Waste Transition:

Saving the Planet and Providing Economic Prosperity

Executive summary

The United States is undergoing a significant environmental transformation involving three major themes that are converging and must be addressed to achieve "net-zero carbon", meaning the amount of greenhouse gas we add to the environment is no more than the amount removed from the atmosphere.

Converging environmental themes

- Circular economy efforts
- Increased renewable energy generation
- Reduced greenhouse gas (GHG) emissions

Circular economy efforts target a reduction in single-use waste and promote the "Three Rs": reduce, reuse, and recycle, as ways to transform waste into new assets with beneficial use. These repeated-use assets, as opposed to single-use assets, may be produced with less virgin materials, lower energy use, and lower GHG emissions.

Three Rs

- Reduce
- Reuse
- Recycle

Renewable energy generation efforts extend beyond wind and solar to include energy derived from organic wastes such as animal, agricultural, forestry, and food waste. Renewable energy from waste has a lower carbon intensity, and produces far less GHG emissions.

GHG reduction efforts in the U.S. are largely focused on the two largest GHG-emitting sectors: agriculture and transportation, sectors that are vital for feeding an ever-growing population. GHG reductions involve both CO_2 emissions from fossil fuel combustion and methane from organic decomposition.

This environmental transformation has broad and strong support.

Multi-faceted support for environmental transformation:

- **Proven technology** – Much of the technology to produce renewable energy from waste has been in existence for decades
- **Commitments & mandates** – A wave of corporate commitments and governmental mandates has created a firm foundation for future growth
- **Economic support** – Renewable energy demand and fuel credits provide strong economic support for the waste-to-energy sector
- **Capital formation** – Investors are becoming increasingly aware of the need to provide capital in support of new projects in order to achieve environmental goals

Ecofin's investments in the waste-to-energy sector are targeted to address each of these three major themes, by:

- Repurposing waste into new, beneficial assets for a more circular economy
- Producing renewable energy for electricity, transportation fuel, and heating
- Achieving significant GHG reductions through the use of waste-to-energy

Growth prospects in the U.S. waste-to-energy sector are strong given the large number of projects recently completed, in construction or planned. In addition, there is a relatively low implementation rate in the U.S. for waste-to-energy compared to other industrialized nations.

How saving the planet and economic prosperity are aligned

The lifestyle we lead generates an enormous amount of waste and with it, significant GHG emissions. Fortunately, cost-effective technologies now exist to reduce GHG emissions from waste and to create profitable by-products with compelling risk-return characteristics for investors.

Following decades of debate, the world is now mobilizing to solve this vast problem. For years, climate change advocates have asked the world to reduce its carbon footprint, but unfortunately economic incentives were not aligned. Those in the developed world became accustomed to cheap power and convenient lifestyles. Climate change advocates asked people to reduce their personal carbon footprint which ultimately meant sacrificing components of their lifestyle.

Fortunately, technology has driven the cost input curve so low that creating wealth and saving the planet are now much more aligned. One can easily observe this when studying the success of utilities and transportation companies, including electric vehicles, class 8 powertrain suppliers and electric vehicle charging companies.

Understanding global warming potentials (as written by the EPA)

Greenhouse gases (GHGs) warm the earth by absorbing energy and slowing the rate at which the energy escapes to space; they act like a blanket insulating the earth. Different GHGs can have different effects on the earth's warming. Two key ways in which these gases differ from each other are 1) their ability to absorb energy (their "radiative efficiency") and 2) how long they stay in the atmosphere (also known as their "lifetime").

The global warming potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of one ton of a gas will absorb over a given period of time, relative to the emissions of one ton of carbon dioxide (CO_2). The larger the GWP, the more that a given gas warms the earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.

- CO_2, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long time: CO_2 emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years.
- Methane (CH_4) is estimated to have a GWP of 28–36 over 100 years. CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that CH_4 is a precursor to ozone, and ozone is itself a GHG."

Cost-effective technologies now exist to not only reduce waste and GHG emissions, but to create profitable by-products. Just as in the utility and transportation industries, economic incentives to "do well by doing good" exist in the waste to energy business. Even more fortuitous is that a rapidly growing market is developing with compelling risk-return characteristics for investors.

