anyone can use.*

We can certainly see how smartphones and access to services are the most important enablers to the farmers in the future. We can give them a capability and knowledge in hand to enhance food production — the set of tools in terms of water usage, pesticides to deal with diseases, or to provide a crop calendar to assist their harvest. Once digitally enabled, new transformational opportunities become available, too. For example, it is possible to connect the dots — connect to market, transport, or other beneficial opportunities outside of agri-food areas, such as tourism.

The power of digital is its transformative impact, and we can see a much wider impact beyond the objective that may be immediately visible or targeted. Once we have switched to digital, other opportunities open up. For example, there is a positive connection between assisting farmers with production and the environment, including aspects around climate change. Another example is a positive impact on food waste and loss. It all works as one transformative ecosystem. That is what drives Digital FAO so strongly forward.

FAO is also introducing the newly formed International Platform for Digital Food and Agriculture. The platform is not a technology platform (such as a cloud solution) but a forum for key topics related to digital food and agriculture, including, for example, use of data, data privacy in agriculture, artificial intelligence and ethical use, remote sensing, precision agriculture, use of blockchain, and many more. This is a unique platform that is able to bring together different players — the UN, the private sector, academia — to participate and contribute in a forum to discuss these topics.

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IT'S ALL THERE

AI for a Greener, Sustainable World

by Curt Hall

Governments and industries worldwide are accelerating their efforts to reduce the carbon footprint associated with their products and services, driven by evolving government regulations, corporate shareholder responsibility initiatives, grassroots environmental campaigns, and green-conscious consumers inspired by celebrity climate activists like Greta Thunberg. These efforts range from consumer digital technologies, corporate data centers, and manufacturing operations to supply chains, resource extraction, shipping and transportation, and agriculture and waste management.

Today, organizations are using artificial intelligence (AI) to help achieve their goals of developing and promoting green technologies and managing environmental impacts. This includes applying AI in conjunction with complementary technologies to carry out carbon reduction strategies and to realize efficiency gains that can lead to cost savings via better energy management and successful decarbonization of key operations.

This article examines how AI and associated technologies can help companies with their net zero carbon and other sustainability efforts. Specifically, it examines how AI can support this vision today and in the not-too-distant future, offers examples of how companies are applying these technologies, and discusses available commercial products and services employing AI to assist companies in attaining their environmental goals.

How AI Can Help with Climate Change and Other Sustainability Efforts

The widespread availability of high-performance cloud computing services and the advent of deep learning neural networks have significantly impacted the development and application of AI technologies. This is especially true of machine learning (ML) systems, which have become quite popular due to their ability to identify patterns and trends in large volumes of data (both historical data and real-time streaming data). As a result of these developments, AI is playing an increasingly important role in helping create a greener, more sustainable world.

Currently, companies and government organizations are utilizing AI-based carbon intelligence platforms to analyze and report on their carbon emissions, while the Internet giants are applying neural networks and other ML algorithms to optimize energy usage in their massive data centers in order to decrease their carbon footprint.

Organizations are using AI to help achieve their goals of developing and promoting green technologies and managing environmental impacts.

Due to the increasing accuracy of machine vision systems (largely attributed to the use of deep learning neural net architectures), organizations are using smart cameras and ML to analyze video and still images of the insides of garbage bins, for example, to streamline their waste management and recycling operations.

It's important to note, however, that although AI gets most of the attention, in reality, most of the AI applications used to solve real-word problems, including those covered here, do not operate standalone. Rather, they combine various forms of AI techniques in conjunction with other advanced supporting technologies. For example, big data management platforms, like Hadoop and NoSQL databases, are frequently used for managing and applying AI analytics to large amounts of data from Internet of Things (IoT) applications (like real-time data streaming from cameras and other sensors deployed on vehicles, machinery, equipment, and other connected devices).

A more recent development is digital twins, an advanced form of simulation and modeling for creating digital versions of machines, buildings, vehicles, infrastructure, equipment, processes, and other assets in software and for visualizing and analyzing these models as they run. These models are synchronized with the actual physical assets or processes they model. This means that changes simulated in a model can be applied to the assets they are modeling (e.g., to lessen loads carried in heavy haul trucks in order to reduce the carbon output of certain mining operations).

Digital twins applications often rely on edge computing, ML, IoT, and other AI technologies for assimilating and analyzing data from sensors used to monitor physical objects (e.g., building management systems, jet engines, pollution control devices) in order to identify patterns and anomalies and to predict outcomes based on these analyses.

