Sustainable Utilities

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1. Introduction

If we parse the title of this paper we end up with two words that may or may not be related. "Sustainable," in the context used here means *"…relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged."*[1] The closest recent paper that I posted on sustainability is described and linked below.

A Circular Jet Fuel: *This paper will explore three interrelated issues. The first is the circular economy model. The second issue is greenhouse gas emissions, more specifically carbon dioxide (CO_2) emissions. The third and main issue is sustainable aviation fuel.*

https://energycentral.com/c/ec/circular-jet-fuel

Although most of the above post is related to very low carbon jet fuel, it starts by explaining the circular economy model, which is closely related to sustainability.

A utility (again, in this context) means "*A commodity or service, such as electricity, water, or public transportation that is provided by a public utility.*"[2]

Given the above definitions, I would say that *a sustainable utility provides a commodity or service using methods so that resources are not depleted or permanently damaged*.

Also since this is Energy Central, we might consider throwing in a few words about energy. However, we (the worlds' utilities) are currently completely revamping our energy production and will use systems to minimize climate change. Thus, I believe that all of the utilities are on the front line of this battle as described below.

Electric Utilities: These will move from generation methods that produce greenhouse gases (GHG) to methods that produce very little GHG. Electric utilities will offset any residual GHG emissions using negative emission technologies. Also, electric utilities need to do this while expanding electric production to service new consumption by users that are transitioning away from using GHG-emitting energy.

Water Utilities: Promote the use water with little waste, and minimize the use of energy while only using electric energy and producing electricity via hydroelectric and other renewable methods (note: See "Project Nexus" linked below).

https://energycentral.com/c/rm/project-nexus-water-energy-integration-future

Gas Utilities: Transition from geologically produced natural gas to renewable natural gas, and other fuel-gasses derived only from electricity and biogenic production.

[1] Merriam Webster listing for sustainable, https://www.merriam-webster.com/dictionary/sustainable

[2] The Free Dictionary listing for utilities, https://www.thefreedictionary.com/utilities

Solid Waste Utilities (garbage collection and processing): Transport the waste and recycle as much of the solid waste as possible using only electric energy. Use landfill gas to produce electric energy.

Public Transit Utilities: Use only electric energy or renewably produced fuel (green hydrogen for instance) for all mass-transit vehicles.

The remainder of this post will explore the above use cases. In many cases this will by referencing earlier posts.

2. Electric Utilities

There are many methods to produce electricity while producing minimal greenhouse gas, and I believe I have covered most of these in earlier posts. In most cases the most recent posts are probably the most relevant today. Thus I will send you to my directory of earlier posts, and to sections in this directory that contain the posts of interest. I will include comments for each method below.

Directory:

https://energycentral.com/c/ec/papers-directory-second-quarter-2022-update

Start with the Index. There are separate sections for solar generation / storage (section 18), wind generation (section 20) and nuclear generation (Section 25). From the index you can either click on section headings and be taken there, or click on individual papers (ditto). Once you are at the beginning of a section, the earliest papers are first (at the time this directory was last updated, and I update this at the beginning of each quarter).

Also I periodically post an update on solar/storage, I recently posted one of these (not in the current directory), and this is linked below.

https://energycentral.com/c/cp/pv-and-storage-late-summer-2022

And I posted an earlier paper right after the last directory update (ditto):

https://energycentral.com/c/cp/major-pv-storage-projects-early-summer-2022

Also, a recent offshore wind post, not in the current directory, is linked below.

https://energycentral.com/c/cp/oceanic-solutions-%E2%80%93-introduction-offshore-wind

Previously I also covered major on-shore wind projects, but I discontinued this a couple of years ago. On-shore wind turbines are different (much smaller) than off-shore turbines, and have come to be commodity products. Also much on the capacity increase in onshore projects is through repowering and expansion of existing projects. Off-shore projects are just starting their initial build-outs now, and these will account for most wind-capacity expansion over the next few years.