What are methane emissions?

Applying simple chemistry, the world has lots of carbon (C), hydrogen (H) and oxygen (O_2). Virtually any organic matter that decomposes emits carbon dioxide (CO_2) and methane (CH_4). That could include grass clippings, food waste, human sewage, animal manure and flatulence/belches (enteric fermentation), and more.

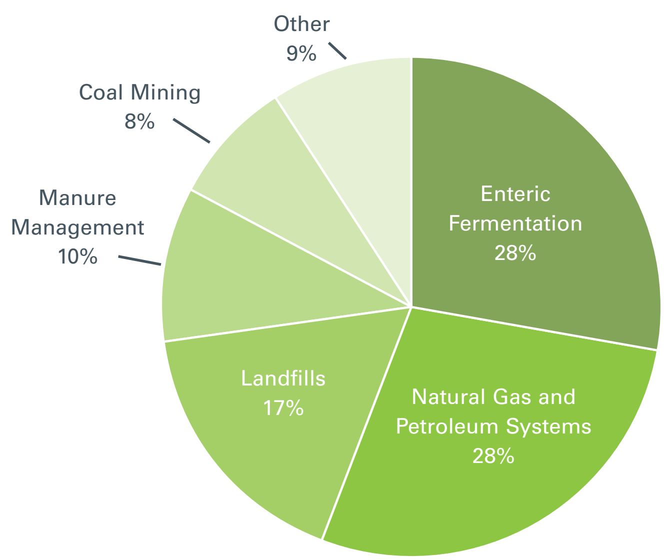
We often discuss CO_2 emissions, and they are very serious. Methane seems to be a lesser discussed topic when it comes to greenhouse gases, likely because it only accounts for 10% of GHGs and because its lifetime in the atmosphere is much shorter than CO_2. That said, according to the EPA's Overview of Greenhouse Gases, "CH_4 is more efficient at trapping radiation than CO_2. Pound for pound, the comparative impact of CH_4 is 25 times greater than CO_2 over a 100-year period." If we want to get to a net-zero carbon world by balancing the amount of emitted greenhouse gases with the equivalent emissions that are either offset or sequestered – and we do - this is an extremely serious issue that needs to be addressed.

Besides just eliminating waste (which is virtually impossible), we can turn most of this waste into three component parts: recycled water, solid waste that can be used as an organic fertilizer, and most importantly, renewable natural gas. The American Gas Foundation defines renewable natural gas (RNG) as gas coming from "biomass or other renewable resources [that] is a pipeline-quality gas [and] is fully interchangeable with conventional natural gas." In other words, renewable natural gas, in layman's terms, is cleaned up methane.

What are the biggest sources of methane?

Methane comes from many sources including landfills (trash dumps), animal manure and enteric fermentation (from dairy cows, swine, and poultry), waste water (sewage), food processing, and forestry. With the exception of natural gas/petroleum systems and coal, nearly all methane comes from these waste-related sources.

2018 U.S. Methane Emissions, By Source



Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018.*

One of the largest sources is simple trash. Worldwide, we dump two billion tons of garbage into landfills every single year, and in the U.S. we generate three times the global per capita level. As that trash decomposes, it produces massive amounts of greenhouse gases – and especially methane (CH_4).

These GHG emissions only compound when we consider human waste water or sewage where significant amount of methane escapes into the atmosphere. Now consider dairy farms, chicken farms and meat processing facilities. Further, think about food waste. In the U.S., food loss is between 31%-40% of overall food production[1]. Of course, even the food that is thrown out requires significant energy for fertilizer, irrigation and transportation, and then we discard it, all exacerbating the greenhouse production issue.

Why should we care?

