Supply Chain Analysis of Bioenergy Production in Pennsylvania

Haley Stauffer[1], Dr. Tom L. Richard[1]
[1]The College of Agricultural Sciences, Department of Agricultural and Biological Engineering, Pennsylvania State University, University Park, PA 16802

Abstract

Reliable energy production is of significant importance worldwide. Communities depend on accessible and sustainable energy resources for their continued well being. In the current climate crisis, it is crucial that alternative renewable energy sources be identified for future energy security and logistical feasibilities be addressed given policy and economic parameters at a global, national, and regional scale. This study will spotlight different feedstock potentials, policy incentives, factors of adoption, and logistical scenarios for anaerobic digester implementation in Pennsylvania (PA) for future renewable natural gas production, as well as carbon capture strategies. Key metrics throughout the state were gathered using the AgStar and US Energy Information Administration databases, the Bioenergy Knowledge Discovery Framework, as well as Department of Energy reports and a journal literature review. Primary feedstocks in PA included in this analysis were food waste, winter rye, switchgrass, and manure. The study was utilized a state (PA), city (Pittsburgh) and University campus (PSU) scales and data was inputted into excel to generate a regional model outlook for bioenergy production through the anaerobic digestion of biomass within these respective areas. In order to address the pressing global issue of increasing greenhouse gas (GHG) emissions, particularly methane (CH4), it is imperative that assess regional solutions, such as biogas production from biomass. Future research areas include a feasibility study of Renewable Natural Gas (RNG) production from biogas in PA, as well as a comprehensive supply chain logistical model for feedstock handling, processing, and distribution of bioenergy within the state.

Feedstocks of Interest:

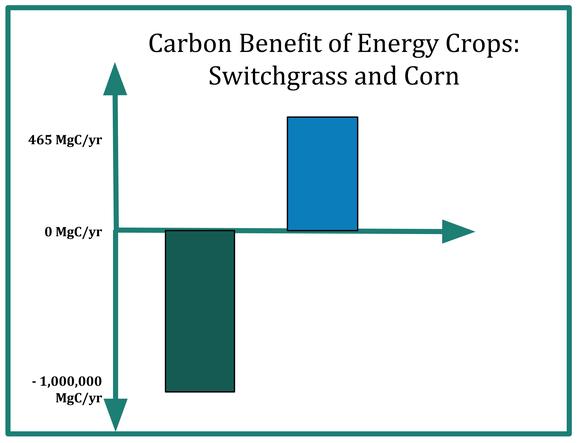

Food Waste


Winter Rye


Switchgrass


Manure

Environmental Impacts: Feedstock Comparison in PA



Corn: Soil Organic Carbon reserves *decrease* by **1,153,355 Mg C / yr**

Switchgrass: Soil Organic Carbon reserves *increase* by **467 Mg C / year**

Anderson-Texeira et al. (2009)

Switchgrass stores **3,268 Mg- 19,614 Mg** of belowground biomass per year in PA

Monti et al., (2011)

Global Bioenergy Significance:

Currently, 88% of global energy production is based on fossil fuels[9,10]. Ensuring reliable and sustainable energy security across the globe is an increasing concern as resources become strained and variable due to a changing climate. Bioenergy can help reverse global warming by securing a resilient and sustainable energy resource whose production can improve soil and water quality and drawdown atmospheric CO2.

Significance to PA: Feedstock Capacity

Food Waste-
- An average of **1,479,215.43 short tons** of food is wasted per year in PA[11]
- Biogas potential of: **~388,088 MJ/yr** in PA according to a 2012 census by the FAO[12]

Winter Rye-
- Total of roughly **943,660.22 short tons** in PA[13]
- Biogas potential of: **~245, 870.67 MJ**

Switchgrass-
- Total of roughly **2,044,601.19 short tons** in PA[14]
- Biogas potential of: **~219,239.81 MJ**

Manure-
- Roughly **21 short tons** of manure in PA/ year/ cow[15]
- Biogas potential of: **~276,030.64 MJ/yr**

Pennsylvania's Current Energy Outlook

5.3%

Share of U.S.Total Net Electricity Generation as of 2019[1]

- PA is the **2nd largest supplier of energy** to other states, after Wyoming

- **2nd state in Natural Gas (NG) production**, after Texas (36% of total electricity produced in the state) as of 2018[1].
- **3rd state in U.S. for coal production** as of 2018 (21% of total PA electricity production)[1].
- **2nd in U.S. for electricity generation from nuclear power** (38% of PA's net generation)[1].