Back to the Index – there are other sections for other renewables and renewable fuel:

- Biomass, Section 12
- Hydrogen, Section 13
- Misc. Renewables, Section 15

I cover Geothermal under the last section and I recently posted the last paper on these technologies, linked below.

https://energycentral.com/c/gn/hot-rocks-part-3-%E2%80%93-widespread-geothermal-power

3. Water Utilities

First of all there are two types of water utilities – domestic water distribution and irrigation agencies. Both are frequently public utilities.

Water utilities and electric utilities are tightly tied together through both generation and load. Where I live (California) much of our electricity comes hydroelectric generation (13.6% in 2020). I recently completed a three-part series on hydro-power linked below.

https://energycentral.com/c/gn/hydro-%E2%80%93-beginnings-birth-grid

https://energycentral.com/c/gn/hydro-%E2%80%93-management

https://energycentral.com/c/gn/hydro-%E2%80%93-part-3-small-hydroelectric-plants

On the load side, the Western U.S. continues to suffer under a long-term severe drought. …*The Southwest, California, and even parts of the Northwest have been stuck in a 20+ year mega-drought, influenced by climate change. While this mega-drought has improved or worsened at times, the last two years have been particularly dry for the West as a whole.*[3]

However, we have a massive water supply on the U.S. West Coast (aka, the Pacific Ocean), we just need to remove the salt. This is typically done via reverse osmosis desalinization, which requires a huge amount of electricity. I explored this in a paper posted a few years ago, which is linked below:

https://www.energycentral.com/c/ec/watts-and-water

There are many other connections between water and electric supply, and I explored these in a post less than a year ago, this is linked below:

https://energycentral.com/c/rm/water-world

4. Gas Utilities

One might think that natural gas utilities (and their supporting production companies) would go out of business at some point in the future. After all, they currently produce their primary product (geologically produced natural gas) by drilling holes in the ground and extracting natural gas and injecting it into a leaky distribution and storage systems. Also everyone agrees that, when it is leaked or combusted, the use of geologically-sourced natural gas is a primary contributor to greenhouse gasses (GHG) and thus climate change.

I would say: "Not so fast." I would agree that the above scenario needs to cease at some point, but in the interim many users will need to transition to some very-low-GHG combustible gas that will work with the existing infrastructure. It is generally agreed that

[3] NOAA, National Integrated Drought Information System (NIDIS), "Western Drought Status Update: July 2022," https://www.drought.gov/documents/western-drought-status-update-july-2022

this will probably be renewable natural gas (a.k.a. biomethane), for some time, then evolve to hydrogen as the infrastructure is upgraded to support this. Some industry/utility needs to produce, store and distribute these gasses, and what better utility than one that already does this with a similar gas. This and related issues were explored in the paper posted a bit over a year ago, which is linked below.

https://energycentral.com/c/cp/tech-race

5. Solid Waste

There are two issues here:

1. Refuse trucks are responsible for most transportation of refuse to disposal and recyclable facilities, and
2. The circular-economy issue of recycling.

We will deal with these one at a time.

5.1. Refuse Trucks

There are quite a few good sources for electric refuse trucks and excellent incentives for these (at least in California). See subsection 3.2.1 in the post linked below.

https://energycentral.com/c/ec/electric-trucks-and-buses-california

5.2. Recycling

This will be the longest subsection of the paper, mainly because I found an excellent article about using artificial intelligence (AI) to sort recyclables in a recent IEEE Spectrum.

It's Tuesday night. In front of your house sits a large blue bin, full of newspaper, cardboard, bottles, cans, foil take-out trays, and empty yogurt containers. You may feel virtuous, thinking you're doing your part to reduce waste. But after you rinse out that yogurt container and toss it into the bin, you probably don't think much about it ever again.[4]

The truth about recycling in many parts of the United States and much of Europe is sobering. Tomorrow morning, the contents of the recycling bin will be dumped into a truck and taken to the recycling facility to be sorted. Most of the material will head off for processing and eventual use in new products. But a lot of it will end up in a landfill.

