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On-farm AD vs. partnership with off-farm AD

AD pros & cons from a farmer's POV?

Much has been written on the pros and cons of anaerobic digestion, but the point of view is often societal, environmental or economic.

What about the **farmer's POV**? Here's a summary from a 2015 Pennsylvania meeting about farm anaerobic digestion.

Opportunities:

- Opportunities for the addition of food waste (**co-digestion**) into methane digesters are increasing.
- Separated solids used for bedding have been shown to be a **very positive benefit as a bedding material for the dairy herd**. The landscape industry may also have interest in the fibrous material for mulching and as a soil amendment allowing for additional local business opportunities.
- Stacking multiple benefits of an anaerobic digester system can result in a **very positive return on investment**. [aka bio-refinery approach]

Caveats and advice

- It is critical to the success of any anaerobic digester system that **one person have a significant passion** to see the system function efficiently and profitability.
- Now is the time for potential owners to do **research and discovery**.
- Producers should develop a **game plan** now so they are ready if the opportunity and circumstances (funding and permitting) present themselves.
- Research companies and vendors to determine which ones have a **proven track record**.
- Producers establish a **trusted team of advisors** to assist in the planning and "what if" process of coming to a go or no-go decision regarding the implementation of an AD system.

Stand-alone on-farm AD?

Construction and operation of digesters requires **capital** (funding) and increased **personnel time**.

These costs may be too steep for a farm of less than 1000 head of dairy cattle.

In 2004, AgSTAR provided cost estimates:

- **Capital costs** at $150 - $500 / cow; and
- **Annual operating costs** of $11,000 - >$50,000 for labor and / or an AD operator.

Co-digestion will increase revenue (essentially increase herd size) **but** will also increase capital costs, project complexity and operational requirements.

Participating in an AD cooperative?

Small farms might reap some of the benefits of AD by becoming **partners** in an **cooperative AD project**.

Farms would **contribute** manure, and possibly other on-farm feedstock materials like extra crops or spoiled feed.

The nutrients from those contributions would be **returned** to farmers.

- Fertilizer
- Bedding
- Nutrient management planning assistance
- *(Some $ for electricity?)*

The partnership could be cooperative, or strictly by contract for goods & services.

Participation in cooperative AD and other partnership models is covered in more detail in the last module of this course.

Assessment!

Please answer the questions in **section 7.1** of the Module 7 Assessment.

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Manure only or co-digestion?

Manure-only is the simpler option.

The digestion of liquid dairy manure is **simpler** in a number of respects.

- **AD design can be simpler** (unmixed plug-flow);
- **Location** of the AD facility next to the barn minimizes transportation and/or pumping of manure; and
- AD operation can be very **automated** if manure is automatically pumped from the barn into the digester.

Caveat: small herd size may not produce sufficient manure to justify AD.

Co-digestion

Co-digestion of off-farm feedstock materials can allow smaller farms to consider AD. However,

- **More complex AD systems** are required for co-digestion;
- Co-digestion requires farmers to **secure sources** of off-farm feedstock;
- AD operation will be complicated by **delivery** of feedstock,
- … more rigorous **record keeping** and **compliance**,
- … and **increased nutrients** to plan for.

Regulation may limit the amount of off-farm feedstock that can be used in on-farm digesters.

- So, farms must be sure they are able to produce the required amount of on-farm material.'
- This may include 'energy' crops.

Assessment!

Please answer the questions in **section 7.2** of the Module 7 Assessment.

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Production of AD feedstock?

On-farm production of AD feedstock

Non-manure on-farm feedstock materials may include:

- sub-par or slightly spoiled feed;
- a variety of crops;
- plant material typically not fed to dairy cattle, like C4 grasses;
- waste fruits; and
- food residuals from on-farm food processing.

On-farm feedstock, manure and other materials may, or may not, be purchased from neighboring farms.

- **Check your state's regulations**.

Spoiled or sub-par feed

Remember that high levels of **mold can inhibit bacterial growth**, and thus anaerobic digestion.

- So, spoiled feed should be delivered to a digester as soon as it discovered.

Spoiled feed from bunkered crops should be delivered to the digester **daily**. Stockpiling or storing spoiled feed will:

- **Reduce its energy value**;
- Promote **overgrowth with molds** and fungi that can inhibit AD;
- Cause the material to decompose and begin to **clump**; and
- **Greatly increase odor** released when these materials are transported to the digester.

Moving spoiled feed to the digester thus becomes a daily task that **increases work of farm personnel**.