1.3%

Share of U.S. Total Renewable Energy (RE) Net Electricity Capacity as of 2019[1]

- PA has 6.1% RE consumption, **40th in US state rankings** as of 2017

- Wind, Hydropower, and biomass generation are among the highest contributors **(36%, 35%, and 24% of total RE generation, respectfully)**[1].
- Solar power accounts for roughly **5% of PA's RE electricity,** but is growing[1].

Pennsylvania's Future Energy Outlook

3.8%

Percentage of Renewable Energy (RE) needed to satisfy PA's 2021 energy goals as of 2017[1].

- 18% of the retail electricity sold in the state be generated from renewable sources by 2021 (PA Alt. Energy Standard (AEPS)

- Suggested increase AEPS RE goals to **30%** by 2050 and have a Regional Greenhouse Gas Initiative (RGGI), to reduce Greenhouse Gas (GHG) emissions by 3%/yr[3].
- A national weighted average of **51% of all energy** in US must be from RE resources by 2050[1].
- **9 states** have 2050 RE laws or goals, but PA is not one of them[3].

7.5%

Rate of growth in Natural Gas (NG) production in PA from 2009 to 2053[2]

- 0.23% annual growth in cubic feet per day of NG production

- The US is the **largest producer** of NG and petroleum in the world[4].
- **39%** of all US energy will be from NG by 2050[4].
- **51%** of all homes in PA are heated by NG[1].
- NG will double its market share and be **70%** of total in state energy production by 2030[4].

Social Impacts of Increased Bioenergy Production in PA

Renewable Energy Jobs in PA[6,7]
- 90,772 employees in PA in 2019 at a 6% growth rate, 200,000 US jobs
- Clean energy employees more than twice the number of PA's workers in fossil fuel industries
- $20 billion in U.S. GDP in 2013

Natural Gas Jobs in PA[7,8]
-Projected 200,000 U.S. jobs lost in 2020 with transition to RE
-Reduction of 3.6% in total fossil fuel production
- NG prices decrease by $0.05 to $0.14 per MMBtu
-$1.3- 3.7 billion consumer savings

U.S. Environmental Cost Benefits[5]
-59 million metric tons of GHG reduced, equalling $2.2 billion benefit (social cost of carbon)
- National average health and environmental benefit of $5.2 billion

Future Work: Optimizing PA's Bioenergy Supply Chain

- Integrated modeling of various feedstocks with techno-economic analyses and life-cycle assessment to evaluate industrial cost and sustainability barriers.
- Logistical mapping of natural gas pipelines, injection sites, and conversion capability for Renewable Natural Gas (RNG) production in PA.
- Conduct a Discrete Sample study to analyze the barriers to adoption and willingness to pay for a bioenergy project on (dairy) farms in PA.
- Conduct a feasibility assessment on increased compression of biogas in PA and its use as trucking transportation fuel by 2050.
- Partner with RE industries, or help effectively transition fossil fuel industries.

Energy Storage Capacity in U.S.

Breakdown of Energy Storage in U.S. Regions without the addition of Wind or Solar based on projected 2020 peak demand[7]

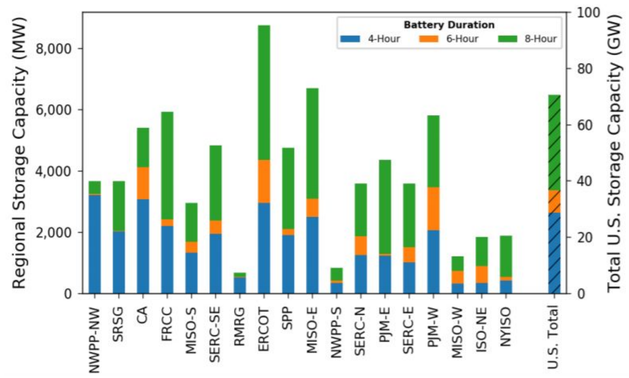


Fig. 2: Focus is placed on the Pennsylvania, New Jersey, and Maryland (PJM-E and a portion of PJM-W) regional total energy battery storage breakdown

Energy Storage Alternatives

1. **How much battery storage would PA need from wind, water, and sunlight (WWS) in 2050?**
   a. Roughly 5000 MW needed in 2020[7]
   b. Energy breakdown of 3.3% residential rooftop solar, 2.4% commercial rooftop solar, 68.8% solar plants, 20% onshore wind plants, 3% offshore wind and 2.6% tidal, wave and hydro to meet 100% RE goals by 2050[16]
2. **Could we substitute that with renewable natural gas by 2050?**
   a. Yes, depending on policies and subsidies in place.
3. **House Bill 2132 sponsored by Representative Christopher Rabb in 2018 has charged PA to be 100% renewable by 2050[17].If PA goes 100% renewable by 2050, how much battery storage would we need?**
   a. Assume a 0.35% increase in renewable energy per year, therefore additional battery storage of 52, 500 MW could be needed[7]
4. **How does this compare with the amount of biogas expected?**
   a. Bioenergy will represent 25% of global energy supply by 2050[18]
   b. Total biogas expected in PA from feedstocks listed above