These are just some examples of how organizations are leveraging AI and complementary technologies to support their decarbonization and other sustainability initiatives.

> *Digital twins applications often rely on edge computing, ML, IoT, and other AI technologies for assimilating and analyzing data from sensors.*

Carbon Intelligence Platforms & Services

One of the biggest problems companies confront with their sustainability efforts is how to develop an accurate representation of their carbon output that will allow them to implement and conduct practical sustainability plans in order to meet their carbon reduction and other climate goals. Companies also struggle with issues around how to practically manage and analyze the vast amounts of carbon-related data necessary to model their carbon footprint. This includes a lack of scalable carbon reporting infrastructure as well as an absence of in-house experts knowledgeable in analyzing and applying the findings.

Technology providers see a viable market in helping such companies. They now offer comprehensive cloud-based carbon intelligence platforms and services employing machine vision, predictive modeling, and other ML techniques, as well as IoT and digital twins technologies. These platforms are designed to help organizations track, measure, and model their emissions in real or near real time, and chart the progress of their sustainability initiatives. Some also implement market mechanisms for issuing, buying, and selling carbon offsets credits.

CarbonChain

CarbonChain's platform targets companies in the extraction industries — specifically for tracking and reducing the carbon emissions of their supply chains.[1] This includes some of the world's most polluting industries: oil and gas, metals, mining, minerals, and agriculture, which are estimated to be responsible for approximately 50% of global greenhouse gas emissions.[2]

The platform uses various technologies to develop models for accurately measuring carbon dioxide (CO2) emissions arising from supply chain operations in the global commodities sector, including ML, big data analytics, IoT, and digital twins. It also maintains a database of greenhouse gas emissions facts and figures reflective of the assets and operations of commodities companies around the world. This data is used in conjunction with digital twins to model equipment, processes, activities, and other assets utilized in the supply chains of commodities industries, ranging from excavators, earth movers, farming equipment, and refining plants (along with other machinery used in mining operations and specific pieces of manufacturing equipment and factories) to ships, trucks, railway, and other transport.

CarbonChain's experts work with sustainability and risk management departments within companies to integrate the models and analytics of organizations' workflow functionality for tracking their carbon risk. This includes a customized dashboard for monitoring carbon risk and for supporting carbon reduction and other sustainability initiatives.

ENGIE North America

ENGIE's Ellipse is a dedicated carbon reduction platform that helps companies track their carbon emissions in real time for net zero carbon reduction initiatives.[3] It is designed to support global carbon mitigation efforts by enabling companies to design decarbonization strategies, track emissions, and chart their progress. It integrates into a company's existing digital environment.

Ellipse features advanced analytics for accurately modeling an organization's carbon output to execute on climate goals. Its ML algorithms are trained on insights from more than 1 million facilities to support "carbon-first" decision making in response to quickly changing market conditions. The Ellipse platform also mitigates the issues of companies having to manage large volumes of carbon-related data. Employing ML and custom APIs, it can aggregate and analyze dynamic data streams to provide an accurate view of emissions across an organization's entire portfolio and supply chain, allowing organizations to identify hot spots and model supplier-specific mitigation scenarios. This real-time view serves to measure carbon as a key performance indicator on an ongoing basis. In addition, reporting, analysis, and data visualization capabilities connect project performance to expected outcomes for measuring carbon impact and ROI.

Pachama

According to climate scientists, reducing emissions is just one part of the solution to the climate change problem. Governments and industries must also focus on removing carbon from the air in order to make a real impact on the buildup of CO2 in the earth's atmosphere.

Pachama comprises scientists, entrepreneurs, and engineers who believe that forests are the most cost-effective and practical way to reduce atmospheric carbon.[4] However, to date, forests have been under-utilized due to a lack of reliable data on how much CO2 they can actually absorb. Moreover, manual tracking of forest carbon absorption is difficult and time-consuming — especially when attempting to apply it in an efficient manner to support commercial carbon offsets markets. Pachama's technology provides a solution to this problem and offers a platform that simplifies how companies can buy and sell carbon credits.

Pachama's platform uses machine vision, predictive analytics, and other ML techniques for remote verification and monitoring of forests. Specifically, it analyzes satellite and LiDAR (light detection and ranging) imagery of forest growth to accurately predict the amount of carbon a particular forest is capturing from the atmosphere.

