Emissions Reduction Evaluation

The New Jersey Department of Environmental Protection (NJDEP) approved and issued the combined renewal and significant modification of the Title V Operating Permit on October 4, 2023 to Joint Meeting of Essex and Union Counties located at 500 South First Street, Elizabeth, NJ. As required by the permit, under GR3 Ref. #1 EJ Special Conditions, the facility must submit to the NJDEP an evaluation of the following emission reduction measures:

1. Switching from fossil fuels combustion to sustainably produced hydrogen or other technically feasible carbon-free technology;
2. Installing the largest feasible solar power system at the facility;
3. Installing the maximum feasible energy storage capacity at the facility; and
4. Any other measure that reduces or eliminates fossil fuel combustion and greenhouse gas emissions from the facility.

Significant Modification Project Summary

Facilities that perform essential services for the community must address any events that may adversely affect the facility's ability to adequately perform their intended operations. Joint Meeting performs wastewater treatment for 11 municipalities in the area.

As a result of storms like Sandy, it has been determined that a Flood Mitigation Project be implemented to avoid debilitating floods caused by storms so that we can effectively continue wastewater treatment operations to better serve the municipalities that discharge to our plant.

As part of the project, the following items will be installed:

- A 10-foot-high wall around the entire facility to be able to stop the flow of any flood waters and keep them from entering our facility.

- 5 flood mitigation electric pumps to be able to overcome any anticipated storm surge from the nearby bodies of water including the Arthur Kill, which we discharge our wastewater effluent into, and the Elizabeth River, which borders our plant on the north side. These pumps will need to be exercised periodically in order to keep them in working condition in the event they are needed.

- 2 additional engines to supply the power required to run the pumps. A significant amount of power is necessary in order to overcome any anticipated storm surge. The installation of these engines in our existing Cogeneration facility which currently contains 4 engines will allow us to power the pumps and maintain operations instead of having to rely on electricity from the grid, which may not be available in the event of a power outage during a storm event.

    - Each engine has the ability to produce 800 KW of electricity and

- Up to 3 million Btu/hr of heat recovery to heat our plant hot water which is used to maintain our digesters at 95 F and to supply building heat. This is equivalent to burning 21 gal/hr of No. 2 Fuel Oil in our boilers, which is a significant savings in money and air pollution.

- Potential air emissions of the 2 new engines will be lower than the existing engines on a per engine basis due to lower annual operating time.

Hydrogen

The promise of hydrogen is based upon it being produced as green hydrogen, by splitting water with electricity, and that electricity coming from a zero-carbon energy source (renewables or nuclear). But there are many issues with trying to transition our fuel needs to use pure hydrogen. Firstly, it is a highly explosive and dangerous fuel which requires high pressures and high cooling requirements to adequately store. And second, because it is such a small and reactive molecule it is very difficult to contain and so it is predicted that there will be large amounts that will escape. These issues lead to difficulties in transporting, storing and handling hydrogen.

On our planet, hydrogen does not generate energy. It stores energy. This is because on our planet, there is essentially no hydrogen gas available. All the hydrogen is bound up with something else, mostly water, so we need to use energy to release the hydrogen from its bound state, and then hydrogen stores that energy. But the processes to release hydrogen gas and then burn hydrogen to make energy again are not 100% efficient. There are some serious losses involved. In other words, the energy needed to get the hydrogen gas, compress it, and transport it to where it is needed is significantly more than the energy we get out of the hydrogen at its destination.

Fossil fuels on the other hand provide net energy. Meaning the amount of energy required to get the fossil fuel out of the ground, refine it, and transport it to where it is needed is far less than the energy we get out of it at its destination.

Most hydrogen is locked up in water or methane which requires an input of energy to release. Currently 90% comes from steam cracking natural gas which requires a lot of energy resulting in a gas (H_2) with half the calorific value of the original gas (natural gas). It also results in a significant amount of carbon dioxide emissions which is the very greenhouse gas that we are trying to eliminate from burning fossil fuels. When producing hydrogen through steam cracking of natural gas, approximately 8-12 kilograms of carbon dioxide are emitted for every kilogram of hydrogen produced, depending on the efficiency of the process and the specific conditions used; this is considered a significant amount of CO_2 emissions. The other way to produce hydrogen is to use vast amounts of electricity to electrolyze water, resulting in more fossil fuels being burned unless renewable energy is available. Even if renewable energy is available to electrolyze water to produce hydrogen, this energy could be used toward the electricity demand of the facility instead. Therefore, more fossil fuel consumption will have to be used to compensate. So from the start, hydrogen is definitely not green due to the energy requirement to produce it.

To make matters worse, hydrogen has a nasty habit of stress cracking steel at high pressures, so all tanks would have to shed their carbon fiber and be X-ray tested once a year, which could also compromise the carbon fiber. All in all, this is a safety nightmare.