‘Energy’ crops

Almost **any farm crop** can be fed to anaerobic digesters.

But there are **caveats**:

- Crops higher in **cellulose and lignocellulose** will require longer HRTs and may not be completely digested.
  - Of course, that can produce more solids with bedding value!
- Crops must be **chopped finely** to avoid clogging pipes, pumps and valves.
  - Silage choppers can work well.
  - Bale choppers may not produce small enough or uniform material.
- Feeding of energy crops should be fairly steady and this **may require extra storage capacity**; new bunkers?
- Chopped crops will **require use of farm equipment and personnel**, likely on a daily basis.

Crops for marginal land?

Almost any vegetation can be fed to anaerobic digesters, including C4 photosynthesizers that would typically not be fed to animals.

It may be possible, and economically feasible, to grow such **perennial grasses** on marginal lands that are not suited for dairy crop production.

- Low quality grasses could also be harvested from generous **riparian buffer strips.**

Low quality forage collected from **brush hogged** property might could also be used for AD feed if chopped finely.

Assessment!

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Clean collection of AD feedstock

Changing manure collection?

Manure used for anaerobic digestion must be collected and stored with care.

- Manure must be **free of**:
  - Large biodegradables like **placentas** that clog pipes, valves & pumps;
  - **Non-biodegradable** contaminants like hoof blocks, vet wrap, ag bag plastics, bandages, etc.,.
  - Significant amounts of **gravel and rock**;
  - Any materials large enough to clog pipes, valves and pumps; and
  - Bacteriocidal compounds like copper sulfate, formaldehyde and similar hoof-treatments used in **foot baths**.
- Note that **rumensin and other antibiotics** used in feed may reduce biogas output. Rumensin clearly inhibits AD.
- While **milk-house wash-water** can be used to dilute semi-solid manure and make it pumpable, the presence of cleaning chemicals will likely reduce biogas output.
- Manure must be either pumped to the digester as it is collected, or stored, in a **temporary reception pit** prior to moving to the digester.

Manure from heifers and dry cows

The solid or semi-solid manure from heifers and dry cows is a valuable feedstock, but is **only available if and when those animals are confined**.

- So, remember that material will likely not be available during the late spring, summer and early fall.
  - During the months that cows are pasteured, **freshly cut forage** may be able to take the place of dry manure.
- Dry manure is easier to feed when it has not sat for long periods of time, so **frequent transfer** to the digester is better than episodic clean out.
  - Stored manure begins to compost & clump.
- When smaller amounts are transported, less of the solid manure needs to be stored at the digester.
- **Equipment and labor time** need to be considered.
- And **avoid adding gravel or stone** to manure when storing & moving it.

Storage of crop feedstock

Most crop material used to feed AD systems is either **fed as it is harvested** or **ensiled**.

- It's important that **gravel, sand and crushed stone** are not mixed into ensiled material during its storage or during collection and transportation to the AD.

- And **ag bag plastic** must be kept out of material fed to the digester.

Off-farm feedstock

Off-farm feedstock accepted for anaerobic digestion must also be collected in a clean stream, **without non-biodegradable contaminants**.

- This is more difficult that it sounds!

For example, here are two methods of collecting food waste.

1. **Collected into totes** (large trash cans) and covered with a bit of sawdust.
    - The generator is responsible for keeping the stream clean.
    - Napkins, silverware, plastic must be excluded.
    - The hauler inspects totes upon pickup and refuses those that contain contaminants.
    - A last chance to remove contaminants occurs when totes are tipped at the digester before being ground and added to the system.
2. **Collected in plastic bags**, and
    - Either pulped at the generator and transported in tanker trucks, or
    - Transported to a central facility and mechanically debagged and pulped.
    - Contaminants will to be ground into the pulp.

In each case, only **human care** keeps contaminants out!

Assessment!

Please answer the questions in **section 7.4** of the Module 7 Assessment.

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On-farm use of co-products

AD co-products for farmers?

AD produces a number of **co-products** that may be useful for farmers:

- Separated solids from effluent;
- Nutrient-rich liquid effluent;
- Heat recovered from the genset; and
- Carbon dioxide from genset exhaust.

Remember that anaerobic digestion decreases carbon content, but **does not significantly effect NPK content of effluent**. The implications for NMP and cropping are discussed in more detail in the NMP module.

Thoughtful and extensive use of co-products is vital to making AD **economically viable**.

Separated solids

Separated solids are **fibrous material** not completely degraded by the AD process and left in digester slurry.