References

1. US Energy Information Association. (2019). No Title. Retrieved from Pennsylvania State Energy Profile website: https://www.eia.gov/state/print.php?sid=PA.
2. Extension, P. S. (2018). No Title. Retrieved from Annual Energy Outlook through 2050 Released by the US EIA website: https://extension.psu.edu/annual-energy-outlook-through-2050-released-by-the-us-eia.
3. Szybist, Mark and Levin, A. (2019). No Title. Retrieved from PA Needs CO2 Limits—and Strong Renewables Policy, Too website: https://www.nrdc.org/experts/mark-szybist/pa-needs-renewable-energy-goals-well-carbon-limits.
4. Trieu Mai, Ryan Wiser, G. B., Lori Bird, Jenny Heeter, D. K., Venkat Krishnan, Jordan Macknick, A., & Millstein, D. (2016). A Prospective Analysis of the Costs, Benefits, and Impacts of U.S. Renewable Portfolio Standards. Retrieved from https://www.nrel.gov/docs/fy17osti/67455.pdf
5. Considine, T. J., Watson, R., & Blumsack, S. (2010). The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update. The Pennsylvania State University College of Earth & Mineral Sciences Department of Energy and Mineral Engineering, (May), 1–21.
6. E2. (2019). No Title. Retrieved from Clean Jobs Pennsylvania 2019 website: https://www.e2.org/reports/clean-jobs-pennsylvania-2019/
7. Denholm, Paul, Nunemaker, Jacob, Gagnon, Pieter, Cole, W. (2019). The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States. Retrieved from https://www.nrel.gov/docs/fy19osti/74184.pdf.
8. Trieu Mai, Ryan Wiser, G. B., Lori Bird, Jenny Heeter, D. K., Venkat Krishnan, Jordan Macknick, A., & Millstein, D. (2016). A Prospective Analysis of the Costs, Benefits, and Impacts of U.S. Renewable Portfolio Standards. Retrieved from https://www.nrel.gov/docs/fy17osti/67455.pdf
9. International Energy Agency. World energy outlook special report 2015: Energy and climate change. Final report. Paris: OECD/IEA; 2015.
10. United Nations Environment Programme. The emissions gap report 2014: A UNEP synthesis report. Final report. Nairobi: UNEP; 2014.
11. http://www.fao.org/save-food/resources/keyfindings/en/
12. FEASIBILITY OF ANAEROBIC DIGESTION OF ORGANIC WASTES FOR BIOFUEL PRODUCTION (2012). *BIOGAS YIELD FROM ANAEROBIC DIGESTION OF ORGANIC WASTES* (spreadsheet).
13. Global Methane Initiative. (2016, October). Overview of Anaerobic Digestion for Municipal Solid Waste. Retrieved July 11, 2019, from https://www.globalmethane.org/documents/AD-Training-Presentation_Oct2016.pdf
14. USDA NASS (2018). Steph Herbstritt Data.
15. Fischer, D. B. (2019). Energy Aspects of Manure Management. Retrieved from http://livestocktrail.illinois.edu/dairynet/paperDisplay.cfm?ContentID=274.
16. Stanford University. (2019). The Solutions Project: 100% Pennsylvania. Retrieved from https://thesolutionsproject.org/why-clean-energy/#/map/states/location/PA
17. Legislative Data Processing Center. (2018). Bill Information: Pennsylvania General Assembly. Retrieved from https://www.legis.state.pa.us/cfdocs/billInfo/billInfo.cfm?sYear=2017&sInd=0&body=H&type=B&bn=2132
18. Souza et al., (2015) Bioenergy & Sustainability. Policy Brief. G. M. Souza et al., Paris. Retrieved from http /bioenfapesp.org/scopebioenergy/images/E-VERSION-SCOPE-Final-lowres.pdf

Acknowledgments

Thank you to Drawdown Scholars Amanda Liebhart, Sarah Schanawald, Matthew Arenas, Risa Lewis, Allie Saunders, and Laura Rodriguez for their assistance with gathering feedstock and logistical data for PA. Thank you to PhD student Stephanie Herbstritt for supplying switchgrass and manure metrics.