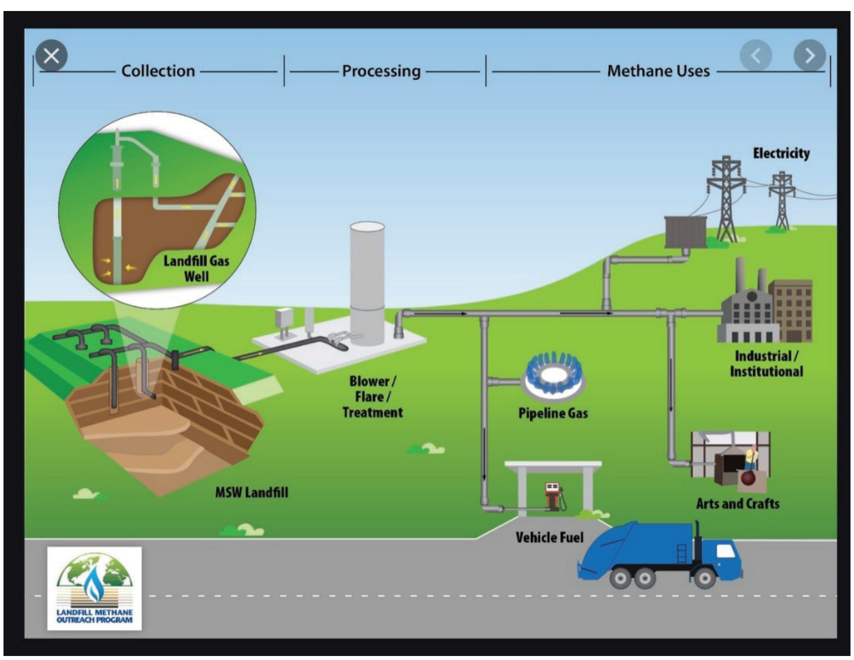
As an environmentalist, by turning methane into renewable natural gas, one can tackle two major climate change issues at once: 1) reducing methane emissions from waste and 2) de-carbonizing the transportation and heating sectors. As an investor, one can potentially generate high returns through investments in abundant, cost-effective technologies.

Of course, current technologies cannot solve for all GHG emissions. Having said that, significant amounts of renewable natural gas can be produced from these waste sources. The American Gas Association estimates that we could produce up to 3.7tBtu of renewable natural gas. That number sounds big yet means little until you realize that, thanks to its net carbon nature, it could displace 95% of the average GHG emissions attributable to natural gas consumption in the entire residential energy sector[2]. Think about that. If we decide to capture these emissions instead of allowing them to float into the atmosphere, we could heat nearly every home in the United States!

If we focused solely on GHG emissions from landfills, we could generate enough compressed natural gas to power more than 20.6 million passenger vehicles for one year. Further, the Argonne National Laboratory's AFLEET tool estimates that natural gas vehicles operating on fuel derived from RNG can yield GHG emission reductions of up to 75%, compared to gasoline or diesel vehicles.

What technologies exist to capture and use these methane emissions?

The ability to capture methane at landfills and convert it into either electricity or to clean it up sufficiently to sell it to the natural gas stream has existed for several decades. Yet even after decades of work, the EPA states that only 565 U.S. landfills of a total of 2,627 currently capture methane. In other words, barely 20% of landfills capture methane emissions, and the rest let it pollute the atmosphere exacerbating our climate change issues.



In a similar fashion, we can capture methane from animal farms by utilizing anaerobic digestion of the manure and other waste from processing that would otherwise be dumped into landfills. Collecting organic waste and recycling it has barely started in most places in the country. Some metropolitan areas have recently banned organic waste from going to landfills. We applaud this move. However, the construction and operation of facilities to compost this material and capture the methane emissions is just now gaining true momentum. We believe this will become another rapidly growing sector of the market. These facilities can turn cost centers (paying to haul off waste) into profit centers as the renewable natural gas is captured and sold into the natural gas stream or used to generate electricity. Further, in many areas, renewable credits can augment the economic returns for investors.

The technology for anaerobic digestion has been utilized worldwide for many decades. Until recently, the implementation has been slow in the U.S., but significant growth is now occurring. For example, according to AgStar, 17 new facilities came online in 2020 with 60 more under construction currently. That's over 25% growth in the last year. AgStar estimates that there are about 8,100 large farms and dairies in the U.S. that have sufficient scale to achieve a profitable anaerobic digestion facility, versus only about 300 such facilities currently in existence, so there is much room for continued growth.