Pachama also implements a carbon offsets market that allows landowners involved in forest restoration and other conservation efforts to receive carbon credits for their work. Companies can purchase these credits to offset their CO2 emissions (one credit equals one ton of CO2 emissions). They can also choose to support a number of reforestation and conservation efforts taking place around the world, review these projects, and invest in those that align with their sustainability goals.

In short, Pachama's platform serves to validate reforestation and other conservation efforts, ensuring accountability, integrity, and transparency in a carbon offsets market. According to the company, Pachama is protecting nearly 2 million hectares of forest to date.[5]

Infrastructure: Key Target for Carbon Reduction Initiatives

Infrastructure, which includes data centers, supply chains, transportation, manufacturing, waste management, and various industrial operations and processes, is a key area companies are targeting for carbon reduction. These areas tend to be high-carbon-output generators. In this section, we explore some infrastructure initiatives.

Data Center Optimization

AI is playing an important part in data center transformation, including making data centers more energy-efficient to address environmental and cost concerns. Data center infrastructure has undergone significant transformation over the last five years to support the immense growth in data traffic volumes that accompanies accelerating developments around digital transformation, e-commerce, outsourcing, and the move to cloud computing.

Major data center providers like Amazon, Facebook, Google, Huawei, and Microsoft use AI to optimize their data centers. This includes precisely managing and predicting cooling system demand, controlling energy consumption, and forecasting availability of electricity generated by green energy sources.

Google & DeepMind AI

One of the main uses of energy in the data center is for cooling the large number of servers that comprise a modern data center. But data centers are complex environments that are difficult to optimize using conventional energy management systems. To address this problem, Google turned to its AI company, DeepMind, to develop an ML application that could automate its data center cooling systems to reduce overall energy consumption.

DeepMind developers trained several deep learning neural net models using data streamed from the thousands of sensors deployed on servers and other data center equipment, including data pertaining to various parameters and operations (e.g., temperature, pump speeds/pressure, power consumption/fluctuation). The models detected trends and anomalies in power usage, which developers were able to apply to model data center dynamics and optimize efficiency. Developers also trained additional neural nets to predict future temperatures and pressure in the data center — information used to ensure that data center operators do not exceed operating constraints that could lead to abnormal energy usage. According to the company, deploying ML in its data centers allowed Google to reduce the amount of energy used for cooling by up to 40%.[6]

Google is also leveraging its search engine and mapping dominance to get more consumers involved in carbon reduction efforts.

Powering Data Centers with Renewable Energy

The most straightforward way to reduce data centers' carbon footprint is to run them entirely on renewable energy. But this is not as easy as it sounds, because energy from renewable sources such as wind and solar is intermittent. Consequently, green energy may simply not be available for purchase when needed.

Data center providers are using AI to address this problem. For example, Google used DeepMind to build a predictive modeling application that helps its data center operators predict how much energy a particular wind farm will generate in a specific period. This knowledge allows engineers to better plan data center energy consumption needs and has led to significant cost reductions.

AI for Traffic Optimization & Sustainable Flights Selection

Companies, government agencies, and other organizations, often in consort, are building AI systems that analyze geographic and other location data for a range of applications. Some of the more popular include transportation optimization like traffic control and airline flight selection.

Google

Google is developing AI applications for optimizing the efficiency of traffic signals in order to reduce congestion and reduce CO2 emissions by limiting the amount of time vehicles spend idling in traffic. The goal is to make routes more efficient across an entire city or roadway network. An initial pilot conducted at four intersections in Israel used predictive analytics to predict traffic conditions and other ML algorithms to improve the timing of when traffic lights change. Google claims it is seeing a 10%-20% reduction in fuel consumption and delay time at intersections.[7] A similar project is in the works to apply the technology in Rio de Janeiro.

Google is also leveraging its search engine and mapping dominance to get more consumers involved in carbon reduction efforts. This includes fuel-efficient routing with Google Maps and providing information on the carbon footprint of flight options on Google Flights:

- **Google Maps and most fuel-efficient routing.** Daily automobile travel is a very carbon-intensive activity. Google has added a new feature to Google Maps that lets users choose the most fuel-efficient driving route and estimates that this has the potential to avoid adding over 1 million tons of carbon emissions per year (i.e., equal to removing more than 200,000 cars from the road). This feature should appeal to both climate-conscious and non-climate-conscious consumers because it will save users money at the pump by reducing their vehicles' fuel consumption. This feature became available in the US in October 2021. It will be available in Europe in early 2022.

