Winter Rye: Energy Potential of Cover Crops with Anaerobic Digestion and Uses for Solid Digestate

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Abstract

Anaerobic digestion is a process that harnesses the metabolic potential of bacteria to produce methane from biomass resources including **winter cover crops.** Biogas production via anaerobic digestion can be used as an alternative for fossil fuels and has the potential to significantly reduce greenhouse gas (GHG) emissions. Methane (CH_4), a GHG with 28-36 times more heat trapping potential than carbon dioxide (CO_2) [1,2], is emitted in large quantities from conventional manure storages, but can become a renewable energy source via anaerobic digestion. One barrier to adopting ADs on farms is **high upfront costs** for equipment. In Pennsylvania (PA), the average dairy farm size is **significantly smaller than most farms with ADs**. Most farmers do not have enough animal waste to make investment in an AD realistic, but **co-digesting manure with crop biomass can achieve profitable economies of scale**. Using data from potential winter rye yields on corn and soybean fields in PA, the total biogas and **energy potential of winter rye was calculated**[3]. Winter rye can potentially to produce **up to 3.05 trillion BTU annually** accounting for 100% of the addressable market. Additionally, the solid digestate from the AD can be used as a fertilizer due to the high ammonium content[4]. As PA is agriculturally bountiful, more ADs installed on farms have the potential to significantly reduce the state's methane emissions.

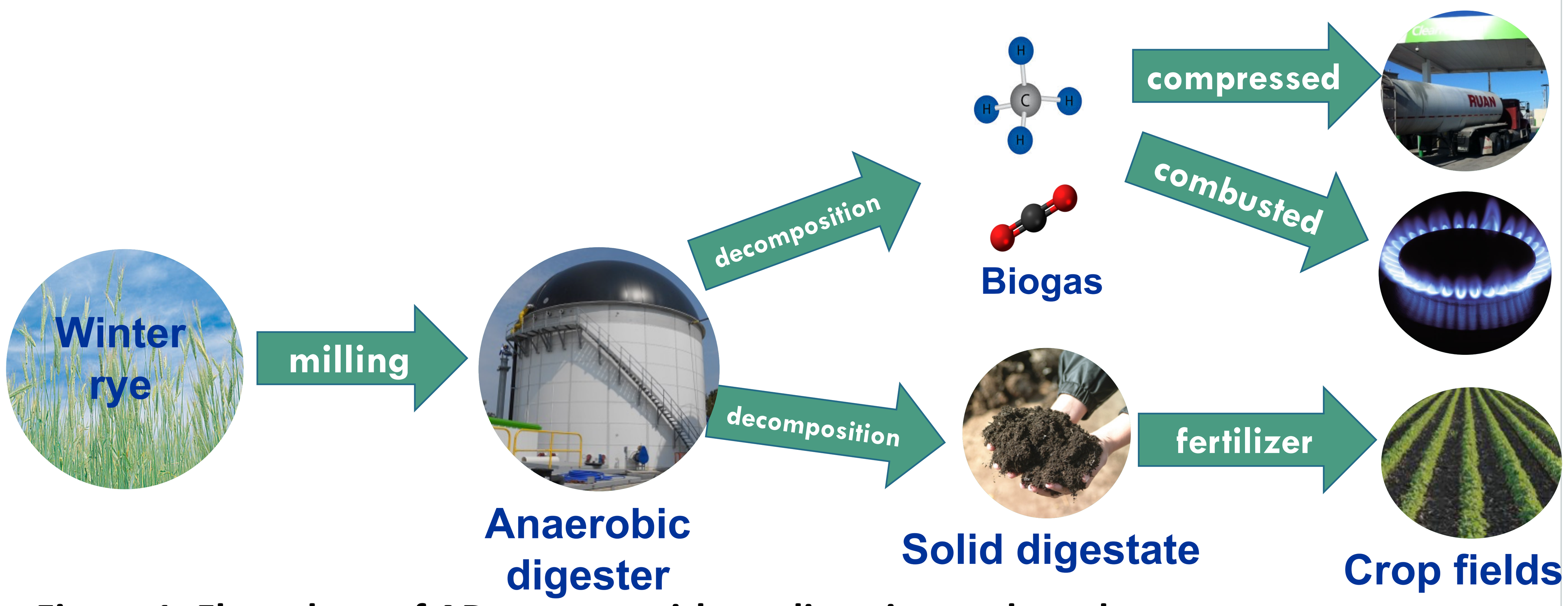

Figure 1: Flow chart of AD process with co-digestion and products

Method

Winter Rye Energy Potential:

The total yield potential of winter rye grown in PA was calculated using data from Feyereisen et al. 2014 [5] archived in the Penn State DataCommons, which includes the dry tons of winter rye that could be grown in the counties of PA on existing corn and soybean fields (see Figure 2). The total volume of biogas was calculated using **grass silage potentials of 160-200 m³/metric tonne** [6].The total energy potential was then calculated from the volume of biogas and **methane energy density of 55.6 MJ/kg CH_4** [7].