We can also capture methane from sewage treatment facilities. Instead of letting these sources generate toxic greenhouse gases, we can turn this waste into three valuable byproducts: 1) methane that can be used for electrical production or injected into the natural gas stream, 2) purified water and 3) solid waste that can be a tremendous organic fertilizer. In the EPA's most recent research, conducted by the Water Environment Foundation in 2015, there were 1,268 anaerobic digester facilities operating at U.S. wastewater treatment facilities, representing only about 8% of the approximately 16,000 municipal wastewater treatment plants in the U.S.

Finally, after reviewing how few methane-capture facilities are operational in the U.S. at landfills (565), on farms (300), and at waste water treatment plants (1,268), it is worth noting that AgStar referenced a staggering statistic in a 2020 report that Germany alone has an estimated 8,000 commercial anaerobic digesters in operation. In other words, the U.S. is far behind other industrialized nations in this regard, and catching-up may take many years of sustained growth.

Growth and investment opportunity

Numerous private equity and credit opportunities have developed to capitalize on these growing trends. The technology has improved. The feedstock and off-take contracts have improved. These opportunities also benefit from positive societal interest. Each of these tailwinds have contributed to reduced risk. Because these are relatively small, nascent and growing markets, capital is short, creating outsized returns for the risk taken. Given regulations and the concern about greenhouse gas emissions, we anticipate significant uptake in methane capture at landfills, animal farms and processing facilities, and water treatment facilities.

In addition to compelling economics and the need to reduce emissions, governmental policy has also bolstered growth. State, local and even national governments have instituted regulations to limit carbon emissions. Many have added credits for renewable natural gas which, of course, augment returns for investors (see Economics example). Further, many parts of the world have already implemented carbon taxation and many other governmental entities are considering them. In the U.S., even the American Petroleum Institute has now come out in favor of carbon taxation. Carbon taxation would likely become a serious driver to spur organizations into capturing their methane emissions.

Lastly, the market is massive. If we assign a $50 price per ton of carbon (roughly the voluntary price in the US and close to the European price), methane emissions represent a $32 billion market. If we focus just on RNG, our simple calculations indicate that it could easily become an additional $11 billion addressable market (AGA estimates with an assumed $3 natural gas price) using today's technologies. As technologies improve, and when we factor in renewable credits, that number could easily triple or quadruple.

What is TortoiseEcofin's role?

At TortoiseEcofin, through our collective registered investment advisors, we have addressed GHG problems in multiple forms. For more than a decade we have encouraged coal to gas switching for electrical production. This adoption has created the single largest decline in GHG emissions in the world. Further, we have encouraged pipeline companies to significantly reduce methane emissions. One of our larger investments, Kinder Morgan, has actually cut methane emissions by 90% since 2016. Of course, the renewable natural gas produced by these projects flows right into the pipelines of our midstream investments.

On a more direct level, we first invested in landfill methane capture ventures 15 years ago. We have since developed investment products at Ecofin with a significant focus for these opportunities within both registered funds and private fund offerings.

In particular, our team's ability to help smaller scale developers access improved capital structures has made a material difference for many projects in light of tight lending standards for regional banks. Through our investment products, we have now provided financing for a dairy farm anaerobic digester, a chicken and swine processing anaerobic digester, a polypropylene recycler, and a thermoforming facility that takes renewable purpose grown and residue fiber crops and converts them to molded fiber products, thus reducing deforestation.

Through an affiliated entity, we have sponsored and seek to sponsor SPACs with target acquisitions of companies making an impact to the energy evolution.

Conclusion

We believe society will no longer tolerate wantonly emitting carbon into the atmosphere – especially when it can be captured and profitably sold. While this is a nascent area of the capital markets, the market is growing quickly, and the demand for capital far outweighs the supply. Due to the rather large supply/demand imbalance, we believe the potential is immense for investors.

