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

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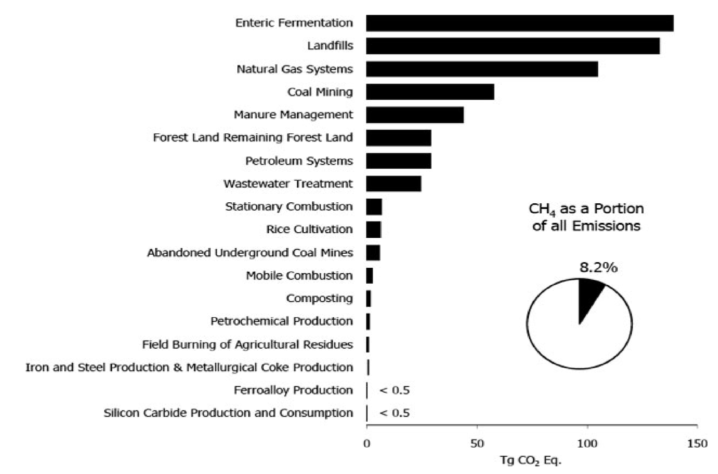
Methane & Climate

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.
The Proposal: These countries—and more specifically municipal areas—should look at technologies capturing anthropogenic methane as an alternative energy source.



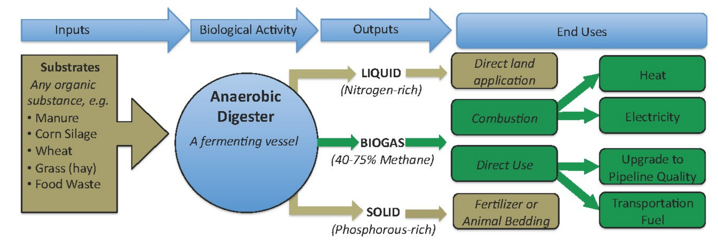
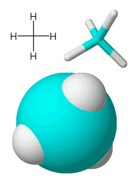


Figure 2. Schematic representation of the process of anaerobic digestion.

Figure 1 (left): *U.S. Environmental Protection Agency Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2007*

Figure 2 (above): McCord, Aleia et al. *Got Gas? An Analysis of Wisconsin's Biogas Opportunity.* University of Wisconsin-Madison, March 2011.

Introduction



An ample and well-established body of literature brings attention to the role of cattle production in climate change. Methane (chemically: CH_4) is a potent greenhouse gas by all accounts, due to its ability to absorb infrared radiation and catalyze atmospheric carbon dioxide reactions. However, the nascent field of alternative energy studies has only begun to consider the potential of cattle-based methane as an untapped product. Methane is largely emitted from cattle, garbage, biomass, wetlands, coal mines, and urban areas, and more recent studies have shown significant patterns of atmospheric methane with cattle production. (Huarte et al 2010)

Several estimates place the daily cattle emissions of a single cow at 250 – 500 liters per day. (Johnson & Johnson, 1995] Moss (1992) cites a range of 100 – 600 l/day. In a newer, non-liner model that accounts for individual animal variability over time, methane gas output was estimated to be between 6.2 – 10.8 g/day (Blaxter & Clapperton 1965) With 1.3 billion cows in production globally (FAO 2005), an estimated 400 billion of 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 Tg/year output to the atmosphere. (Crutzen et al 1986) Also, the number of cattle globally has increased more than 4-fold since the late 19th century.

Several reports, such as those released by the Intergovernmental Panel on Climate Change (IPCC) in 2008, have noted the need to mitigate methane emissions from cattle in order to reduce the industry impact on global climate change. However, this seems unlikely without reversing the trend towards ever-expanding global cattle stocks. Also, while the largest methane source is enteric gas, most biogas digesters feed off the manure from centralized cattle operations. However, he technical aspects of anaerobic digestion are not considered in-depth here.

References

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Hynes, Stephen et al (2009). A spatial micro-simulation analysis of methane emissions from Irish agriculture. *Ecological Complexity,* vol. 6(2). PP 135 -146.

Johnson, K.A. & Johnson, D.E. (1995). Methane emissions from cattle. Journal of Animal Science, Vol 73, Issue 8 2483-2492.

Moss, Angela (1992). Methane from ruminants in relation to global warming. Chemistry and Industry, no. 9, pp. 334-336.

K. L. Blaxter and J. L. Clapperton (1965). Prediction of the amount of methane produced by ruminants. British Journal of Nutrition, 19 , pp 511-522

Crutzen, P. J., Aselmann, I. And Seiler, W. (1986), Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. Tellus B, 38B: 271–284.