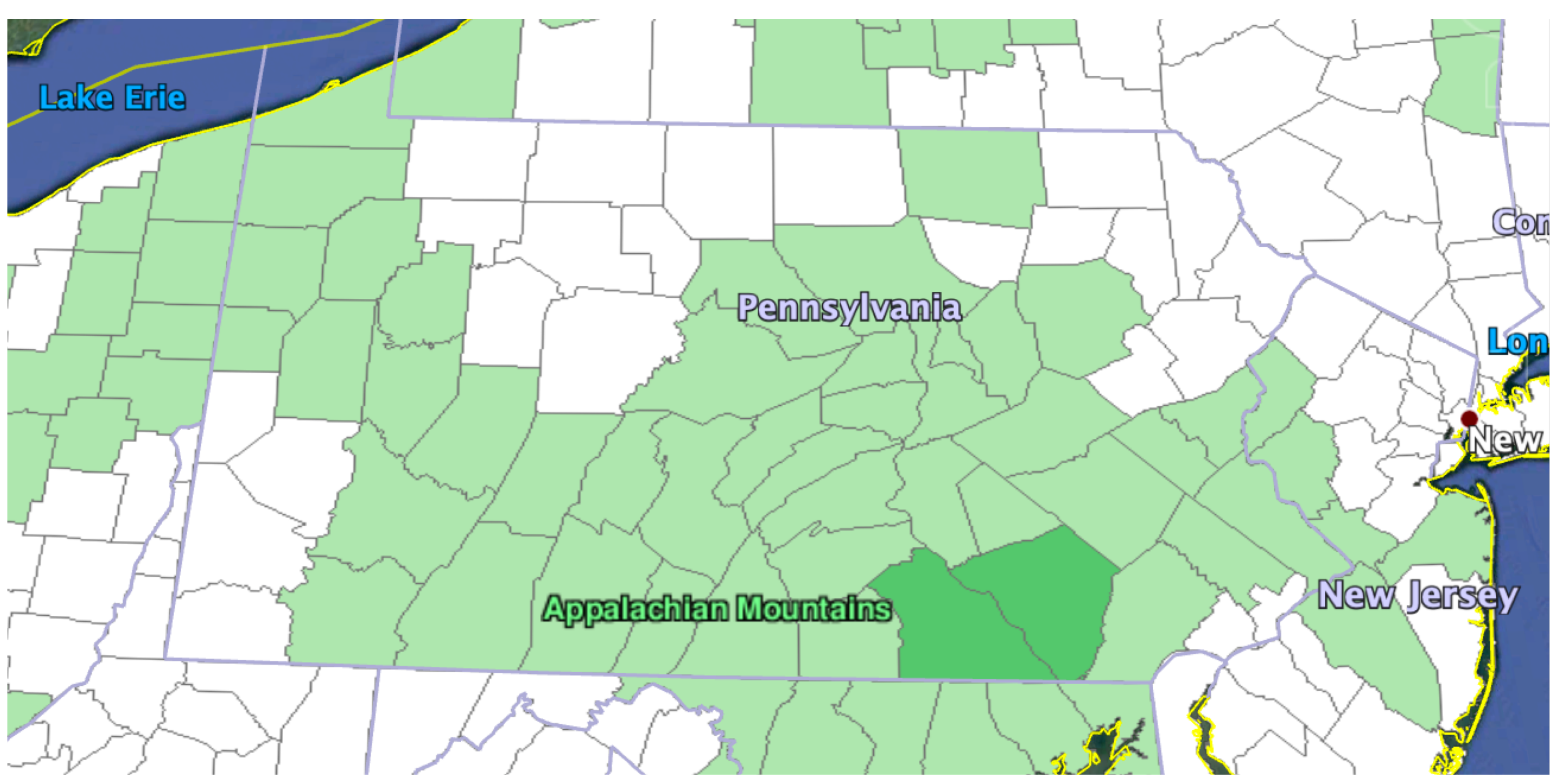

Figure 2: Map of counties from database with darker green color representing more winter rye potential [5]

Results

- The potential total annual harvest of winter rye was calculated to be **1,685,107 metric tonnes** in PA.
- From this harvest, between **0.7 to 3.1 trillion BTU** could be generated (see Figure 3).
- Comparatively, Pennsylvania currently produces only 15 trillion BTU from biofuel but uses 164.4 trillion BTU from biomass energy annually [8].

Energy Yield from PA Winter Rye in Trillion BTU

Adoption Rate	Low Scenario (160 m³/tonne)	High Scenario (200 m³/tonne)
100%	2.44	3.06
50%	1.22	1.53
30%	0.73	0.92

Figure 3: Energy that can be produced from Winter Rye yields in PA for different adoption rates, assuming 160- 200 m³ of biogas per metric tonne of silage [6]

Conclusion

- The large summer crop acreage of corn and soy fields allows PA to plant lots of winter rye while still producing food crops.
- Winter rye can be mixed with animal waste to produce more methane and can be used as an incentive for implementing more ADs in PA.
- Not only does winter rye create more energy, but the solid digestate can be used as a **beneficial organic fertilizer**.
- Winter rye can produce as much as **3 trillion BTU** (100% of potential supply). A 30% adoption rate would produce **0.73 to 0.92 trillion BTU.** In the low scenario, this would **increase energy production from biofuel in PA by almost 5%**.

Future Experimentation

- Evaluate coproduct value of winter rye digestate through compositional analysis
  - Find total carbon and total nitrogen content of digestate, as well as the available ammonium, to determine potential as a fertilizer.

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References- See addendum for full references

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