So how much of the material that goes into the typical bin avoids a trip to land-fill? For countries that do curbside recycling, the number—called the recovery rate—appears to average around 70 to 90 percent, though widespread data isn't available. That doesn't seem bad. But in some municipalities, it can go as low as 40 percent.

What's worse, only a small quantity of all recyclables makes it into the bins, just 32 percent in the United States and 10 to 15 percent globally. That's a lot of material made from finite resources that needlessly goes to waste…

[4] Jason Calaiaro, IEEE Spectrum, "AI Takes a Dumpster Dive," July 2022 paper issue, This article is available on-line but you need to be an IEEE Member to access the full content.

There is a way to do better. Using computer vision, machine learning, and robots to identify and sort recycled material, we can improve the accuracy of automatic sorting machines, reduce the need for human intervention, and boost overall recovery rates.

My company, Amp Robotics, based in Louisville, Colo., is developing hardware and software that relies on image analysis to sort recyclables with far higher accuracy and recovery rates than are typical for conventional systems. Other companies are similarly working to apply AI and robotics to recycling, including Bulk Handling Systems, Machinex, and Tomra. To date, the technology has been installed in hundreds of sorting facilities around the world. Expanding its use will prevent waste and help the environment by keeping recyclables out of landfills and making them easier to reprocess and reuse…

By the 1990s, hyperspectral imaging, developed by NASA and first launched in a satellite in 1972, was becoming commercially viable and began to show up in the recycling world. Unlike human eyes, which mostly see in combinations of red, green, and blue, hyperspectral sensors divide images into many more spectral bands. The technology's ability to distinguish between different types of plastics changed the game for recyclers, bringing not only optical sensing but computer intelligence into the process. Programmable optical sorters were also developed to separate paper products, distinguishing, say, newspaper from junk mail.

So today, much of the sorting is automated. These systems generally sort to 80 to 95 percent purity—that is, 5 to 20 percent of the output shouldn't be there. For the output to be profitable, however, the purity must be higher than 95 percent; below this threshold, the value drops, and often it's worth nothing. So humans manually clean up each of the streams, picking out stray objects before the material is compressed and baled for shipping…

We've pushed the current systems as far as they can go. Only AI can do better.

Getting AI into the recycling business means combining pick-and-place robots with accurate real-time object detection. Pick-and-place robots combined with computer vision systems are used in manufacturing to grab particular objects, but they generally are just looking repeatedly for a single item, or for a few items of known shapes and under controlled lighting conditions. Recycling, though, involves infinite variability in the kinds, shapes, and orientations of the objects traveling down the conveyor belt, requiring nearly instantaneous identification along with the quick dispatch of a new trajectory to the robot arm…

AI makes it theoretically possible to recover all of the recyclables from a mixed-material stream at accuracy approaching 100 percent, entirely based on image analysis. If an AI-based sorting system can see an object, it can accurately sort it.

Consider a particularly challenging material for today's recycling sorters: high-density polyethylene (HDPE), a plastic commonly used for detergent bottles and milk jugs. (In the United States, Europe, and China, HDPE products are labeled as No. 2 recyclables.) In a system that relies on hyperspectral imaging, batches of HDPE tend to be mixed with other plastics and may have paper or plastic labels, making it difficult for the hyper-spectral imagers to detect the underlying object's chemical composition.

An AI-driven computer-vision system, by contrast, can determine that a bottle is HDPE and not something else by recognizing its packaging. Such a system can also use *attributes like color, opacity, and form factor to increase detection accuracy, and even sort by color or specific product, reducing the amount of reprocessing needed. Though the system doesn't attempt to understand the meaning of words on labels, the words are part of an item's visual attributes.*

We at Amp Robotics have built systems that can do this kind of sorting. In the future, AI systems could also sort by combinations of material and by original use, enabling food-grade materials to be separated from containers that held household cleaners, and paper contaminated with food waste to be separated from clean paper…

It's hard enough to train a neural network to identify all the different types of bottles of laundry detergent on the market today, but it's an entirely different challenge when you consider the physical deformations that these objects can undergo by the time they reach a recycling facility. They can be folded, torn, or smashed. Mixed into a stream of other objects, a bottle might have only a corner visible. Fluids or food waste might obscure the material.