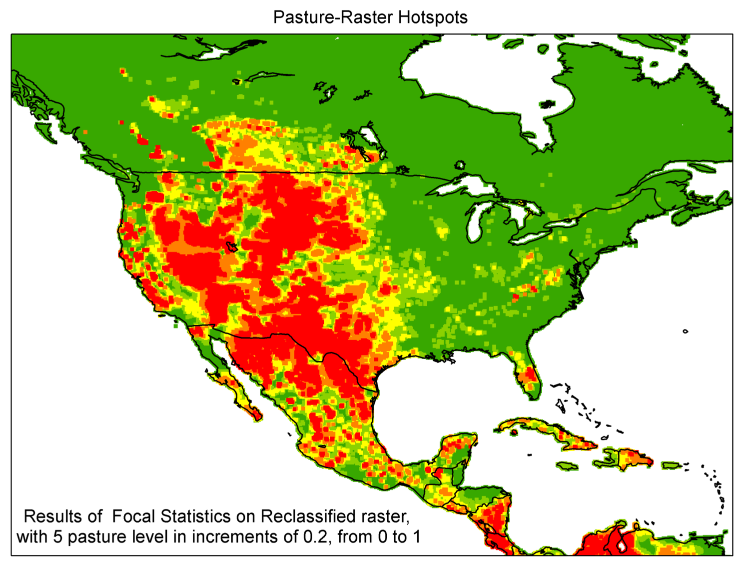
Data
Ramankutty, N., A.T. Evan, C. Monfreda, and J.A. Foley. (2010). *Global Agricultural Lands: Pastures, 2000*. Data distributed by the Socioeconomic Data and Applications Center (SEDAC): http://sedac.ciesin.columbia.edu/es/aglands.html. [October 3, 2011].

USDA. *Cattle*, U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, D.C.,: http://www.nass.usda.gov . [December 8, 2011]

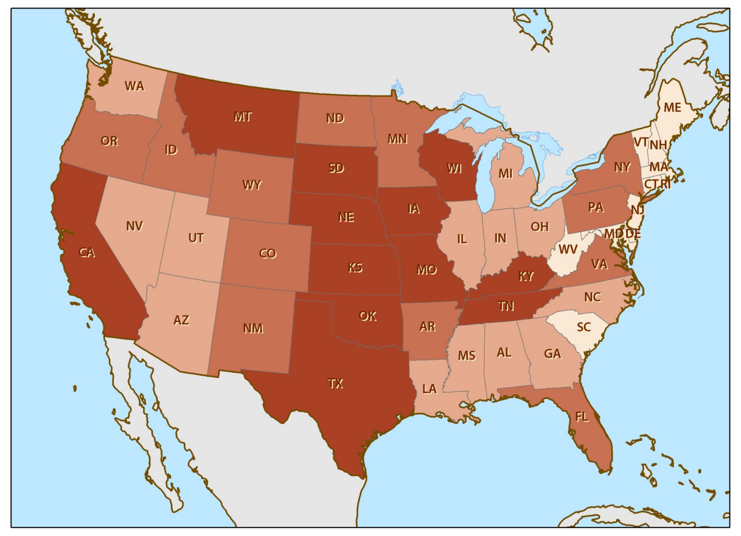
World Bank & International Energy Agency. World Development Indicators - agricultural methane emissions: http://data.worldbank.org/indicator/EN.ATM.METH.AG.ZS/ . [October 9, 2011]

UN Food and Agriculture Organization. FAO Agro-Maps - World Cattle Stocks, 2005. http://www.fao.org/