Recently we had the tragic accident of the submersible that imploded in the North Atlantic when it was diving to the Titanic. This is an example of carbon fiber weakening under repeated pressurization/depressurization cycles.

You cannot transport hydrogen efficiently. Politicians have talked about re-purposing existing natural gas networks, but you can only safely transport hydrogen by mixing it to maximum of 30% in natural gas. Hydrogen is such a small molecule it escapes 5–8 times more readily than natural gas, and the tracer mercaptan molecule that is added will not follow the hydrogen.

If you attempted to pipe 100% hydrogen down existing networks it would leak and fill up void spaces everywhere, and there would be no way to detect it. Add to this hydrogen has a much broader range of flammability and has a lower ignition energy requirement and you have another safety nightmare. You are piping an untraceable, dangerously explosive, highly escaping gas.

All of the above problems also require additional energy to be used, so when you calculate from production to usage, you have ended up emitting more carbon dioxide into the air than conventional fuels.

Joint Meeting has invested millions of dollars installing a Cogeneration facility capable of burning the biogas that is generated as a byproduct from the 4 anaerobic digesters onsite which are part of the wastewater treatment process. The facility is complete with an entire pretreatment system to clean the digester gas so that it can be sustainably burned by 4 soon to be 6 internal combustion engines and protect them from damage. These engines are also capable of running on natural gas.

To convert an engine from natural gas to hydrogen, significant modifications are needed, primarily focusing on adjusting the combustion system to accommodate hydrogen's unique properties, including its faster burning rate and lower energy density, which may require changes to fuel injection systems, ignition timing, and potentially the addition of components like direct injection systems or pilot fuel injectors to ensure stable combustion; this often involves specialized engine components and control systems designed specifically for hydrogen operation.

Key points about converting engines to hydrogen:

- Combustion challenges:
  Hydrogen burns much faster than natural gas, leading to potential issues like pre-ignition and high peak pressures, requiring adjustments to the combustion chamber design and ignition timing.
- Fuel injection modifications:
  Direct injection systems are often preferred for hydrogen engines to precisely control fuel delivery and minimize combustion issues.

- Lower energy density:
  Due to its lower energy density, more hydrogen needs to be injected compared to natural gas to achieve the same power output.
- Potential for pilot ignition:
  In some cases, a small amount of a different fuel like diesel might be used as a pilot fuel to initiate combustion in a hydrogen engine.
- Engine control unit (ECU) adjustments:
  The engine control unit needs to be reprogrammed to manage the different combustion characteristics of hydrogen.

Considerations for conversion:

- Existing engine design: Not all engines are easily adaptable to hydrogen, and some may require significant modifications or even redesign.
- Hydrogen production method: The environmental impact of the conversion depends heavily on how the hydrogen is produced.
- Infrastructure availability: Access to a hydrogen fueling station is crucial for widespread adoption.

Solar Panels

The property at Joint Meeting is very compact and crowded with wastewater treatment equipment and tanks with very little unused land to install a solar panel system. In addition, some of the unused land contains underground pipes or utility lines which cannot be covered with solar panels in the event of a leak and the ground has to be dug up, which does happen periodically.

Furthermore, the buildings at the facility are older and some are also metal fabricated with metal rooftops which would have to undergo an engineering evaluation to determine if they can sustain the weight of solar panels and if the integrity of the roof is sufficient or needs to be replaced. Typically, if the age of the roof is 15 years or more, it is recommended to be replaced prior to installing solar panels. All of the buildings at the facility are at least 15 years old and most are much older.

There is a town in Northern California, Oroville, that operates a 6.5 MGD WWTP which services 15,000 households and many industrial users.[1] In 2002, amidst an energy crisis that saw the price of utilities rise 41 percent, the Oroville Sewage Commission (SC-OR) decided to pursue solar power as a solution to reduce costs and increase energy self-reliance. That same year, the utility installed a 520 kW ground-mounted solar array capable of being manually adjusted seasonally to maximize the solar harvest. The solar array consists of 5,184 solar panels covering three acres of land adjacent to the WWTP. The total cost of the solar system, which is the fifth-largest solar energy system in the United States, was $4.83 million. Three acres is needed for a solar power system that generates only 520 kW at a whopping cost of nearly $5 million.

In comparison, the Joint Meeting was able to install a Cogeneration facility containing 4 engines of 800 kW each for $16 million in 2008. This corresponds to a cost of $5,000 per kW compared to $9,288 per

kW for solar. A comparable solar power system of 3200 kW (4 engines x 800 kW) or 76,800 kWh daily (3200 kWh x 24 hr/day) would need 38,400 solar panels assuming 1 solar panel generates 2kWh daily. At 2,000 panels per acre of land, this translates to 19 acres of land would be needed for a system of this size. This would cover 20% of the entire plant site. The unavailability of usable land suitable to build a solar panel system on the Joint Meeting property in addition to the high cost makes solar an unfeasible option for Joint Meeting especially considering the significant investment already made toward a Cogeneration facility to utilize the biogas generated onsite. In addition to the 4 engines, another 2 engines will be added to the facility as part of the Flood Mitigation project.