Solids are:

- Separated from digestate slurry using a solids separator;
  - Often a screw press auger;
- Generally about 65% moisture, 35% solids; and
- Nutrient rich, and often enriched for phosphorous.
- Bacterial levels in solids are **decreased**, but not eliminated by AD.
- When solids are stored in piles they begin to compost, generating significant amounts of **heat** and often **becoming moldy**.
  - Spreading piles into a thin layer allows drying and safer storage.

Solids are generally **the most highly valued co-product** on dairy farms because they can be used as bedding.

Solids can also be **composted** to create soil amendment.

Separated solids: mastitis?

Cornell University has compared the use of a wide variety of dairy bedding materials including separated raw manure, separated composted manure, separated solids from AD with and without composting, and sand.

- Bedding strategies and economics were studied.
- Mastitis, somatic cell count, foot and leg health were assessed.

Conclusions:

- Using manure solids can provide an economic benefit **without adversely affecting herd health**.
- Bacterial levels in the bedding alone are not what cause high SCC or mastitis.
    - **Management of the bedding** in the stalls is much more important than analyzing it for pathogens.
    - **Keeping stalls free of manure and urine**, regardless of bedding type, will go a long way toward keeping SCC and mastitis under control.
- Use a dried manure solids system that **fits into your farm's routine** and one with which you are most comfortable.

Cornell Waste Management Institute (2010):
'Use of dried manure solids as bedding for dairy cows…'

Separated solids: sales?

If a farm AD project produces more separated solids than it needs it **may** be able to sell them to other farms as bedding.

However, in Vermont regulators are hesitant to allow solids to be transferred for use as bedding **if any beef has been included in AD feedstock**.

- Reluctance stems from fears about biosecurity due to **bovine spongiform encephalopathy** (BSE), aka mad cow disease.
  - The BSE prion pathogen cannot be inactivated by pasteurization.

Heat?

Heat is one of the **most frequently ignored** co-products of anaerobic digestion. Heat is difficult to transfer, so can only be used on-site.

The most frequent use for recovered heat is **heating of greenhouses** used to grow a valuable crop like winter tomatoes.

Heat can be used to **dry solids** and prevent storage issues.

- Unless the solids are pelletized first, they tend to be very powdery.

Since the heating of homes and other buildings accounts for a very large part of Vermont's carbon footprint, it would be very beneficial to use waste heat for **space heating**.

- Industrial, institutional or residential spaces all need heat.
- Co-location of AD is a challenge, particularly for on-farm AD.
- Some on-farm AD has used waste heat to heat farm homes, or other farm businesses.

Carbon dioxide

Plants use carbon dioxide as a **building block** and transform it into carbon-rich structural molecules like cellulose.

CO_2 from a generating engine's exhaust can be used to fuel plant growth if it the exhaust gas is **scrubbed** to remove harmful gases like carbon monoxide.

Recovered CO_2 can then be added to the atmosphere of a greenhouse as long as levels are not dangerous to human workers.

Assessment!

Please answer the questions in **section 7.5** of the Module 7 Assessment.

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Effect of AD on nutrient management

Liquid effluent

The liquid remaining after solids separation is **nutrient-rich** and can be used as a fertilizer.

- AD reduces carbon content, but not nitrogen, phosphorous & potassium levels.

AD changes the chemical form of nutrients, **mineralizing** them.

- Mineralized nutrients are **very bioavailable** and are quickly taken up by plants.
- However, **if applied incorrectly** or not used by plants, these bioavailable nutrients could enter bodies of water and encourage growth of algae and depletion of dissolved oxygen.

Ammonia is the dominant form of nitrogen in liquid effluent.

- Broadcast spreading will allow the ammonia to evaporate into the atmosphere and it won't reach crops.
- Instead, effluent should be **injected** into the soil or spread at the soil's surface.

More bioavailable NPK vs. more land?

The mineralized nutrients produced by AD may be **more effective fertilizer** than undigested manure.

- So, less AD effluent than manure may be needed to crop the same acreage.
- Cover crops may be useful sinks for nutrient management.
- Alternately, **farmers must find a use for increased fertilizing power**.

If manure is brought in from other farms, or if off-farm feedstock is brought in for co-digestion, then AD will produce **a significant excess of nutrients**.

- This may eliminate the need for synthetic fertilizer purchase.
- Or, it may provide **nutrients that will need homes**.
- 'Orphaned' nutrients could be shared with, or sold to, other local farmers.
- Trucking should be kept to a minimum.

Assessment!

Please answer the questions in **section 7.6** of the Module 7 Assessment.

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Transportation & storage issues

Storage: without off-farm feedstock

Will an on-farm digester increase the need for storage?