- **Google Flights and carbon estimation.** Currently, users can view carbon emissions information alongside the price and duration of flight information when they search Google Flights.[8] To produce these estimates, Google Flights combines data from the European Environmental Agency (EEA) with flight-specific data provided by airlines and others, including type of aircraft, trip distance, and the number of seats in each seating class. Google/Alphabet CEO Sundar Pichai discusses this and other Google sustainability efforts on his blog.[9]

TranSEC

Government agencies, businesses, universities, and other organizations are working together to build AI systems that analyze geo-mapped and other location-based data. There is considerable innovation in this area, particularly involving the implementation of traffic planning and safety applications that deliver the added benefit of reducing vehicle carbon footprints by reducing unnecessary drive times and vehicles stuck idling in traffic.

TranSEC (which stands for transportation state estimation capability) is a big data and ML application that analyzes driver data to track and alleviate urban traffic congestion.[10] It was developed by the US Department of Energy's Pacific Northwest National Laboratory (PNNL) to provide urban transportation analysts and traffic engineers with detailed information about city traffic patterns in order to relieve bottlenecks and other problems.

Most publicly available traffic information at the street level is sparse and incomplete. Consequently, traffic engineers have had to rely on isolated traffic counts, collision statistics, and speed data to determine roadway conditions. In contrast, TranSEC integrates anonymized GPS traffic data sets sourced from hundreds of thousands of online Uber drivers with other publicly available traffic sensor data to map street-level traffic flow over time. This big data integration and ML analysis capability provides a more encompassing picture of city traffic, including a method detailing how traffic is actually moving around cities.

Basically, TranSEC provides street-level estimation over a large metropolitan area. Moreover, the tool (and its models) is portable, so cities can apply it to any urban area where aggregated traffic data is available. TranSEC differs from consumer smartphone traffic apps like Waze. While the latter is designed for individual drivers trying to get from point A to point B, city traffic engineers are concerned about how to help *all* vehicles get to their destinations efficiently. This difference is key. For example, a route that is efficient for an individual driver could possibly lead to too many vehicles trying to access a road that was not built to handle high traffic volume. TranSEC also has a capability most other traffic monitoring applications lack: it can analyze sparse and incomplete information.

In one pilot application, which used public data from the entire 1,200-square-mile Los Angeles, California, metropolitan area, the PNNL team reduced the time needed to create a traffic congestion model from hours to minutes.[11] This is significant because it demonstrates that real-time (or near-real-time) traffic analysis is feasible.

TranSEC's ML component improves the accuracy of analyses over time; as the tool ingests and processes more data, it becomes more refined. Here, the importance of ML analysis for traffic monitoring applications shows its worth, by providing the ability to understand how disturbances spread across networks. Fed enough data, ML can predict impacts so that traffic engineers can create strategies to work around them.

PNNL researchers used a graph-based model combined with novel sampling methods and optimization engines to learn both the travel times and the routes. TranSEC has applications beyond roadway traffic optimization, including uses in analyzing transit and freight traffic. PNNL plans to make TranSEC available to municipalities nationwide. Researchers could also apply it to other scenarios, such as autonomous vehicle routes. TranSEC core technology is available for licensing for all fields of use. It is scalable and can be used with high-performance computing for building full-scale city models or desktop computers for smaller-scale modeling applications.

Machine Vision & ML for Waste Management

Companies are using machine vision and ML to develop smart camera applications for optimizing waste management and recycling operations (e.g., to support smart cities projects, governments are equipping dumpsters with smart cameras that measure and track waste production).

By analyzing this waste output data, operators can optimize their waste collection services by eliminating unnecessary dumpster pickups, enabling cities and companies to shrink their carbon footprints and reduce costs. Additionally, AI-powered smart camera technology can identify contaminants in recycling streams for removal prior to entering a recycling facility.

Compology

Compology's smart camera and complementary smart metering software is designed to modernize recycling infrastructure by identifying contaminants in recycling dumpsters before they contaminate loads in a processing facility. It also measures and tracks waste production, providing users with the data they need to plan waste pickups effectively to reduce carbon emissions.

