Where’s the Beef? A suitability study for siting biogas facilities to capture methane from cattle production for urban energy consumption

Methane & Climate

The Problem: Cows emit copious amounts of methane. Countries with large cattle stocks, also tend to have a large methane footprint. This methane source is a climate hazard.

Introduction

An ample and well-established body of literature brings attention to the role of cattle production in climate change. Methane (CH4) is a potent greenhouse gas by all accounts, due to its ability to absorb infrared radiation and catalyze atmospheric carbon dioxide reactions. However, the massive field of alternative energy studies has only begun to consider the potential of cattle-based methane as an ungeopolized product. Methane is largely emitted from cattle, garbos, biomass, swine, coal mines, and urban areas, and more recent studies have shown significant patterns of atmospheric methane with cattle production. (Hume et al 2018)

Several estimates place the daily methane emissions of a single cow at 250 – 500 liters (Johnson & Johnson, 1995) hence a range of 100 – 600 liters. In newer, non-linear model that accounts for individual animal variability over time, methane gas output was estimated to be between 6.2 – 10.8 g/day (Billot & Clapperton 1965). With 1.3 billion cows in production globally (FAO 2005), an estimated 400 billion liters of methane gas are released into the atmosphere daily. Methane from all cattle globally has been considered against other methane sources and still stands out as the largest source of methane emissions, with an estimated 55 Tpy/year output to the atmosphere. (Cottral et al 1996) Also, methane of cattle globally has increased more than four-fold since the late 19th century.

Several reports, such as those released by the Intergovernmental Panel on Climate Change (IPCC) in 2006, have raised the need to mitigate methane emissions from cattle in order to reduce the industry’s impact on global climate change. However, this seems unlikely without reversing the trend to widespread expansion of global cattle stocks. Also, while the largest methane source is enteric gas, most biogas digesters feed off the methane from centralized cattle operations. However, in technical aspects of anaerobic digestion are not considered in-depth here.

Model Inputs

1. Pasture intensity
2. Cattle populations by state
3. Methane Hotspots & proximate cities
4. High Urban Density clusters

Data

To left (US Maps): 1. Identify methane lonnges as areas of methane intensity through aggregation. Aggregates result equal breaks from 0 – 1. Create polygon for highest percent intensity areas “Methane hotspots” as areas above this threshold. 3. Classify state polygons based on cattle populations, not individually to areas or human populations. Select cities by choosing cities from states with live cattle populations.

To right (Global Maps): 1. Select cities by location considering proximity (10 miles) to a methane hotspot. Limit to most suitable states under 200 square miles will be eliminated. 2. Urban density was found by using the kernel density function from ArcGIS. Then the areas were classified according to natural breaks, the denser that were, exported, and polygons formed from the central data. Last, these were used to portray intensity areas “energy vulnerable” areas.

Results

Based upon politically defined areas, I calculated the most suitable states or countries based on cattle populations or total methane stocks from agriculture. For the US, I classified states based on total cattle populations relative to the world. I supposed the most suitable countries based on World Bank data estimating total country populations. For the world, I supposed the largest source of atmospheric methane emissions in the world – methane-to-biogas suitability was primarily conveyed this way. I maintained and aggregated this same several times to achieve a smoother effect, and shaped polygons to “transport.”

With a kernel density function, I took the ERS Climate World Maps and created a new density of “dense urban zones” (high density of cities with more than 20,000 in-habitants) that would be the most in need of alternative energy sources. Only areas of cities identified within a close radius of the pasture temporal also fall in these areas of dense urban zones.

The final results, come in the form of cities, selected in reference to proximity to methane hotspots, urban density, and cattle studies. For global cities, I selected only 1,000,000 inhabitant cities in countries that are not listed as all dependent.

Also, according to (Huarte et al 2009) the methane to natural gas scheme works well if you can calculate the biogas directly into the natural gas infrastructure. While I managed to geospatially the natural gas pipeline network of the US, there should be quality data sets used in order to consider potential to biogas capture market.

Analyze

In this model, suitability is highly associated with available pasture land and the methane potential is considered by cow populations instead of methane availabil- ity or urban density. However, I assume here that cities near these areas will move on for cattle operations and suitable to biogas operations.

With the assumptions listed previously, I created a short list of most suitable cities, with slightly different criteria for US and for global cities, based upon the data available. Interestingly, the best suited cities lay on the border or just outside of the methane hotspot polygons, not inside.

Future Research

One of the main fallacies in this research that could use further research would be looking at the point data for individual feedlots and their capacity for the analysis of the network of highly concentrated methane emission areas. This, in fact, may be the most suitable locations for siting methane to biogas capture. In addition, a more refined raster map for natural gas pipelines would help the suitability analysis. With different types of operations considered, e.g. dairy vs. beef feed and industrial vs. pastoral systems, the results could vary significantly.

Surely, there are missing considerations in this analysis and questions that may be at hand. Does methane-to-biogas actually work well for urban energy infrastructure or could it provide a greater return on invest- ment for rural energy infrastructure? Does methane energy capture have any real impact in averting methane’s influence on climate change? What are the larger systematic issues with an anthropogenic-driven and highly polluting meat production industry?