Economics example

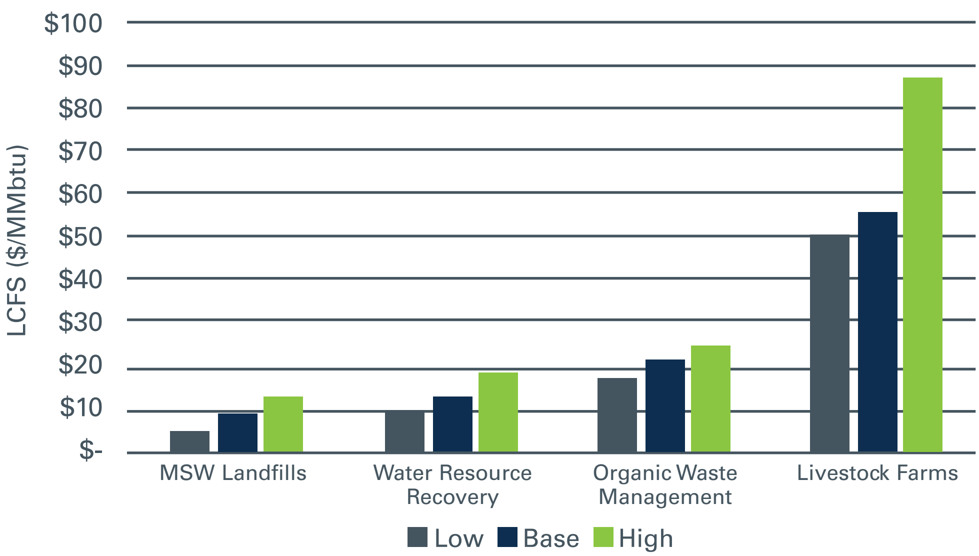
The economics for renewable natural gas improve substantially with government incentives. RNG is eligible for various credits including Renewable Identification Numbers (RINs) under the Federal Renewable Fuel Standards and Low Carbon Fuel Standard (LCSF) credits under the California Air Resources Board. Both RINs and LCFS are transferrable, and trading markets exist for both. Depending on the source of the RNG, the quantity of RINs generated will vary slightly, and LCFS credits can vary greatly. Specifically on the LCFS, fuel is given a carbon intensity (CI) score which determines the quantity of credits generated. RNG's CI score can generally range from 80 on the high end for landfill gas to -350 for RNG from dairy and swine manure. At recent market prices, the credit value generated for gas with 80 CI is roughly $4.75/MMBtu and -350 is $85/MMBtu. For reference, the spot price of Henry Hub natural gas has averaged $2.63/MMBtu for the 5 years ending 12/31/20. While California is the primary LCFS market today, Oregon has implemented a similar program, and numerous other states and state coalitions are contemplating implementation. On a national level, Canada has announced they are in the process of implementing as well, and the U.S. House has introduced a bill to implement a national LCFS-style program. For RNG to be eligible for California LCFS credits, pipeline injection can occur anywhere in the U.S. where there is flow potential to the California market. And project economics are stackable, so RNG-producing projects can benefit from brown gas sales, LCFS credits, and RIN credits.

Ranges of Fossil and Renewable Vehicle Fuels from CARB

	Fuel	Feedstock	Average CI g CO_2/ MJ	Range g CO_2/ MJ	Change Relative to Diesel
1	Diesel	Crude	100	100	N/A
2	CNG	Nat Gas	80	78-81	-21%
3	LNG	Nat Gas	90	86-94	-11%
4	Electricity	California Grid	105	1056	3%
5	Renewable Gas - CNG	LFG	46	31 to 79	-55%
6	Renewable Gas - CNG	Manure	-270	-370 to -150	-370%
7	Renewable Gas - CNG	Waste Water	30	8 to 45	-70%
8	Renewable Gas - CNG	Food Waste	-11	-23 to 5	-111%
9	Renewable Gas - CNG	LFG	54	7 to 83	-48%

Source: CARB LCFS Certified Pathways

LCFS Credits



Sources: CARB, EIA, Credit Suisse estimates

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[1] FDA, "Food Loss and Waste"

[2] AGA/ICF