We train our systems by giving them images of materials belonging to each category, sourced from recycling facilities around the world. My company now has the world's largest data set of recyclable material images for use in machine learning.

Using this data, our models learn to identify recyclables in the same way their human counterparts do, by spotting patterns and features that distinguish different materials. We continuously collect random samples from all the facilities that use our systems, and then annotate them, add them to our database, and retrain our neural networks. We also test our networks to find models that perform best on target material and do targeted additional training on materials that our systems have trouble identifying correctly…

Today's recycling facilities use mechanical sorting, optical hyper-spectral sorting, and human workers. Here's what typically happens after the recycling truck leaves your house with the contents of your blue bin…

The first stage is the presort. Human workers remove large or problematic items that shouldn't have made it onto collection trucks in the first place—bicycles, big pieces of plastic film, propane canisters, car transmissions.

Sorting machines that rely on optical hyperspectral imaging or human workers separate fiber (office paper, cardboard, magazines…) from the remaining plastics and metals. In the case of the optical sorters, cameras stare down at the material rolling down the conveyor belt, detect an object made of the target substance, and then send a message to activate a bank of electronically controllable solenoids to divert the object into a collection bin…

The non-fiber materials pass through a mechanical system with densely packed camlike wheels. Large items glide past while small items, like that recyclable fork you thoughtfully deposited in your blue bin, slip through, headed straight for landfill—they are just too small to be sorted. Machines also smash glass, which falls to the bottom and is screened out.

The rest of the stream then passes under overhead magnets, which collect items made of ferrous metals, and an eddy-current-inducing machine, which jolts nonferrous metals to another collection area.

At this point, mostly plastics remain. More hyperspectral sorters, in series, can pull off plastics one type—like the HDPE of detergent bottles or the PET of water bottles—at a time.

Finally, whatever is left—between 10 to 30% of what came in—goes to landfill…

6. Transit Utilities

These are complex networks managed by multiple nested agencies. A good example of these are my home state's (California's) two major metropolitan areas: the San Francisco Bay Area and Southern California (LA and San Diego). The largest transit agencies are described in last year's post linked directly below, in sections 5 and 6. Sections 2 through 4 describe the High-Speed Rail (HSR). The first segment of the latter is currently being built in our Central Valley. Also a 2022 update to the post linked below was posted on September 1. The 2022 update is the second link below. HSR will use direct electric propulsion via an overhead catenary system.

https://energycentral.com/c/ec/california-rail-electrification-2021-update

https://energycentral.com/c/ec/california-rail-electrification-2022-update

Right now the focus for the non-HSR transit agencies is in two areas:

1. Electrify all busses for all agencies
2. Electrify all tracked non-HSR rail systems for all agencies

6.1. Buses

Regarding California, the California Air Resources Board (CARB) has created the Innovative Clean Transit (ICT) Regulation: The ICT regulation was adopted in December 2018 and requires all public transit agencies to gradually transition to a 100 percent zero-emission bus (ZEB) fleet. Beginning in 2029, 100% of new purchases by transit agencies must be ZEBs, with a goal for full transition by 2040. It applies to all transit agencies that own, operate, or lease buses with a gross vehicle weight rating (GVWR) greater than 14,000 lbs. It includes standard, articulated, over-the-road, double-decker, and cutaway buses.[5]

California is also offering generous rebates for EV buses. See section 3.1 in the paper linked below:

https://energycentral.com/c/ec/electric-trucks-and-buses-california

6.2. Trains

There appear to two approaches to electrifying existing passenger trains:

1. Heavy rail: full electrification via the installation of overhead catenary system.
2. Light rail or heavy rail: renewable fuel, probably hydrogen, plus fuel cells or gas turbines (see the post linked below).

https://energycentral.com/c/ec/hydrail

[5] CARB, "Innovative Clean Transit (ICT) Regulation Fact Sheet," May 2019, https://ww2.arb.ca.gov/resources/fact-sheets/innovative-clean-transit-ict-regulation-fact-sheet