Compology's smart cameras analyze dumpsters or recycling streams to identify four key data points: fullness, content, location, and activity. This allows garbage pickup or recycling centers to operate more efficiently. Specifically, Compology's technology reduces the number of miles garbage trucks must drive and helps improve the amount of material that can be recycled by keeping it out of landfills.

McDonald's in Las Vegas, Nevada, teamed up with Global Trash Solutions (GTS) and Compology to use the latter's smart cameras and waste-metering solution to take images inside McDonald's dumpsters three times a day. By knowing just how full its dumpsters are and when they actually need to be emptied, McDonald's was able to optimize its waste and recycling service levels to match its actual waste output, allowing the franchise to cut monthly waste spend by 31%.[12]

Optimizing dumpster pickup schedules enabled McDonald's to save money and reduced the miles garbage trucks traveled by servicing each of McDonald's Las Vegas locations by approximately 8,000 miles. This, effectively, reduced carbon emissions by approximately 32 metric tons, or 640,000 pounds of CO2/year. Waste metering also uncovered that 25% of McDonald's Las Vegas dumpsters were contaminated with nonrecyclable materials.[13] Compology's smart metering system now auto-generates alerts to notify teams about specific dumpster contamination, allowing them to proactively remove the contaminants before they can foul recycling operations.

In October 2021, the US city of Miami, Florida, partnered with Compology to equip city dumpsters with smart cameras that measure how much and what types of waste are present. The city government is installing smart cameras in dumpsters in municipal buildings, police and fire stations, and parks, including the Miami Marlins' Major League Baseball ballpark. This effort will help modernize the city's recycling infrastructure and is expected to reduce waste collection costs by a projected 30%-40%.[14]

By implementing Compology's technology, the city expects to reduce CO2 emissions, traffic congestion, noise pollution, and illegal dumping, while improving code compliance and enhancing urban development efforts. Data from this initial project will underpin the design of a waste-metering program for all municipal buildings and private businesses in Miami.

Zero-Emission & Autonomous Heavy Equipment for Mining and Industry

Mining operations are some of the most carbon-intensive in the world. Naturally, mining companies are seeking ways to reduce their carbon-heavy footprints. Heavy equipment manufacturers have responded and are developing new lines of zero-emission and autonomous bulldozers, extractors, heavy haul trucks, and other equipment for mining and industrial operations.

These vehicles utilize AI in several ways. AI (ML in particular) and machine vision are crucial components of autonomous driving systems. Additionally, AI serves to analyze the extremely large volumes of data streaming from myriad sensors deployed on heavy equipment mining vehicles, ranging from real-time data from sensors measuring operating environmental conditions (e.g., temperature, humidity, road conditions) to the state of key onboard components like battery energy usage, engine and power train KPIs, wear-and-tear, load-bearing hydraulics, and so on.

Caterpillar

Caterpillar has several zero-emission/autonomous earth-moving machine projects underway. This includes the Cat D11 XE electric drive dozer prototype. Another is the Cat R1700 XE LHD underground loader, featuring full battery electric propulsion, which generates significantly less heat and noise.[15] It has a 16.5-ton payload and 11.2 mph top speed and offers multiple levels of autonomy, including line-of-sight remote, tele-remote, and copilot (i.e., requiring only directional input from the operator) operation. Additional components available offer fully autonomous capabilities.

Cat 793 220-ton zero-emissions autonomous haul trucks are currently under development. In September 2021, Caterpillar and mining conglomerate Rio Tinto signed a memorandum of understanding in which the latter will assist Caterpillar in developing these zero-emissions heavy trucks, including testing them in preproduction trials at Rio Tinto's Western Australian mining operations.[16]

No definite date has been given for when Rio Tinto will deploy the trucks in production. However, Rio Tinto Chief Commercial Officer Alf Barrios stated, "We should be able to validate these zero-emissions haul trucks in just a few years' time."[17] It is anticipated that the first operational deployment of the new zero-emissions trucks will consist of 35 vehicles at Rio Tinto's Australian Gudai-Darri mine.

Conclusion

This article provides some examples of how companies and governments are applying AI and complementary technologies to help create a greener, more sustainable world. In reality, there are too many use cases to cover.

The most important takeaway from these findings is that the technologies are currently available and that innovative organizations are now applying them to make progress with their decarbonization and other sustainability initiatives.

Finally, having researched this article, I believe it will not be a lack of advanced technologies that prevents the world from averting globally disruptive climate changes — the technology exists today — but rather a lack of will on the part of our political leaders.

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