Landfill Mining And Reclamation

One of the first questions any green project (or aspirational fiction setting) gets is “where do the raw materials come from?” Sometimes this is sincere, sometimes it's meant to be a gotcha.

It's important to remember that an alternative can be better without being perfect, and that an improvement on the status quo can still be ugly in its own right. But we also have more options than we think we do.

In our page on long-lasting stuff we discussed a few ways a solarpunk society could scale back new production while still meeting peoples' needs by changing how and why it makes things. If your setting is extremely committed to degrowth, and perhaps willing to do without sometimes, they might be able to manage something close to a closed system where recycling meets the majority of their input requirements.

But it's unlikely that it will be able to cover everything. Not all materials can be reused forever, they may get contaminated, lost, or need to be refreshed with new stock.

Thanks to centuries of extractive industry a tremendous amount of refined materials are already present and easily accessible on the surface of the earth. Recovering them from things like cars and buildings is likely an important part of any circular economy.

Another likely source is landfill mining.

Landfill Mining

Landfill mining is a process which excavates and processes solid wastes which have previously been dumped in a landfill. The goal is generally to recover one or all of the following: recyclable materials, a combustible fraction (meaning stuff you can burn for energy), reusable soil/compost, and landfill space. Most real life landfill mining examples I've found are of old, unlined pits which were filled before modern safety requirements and the widespread practice of sorting and recycling trash.

Beyond gleaning materials, there are a few reasons to mine landfills:

Though a solarpunk society will no doubt strive to throw out as little as possible, there's always going to be some true waste for which long term storage is probably the best solution. Landfill space is limited and the construction of new landfills is likely to be even more tightly restricted in a solarpunk setting. Landfill Mining can be used to remove a huge amount of reusable stuff and clear space in a landfill which has already been grandfathered in.

It can also be an opportunity for a do-over - if you're already digging everything out of the pit and sorting it, you can use that as an opportunity to remediate poorly designed or improperly operated landfills and to upgrade landfills that do not meet environmental and public health specifications.

Old landfills are often essentially a layered hole full of an unsorted mix of trash, everything from kitchen waste to appliances (also called white goods), building debris, automobiles and parts, electronics, and more. In a unlined, uncapped pit, water can move freely through the site, picking up heavy metals, persistent organic pollutants such as mineral oil and PAH, VOCs, pesticides and PCBs, and fuels, forming a toxic leachate which can migrate with the flow of groundwater, contaminating soil, wells, aquifers, and springs which feed surface water bodies.

Improving these sites would entail emptying the pit, sorting and shipping out the salvageable stuff, doing the necessary soil and groundwater testing and any environmental restoration, and building proper lined (and eventually capped) pits to contain whatever waste couldn't be salvaged.

Landfill Mining can even be used to empty out and close a landfill for good, removing a potential safety hazard and opening the land to restoration or some other use such as redevelopment. This is sometimes done in the US, where the 30-year monitoring requirements from date of closure mean that a landfill which is not in use still (correctly) remains an ongoing budget expense for the community (in addition to the often untracked ecological and health costs).

What kind of stuff can you get?

The available materials will depend on what purpose the landfill was put to, when it was operational, and the neighboring community and industries it served.

For example, Construction and Demolition (C&D) waste makes up about 25-40% of total landfill waste in many regions. The majority of this waste is concrete rubble. Also industrial landfills may contain a much narrower collection of waste products. Just the same, older unlined pits tend to be mixed waste; and the mixed-waste landfill is still the most common landfill type worldwide.

From a narrative perspective there's a lot of potential here, from the cold open where a mining crew finds something life changing (good or bad) to the treasure-hunt nature of the research into whatever documentation still remains on operational procedures and potential customers, to the almost archeological work of sifting through the strata of garbage.

Generally landfill mining can obtain all of the following rough categories, though in the present day not all sites bother exploiting each resource, usually for reasons of cost. In a solarpunk setting it may be safe to assume that the cheapest and most damaging alternatives are prohibited or otherwise ruled out, so sourcing them from landfill mining may be much more reasonable.