Downside of Solar Energy

The International Renewable Energy Agency (IRENA)'s official projections assert that "large amounts of annual waste are anticipated by the early 2030s" and could total 86 million tons by the year 2050.[2] That's a staggering amount, undoubtedly. But with so many years to prepare, it describes a billion-dollar opportunity for recapture of valuable materials rather than a dire threat. The threat is hidden by the fact that IRENA's predictions are premised upon customers keeping their panels in place for the entirety of their 30-year life cycle. They do not account for the possibility of widespread early replacement.

Using real U.S. data, they modeled the incentives affecting consumers' decisions whether to replace under various scenarios. They surmised that three variables were particularly salient in determining replacement decisions: installation price, compensation rate (i.e., the going rate for solar energy sold to the grid), and module efficiency. If the cost of trading up is low enough, and the efficiency and compensation rate are high enough, they posit that rational consumers will make the switch, regardless of whether their existing panels have lived out a full 30 years.

If early replacements occur as predicted by their statistical model, they can produce 50 times more waste in just four years than IRENA anticipates. That figure translates to around 347,130 tons of waste, based on an estimate of 99 tons per MW weight-to-power ratio.

Alarming as they are, these stats may not do full justice to the crisis, as this analysis is restricted to residential installations. With commercial and industrial panels added to the picture, the scale of replacements could be much, much larger.

The industry's current circular capacity is woefully unprepared for the deluge of waste that is likely to come. The financial incentive to invest in recycling has never been very strong in solar. While panels contain small amounts of valuable materials such as silver, they are mostly made of glass, an extremely low-value material. The long lifespan of solar panels also serves to disincentivize innovation in this area.

As a result, solar's production boom has left its recycling infrastructure in the dust. To give you some indication, First Solar is the sole U.S. panel manufacturer we know of with an up-and-running recycling initiative, which only applies to the company's own products at a global capacity of two million panels per year. With the current capacity, it costs an estimated $20–$30 to recycle one panel. Sending that same panel to a landfill would cost a mere $1–$2.

The direct cost of recycling is only part of the end-of-life burden, however. Panels are delicate, bulky pieces of equipment usually installed on rooftops in the residential context. Specialized labor is required to detach and remove them, lest they shatter to smithereens before they make it onto the truck. In addition, some governments may classify solar panels as hazardous waste, due to the small amounts of heavy metals (cadmium, lead, etc.) they contain. This classification carries with it a string of expensive restrictions including that hazardous waste can only be transported at designated times and via select routes, etc.

The same problem is looming for other renewable-energy technologies. For example, barring a major increase in processing capability, experts expect that more than 720,000 tons worth of gargantuan wind-turbine blades will end up in U.S. landfills over the next 20 years. According to prevailing estimates, only five percent of electric-vehicle batteries are currently recycled, a lag that automakers are racing to rectify as sales figures for electric cars continue to rise as much as 40% year-on-year. The only essential difference between these green technologies and solar panels is that the latter doubles as a revenue-generating engine for the consumer. Two separate profit-seeking actors, panel producers and the end consumer, thus must be satisfied in order for adoption to occur at scale.

Energy Storage

Energy storage is mostly applicable to renewable energy systems such as solar or wind power systems, however, at Joint Meeting, it is not feasible to install these systems. Additionally, since Joint Meeting operates 24 hours a day, 7 days a week, the energy generated by the Cogeneration facility is constantly being used making it unfeasible to beneficially make use of any energy storage system.

Conclusion

Joint Meeting is already doing everything that is feasible to reduce or eliminate fossil fuel combustion and greenhouse gas emissions from the facility. The facility is maximizing its use of biogas that is generated from the digesters to minimize its use of natural gas. Additionally, biogas and natural gas use is being maximized to minimize the use of fuel oil.

Furthermore, as explained in the project summary above, all engines in the Cogen facility including the two new engines to be installed as part of the flood mitigation project, incorporate up to 3 million Btu/hr of heat recovery per engine to heat our plant hot water which is used to maintain our digesters at 95 F and to supply building heat. This is equivalent to burning 21 gal/hr of No. 2 Fuel Oil in our boilers, which is a significant savings in money and air pollution. Additionally, potential air emissions of the 2 new engines will be lower than the existing engines on a per engine basis due to lower annual operating time.

References

[1] Renewable Energy Fact Sheet: Solar Cells, EPA, August 2013

[2] The Dark Side of Solar Power, by Atalay Atasu, Serasu Duran and Luk N. Van Wassenhove, Harvard Business Review, June 18, 2021