It depends!

- For an **on-farm, manure-only digester**, effluent volume should fit into the farm's existing manure pit.
- Separated solids may be used for bedding as quickly as they are produced by the digester.
- **Excess solids may need new storage**. Beware of the heat produced by piled fresh solids.
- Again, if solid manure is fed as quickly as it's generated, it won't have to be stored and moved twice.

If the farm's existing manure pit is used to collect manure prior to pumping to the digester, a **new pit or pond** will be needed for AD effluent.

Storage of off-farm feedstock

Digesters accepting off-farm feedstock will almost certainly need **on-site storage** for those materials.

Low-strength off-farm feedstock can be fed directly to the digester if the volumes don't exceed reasonable portions of the daily feed volume.
But, **high-strength** off-farm feedstock will have to be stored on-site if the volumes delivered exceed the amount appropriate for daily feeding.

- **Storage tanks** may be used for liquid materials.
- Covered and enclosed **bunkers** or **bays** can be used to store solid feedstock.

Tanks: Pulped materials (those with some solids content) tend to settle during storage.

- **Robust mixing and pumping systems** will be need to mix settled feedstock and deliver it to preparation pits or tanks.
- Tanks may need to be **heated** to prevent freezing or gelling.

Ventilation, with charcoal filters or other strategy, of tanks and solids bays is essential for odor control and for personnel safety!

Co-digestion: storage of co-products

Digesters **accepting off-farm feedstock** will almost certainly need to increase storage of effluents.

Estimate the increase in liquid effluent volume as the volume of added, non-manure feedstock.

- **New storage ponds** may needed for effluent.
- If the new storage is sufficiently far from the digester to require trucking, then
  - …a **small effluent storage tank at the digester** is needed to hold effluent for transportation.

A large, **covered storage area** will be needed if the digester produces more solids than the farm can use, and the solids are sold as a revenue producer.

- Because of their **high phosphorous** content, solids should not be field stacked or exposed to water that can leach phosphorous and carry it to surface or groundwater.

Transportation: manure-only

Will operation of an on-site digester increase the use of (or need for) farm equipment for transportation?

For **manure-only digesters** that pump manure directly from the barn, additional transportation will **only** be necessary if:

1. Solid manure needs to be moved to the digester and mixed into liquid dairy manure. This requires powerful mixing by chopper pumps and or impellers.
   - Manure spreaders or small wagons/trailers can be used to move solid manure.

2. The storage pond for liquid effluent is far from the digester facility.
   - Manure tanker / spreaders can move liquid effluent.

Transportation with co-digestion

On-farm **co-digestion is very likely to increase the use of farm equipment** and the need for regular transportation of feedstock and co-products.

Feedstock:

- Liquid feedstock will be delivered by generators or haulers and can be stored in on-site tanks, so no on-site transportation will be needed.
- Solid feedstock materials – like manure, spoiled feed, or energy crops – may be delivered by generators, or may need to be picked up by digester operators.
    - **Loaders, skid steers, tractors, manure-spreaders, wagons or trailers** may be needed.
    - After transportation and storage on-site, solids will needed to be **moved again**, from the storage site into the digester.

Transportation with co-digestion

Co-products:

Liquid effluent volumes are **usually increased** by co-digestion.

- Effluent may, or may not, need to be moved from the digester to a storage pond.
- Increased volumes will require more transportation to, and spreading on fields.
    - **Partner farms** may, or may not, pick up and spread their share of effluent. But the **AD operator** will likely have responsibility for the facilities overall nutrient management plan and proper use of nutrients.

Separated solid volumes are **also increased** by co-digestion.

- Solids may, or may not, need to be transported to a covered on-site storage bunker or shed.
- **Partner farms**, or farm customers, may or may not pick up solids.

Assessment!

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Opportunities for synergy

Requirements for synergy

Synergy (n.) the interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects.

Can synergy occur between farms and AD?

Farmers need to understand their own **farm operations** in terms of:

- Economics
- Logistics
- Transportation
- Storage
- Equipment
- Nutrient management
- Personnel

Farmers need to understand the implications of installing and operating **on-farm AD** or **partnering** with an AD facility.

Models for AD?

Farms can participate in, or use, AD in a number of **different models**:

1. Stand-along on-farm AD
2. Membership in a cooperative AD
3. Partnership with an existing on-farm (or biomass) AD plant

These models will be discussed in more detail in the last two modules of this course.

Assessment!

Please answer the questions in **section 7.8** of the Module 7 Assessment.