The resources:

Soil - Landfills often contained a lot of organic matter. Kitchen scraps and food waste, fall leaves if they weren't burned, various forms of animal waste, and similar. A buried landfill might not be the ideal site for composting but if it's been going long enough the organic waste has likely broken down fairly well. Combine that with the practice of periodically burying the garbage for smell, scavenger and hygiene reasons, and it's likely that a fair portion of the landfill is soil:

“The soil fraction recovered by mining typical landfilled MSW will probably comprise the largest percentage by weight of all materials; a range of 50% to 60% can be expected, although values from 30% to 70% have been reported. The ratio of soil to other materials depends upon the type of waste landfilled, landfill operating procedures, and the extent of degradation of the landfilled wastes.”

Examples from this article mentioned the soil fraction testing clean enough to be used as results of analyses indicated that it qualified for off-site use as clean fill in public construction projects or returned to use as daily landfill cover. However given that the paper is somewhat old, and the examples are even older, I'd be skeptical that the tests covered all the dangerous contaminants we track today.

Our page on phytoremediation has a few examples of ways soil can be cleaned if necessary.

Fuel - a portion of the excavated waste can be burned in a municipal waste combustor (MWC) to produce heat and energy. This one might be contentious within a solarpunk setting. A properly-built and -filtered Municipal Waste Combustion facility should catch a lot of the pollution and it's a common answer for turning a waste product into energy in the present day, but it still releases greenhouse gasses and other contaminants. In fact when I was researching the section on “contaminants and where they come from” for the Phytoremediation page, I was struck by how many resources I found listed incineration of municipal solid wast or medical waste as a main cause for human exposure.

It seems like this component is essentially the leftover materials, and would include paper, wood, fabrics, and whatever plastics and rubber isn't otherwise recovered: “In a typical LFMR operation, once the oversize non-processibles, the dirt fraction, and the ferrous metals are removed, the remaining material may be recovered as fuel for a waste-to-energy facility, processed for recovery of other recyclables, or landfilled as residue.”

Combustible reclaimed waste burns less efficient than cleaner waste so it is usually mixed with fresh municipal solid waste:

“Mined material is combusted with raw MSW in a ratio of about 1:3 (weight basis). Earlier tests using unscreened mined material required a ratio of 1:7 or 1:8 in order to maintain design conditions for combustion, due to the relatively low heating value of mined wastes.”

Recyclable materials - Landfill waste contains many recyclable resources including metals, glass, and plastics. The most valuable are metals such as aluminum cans and assorted steel, iron, and copper scrap.

From what I've read, it looks like metals are the easiest to recover, probably because they're easier to sort from one another and less damaged by being mixed with dirt etc (since refining metals from lower-content ore is a pretty well-solved industrial challenge at this point). The concentration of aluminum in landfills can be as high as in mined ore deposits.

Discarded electronics can contain gold, platinum group metals, and scarce rare earth metals. This is far from a complete list of metals - anything previously used in manufactured products, from lead to titanium will be present in some amount.

White goods and scrap metal will require cleaning to remove soil, and then the material can be sorted, baled, and sold. This can happen onsite or at a materials recovery facility depending on local logistics and the cost of transportation.

Similarly, this article talks about recovering rare earth elements from coal ash landfills. I'm not sure to what extent this kind of waste appears in municipal landfills but I feel it still qualifies as a form of landfill mining. This article mentions a similar result with ash waste from a municipal incinerator being easier to process for metals than municipal solid waste.

As for plastics, recovered plastics can be even more challenging to recycle than metals:

“The reprocessing of excavated plastics is particularly challenging due to the high presence of organic and inorganic contaminants, large variability in polymer types and grades, and the possible occurrence of chemical and thermo-oxidative degradation. For these reasons, energy recovery” (burning) “is often indicated as the most suitable route for the valorization of landfill-recovered plastic (LRP). LRP composition depends on the nature of the landfill (municipal, industrial) and on changes in the waste-stream input over the years.”

This paper provides some recommendations on how these plastics could be reused:

https://pmc.ncbi.nlm.nih.gov/articles/PMC6419269/

With a bit of overlap with bioremediation, this paper describes a process for using microorganisms to turn a specific type of waste product into a drug which treats Parkinson's.

Other Information about Recovered Resources:

It sounds like closed/sealed landfills are more hazardous to work on because they haven't had as much time to settle/decompose/leach out, but may also have more intact contents.

As far as using landfills as a source for raw materials, there are a other few advantages over mining ore directly from the earth:

- It's already a disturbed site. Any existing landfill is essentially acres of land which have already been put to a pretty destructive use.
- If done right, landfill mining can actually improve environmental health and public safety by removing a source of contaminants in ground and surface water.
    - Traditional mining, by contrast, often has terrible impacts on the environment, both by removing and reshaping the landscape and by contaminating the surrounding land with runoff or windblown dust.
- Landfills are, by design, easily accessible. They're located near human settlements and connected to road and sometimes rail networks, or in some cases, ports for ships/boats. This means the landfill mining operation doesn't need to build the kind of inroads through pristine land to access remote mining sites that traditional operations may require.

What Does Landfill Mining Look Like?

The term mining is actually pretty accurate, as the operation tends to look a lot like an open pit mine, with heavy equipment digging huge holes through layers of soil and trash and other equipment transporting and sorting it.

You would likely see:

- Excavators (likely backhoes, clamshells, and front end loaders).
- Moving floor and elevator conveyor belts
- Rotating trommel screens (in different sizes from coarse to fine)
- An electromagnet
- An air classifier(?)
- Odour control sprayer
- Dump trucks and trailers
- Monitoring equipment (e.g., a combustible gas meter, a hydrogen sulfide chemical reagent diffusion tube indicator, an oxygen analyzer, or any equipment specific to known contaminants of concern)

A lot of this assembly line is transported on trucks from site to site, or directly mounted on trailers.

The general process looks something like this:

- People use excavators or front end loader to uncover the landfilled materials and place them on a moving floor conveyor belt to be taken to the sorting machinery.
- a rotating trommel screen is used to separate materials by size.

    - First, a large trommel separates materials like appliances and fabrics.
    - A smaller trommel then allows the biodegraded soil fraction topass through leaving non-biodegradable, recyclable materials on thescreen to be collected.
    - The size and type of screen used depends on the end use of the recovered material. For example, if the reclaimed soil typically is used as landfill cover, a 2.5-inch screen is used for separation. If, however, the reclaimed soil is sold as construction fill, or for another end use requiring fill material with a high fraction of soil content, a smaller mesh screenis used to remove small pieces of metal, plastic, glass, and paper.
    - Trommel screens are more effective than vibrating screens for basiclandfill reclamation. Vibrating screens, however, are smaller, easierto set up, and more mobile. The large holes in the screen allow most wastes to pass through, leaving behind the over-sized, non-processable materials. The over-sized wastes are removed from in-side the screen. The coarse trommel empties into the fine rotating trommel. The fine rotating trommel allows the soil fraction to pass through, leaving mid-sized, non-biodegradable, mostly recyclable materials.
- These materials are placed on another conveyor belt and an electromagnet is used to remove the ferrous material from the waste mass as it passes along underneath.
- Some sources reference using an air classifier to separate light organic materials from heavy organics. (The examples in the wiki link are big installations but I did find some trailer-mounted portable examples).
- A front-end loader is used to move sorted materials to trucks for further processing (or for return to a lined pit). For organic materials this would include testing to determine any contaminants which would bar reuse.
- Odour control sprayers are wheeled tractors with a cab and movablespray arm mounted on a rotating platform. A large reservoir tankmounted behind the cab holds neutralizing agents, usually in liquidform, to reduce the smell of exposed wastes

Resources

The wikipedia page gives a good overview of landfill mining:

https://en.wikipedia.org/wiki/Landfill_mining

These two academic papers do a good job of covering the topic in more depth, and both provide descriptions of real life examples, including their motivations and the specific class of resources which were extracted:

https://semspub.epa.gov/work/01/277818.pdf

https://www.researchgate.net/publication/287210621_Landfill_Mining_-_Process_Feasibility_Economy_Benefits_and_Limitations

This article covers some of the present-day economics around landfill mining in decent detail:

https://www.nerc.org/why-aren%E2%80%99t-we-mining-landfills

This paper talks about contaminants in the soil fraction:

https://www.sciencedirect.com/science/article/abs/pii/S0959652622027251