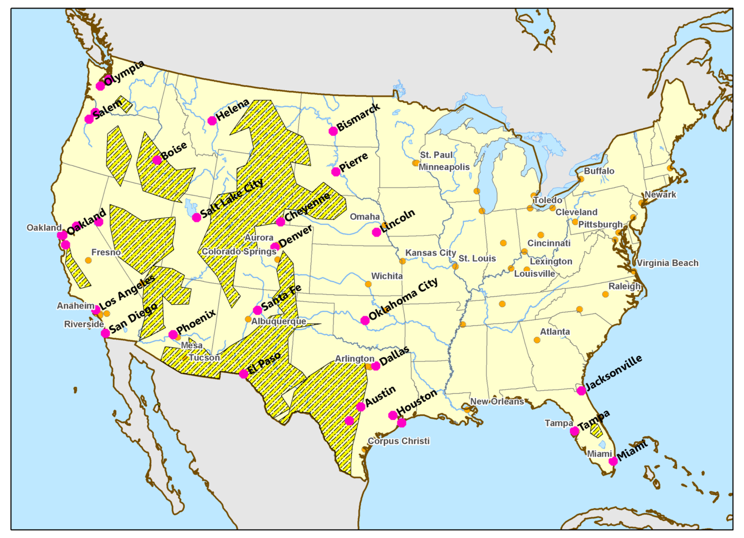
Model Inputs



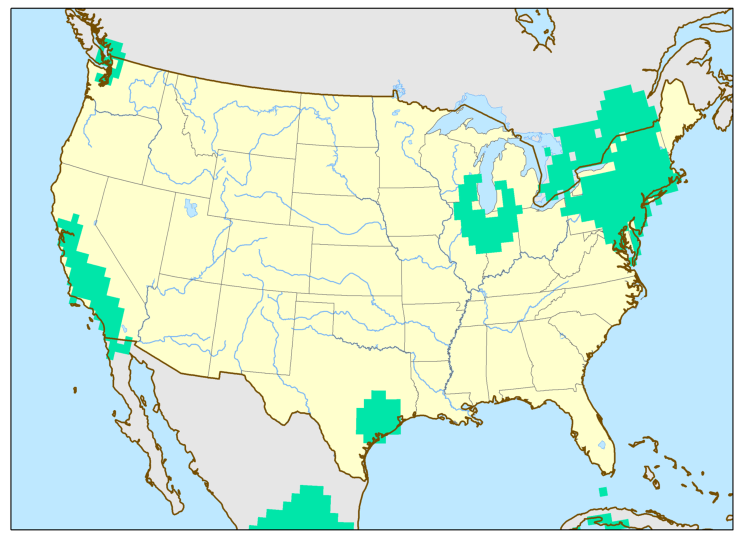
1. Pasture intensity



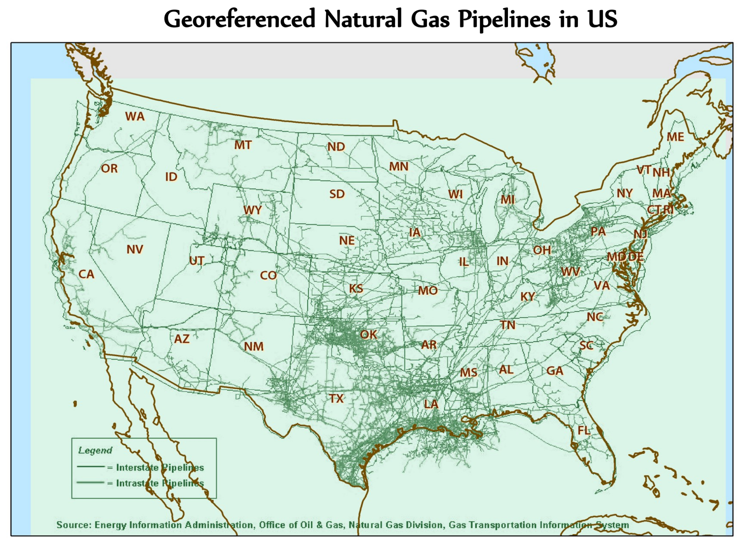
2. Cattle populations by state



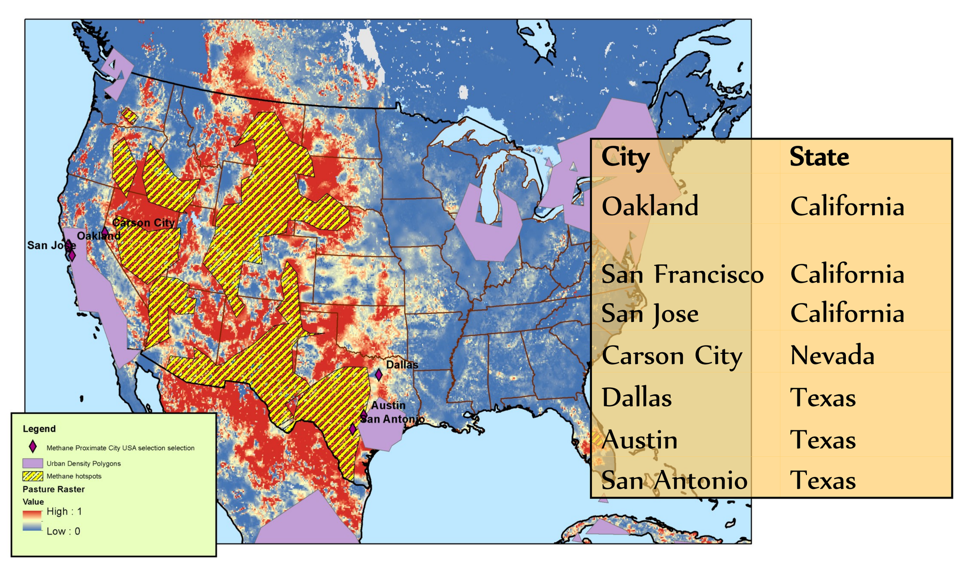
3. Methane Hotspots & proximate cities



4. High Urban Density clusters



Output: **Most suitable US cities for methane-to-biogas**



City	State
Oakland	California
San Francisco	California
San Jose	California
Carson City	Nevada
Dallas	Texas
Austin	Texas
San Antonio	Texas

Data

To left (US Maps):

1. Identify methane hotspots on raster of pasture intensity from remote sensing. Reclassify. Aggregate. Five equal breaks on 0 – 1 scale. Create polygons for highest pasture density areas . "Methane Hotspots" are shown in Map 3.

2. Classify state polygons based on cattle populations, not normalized by area or human population. Select cities by exclusion from states with low cattle populations.

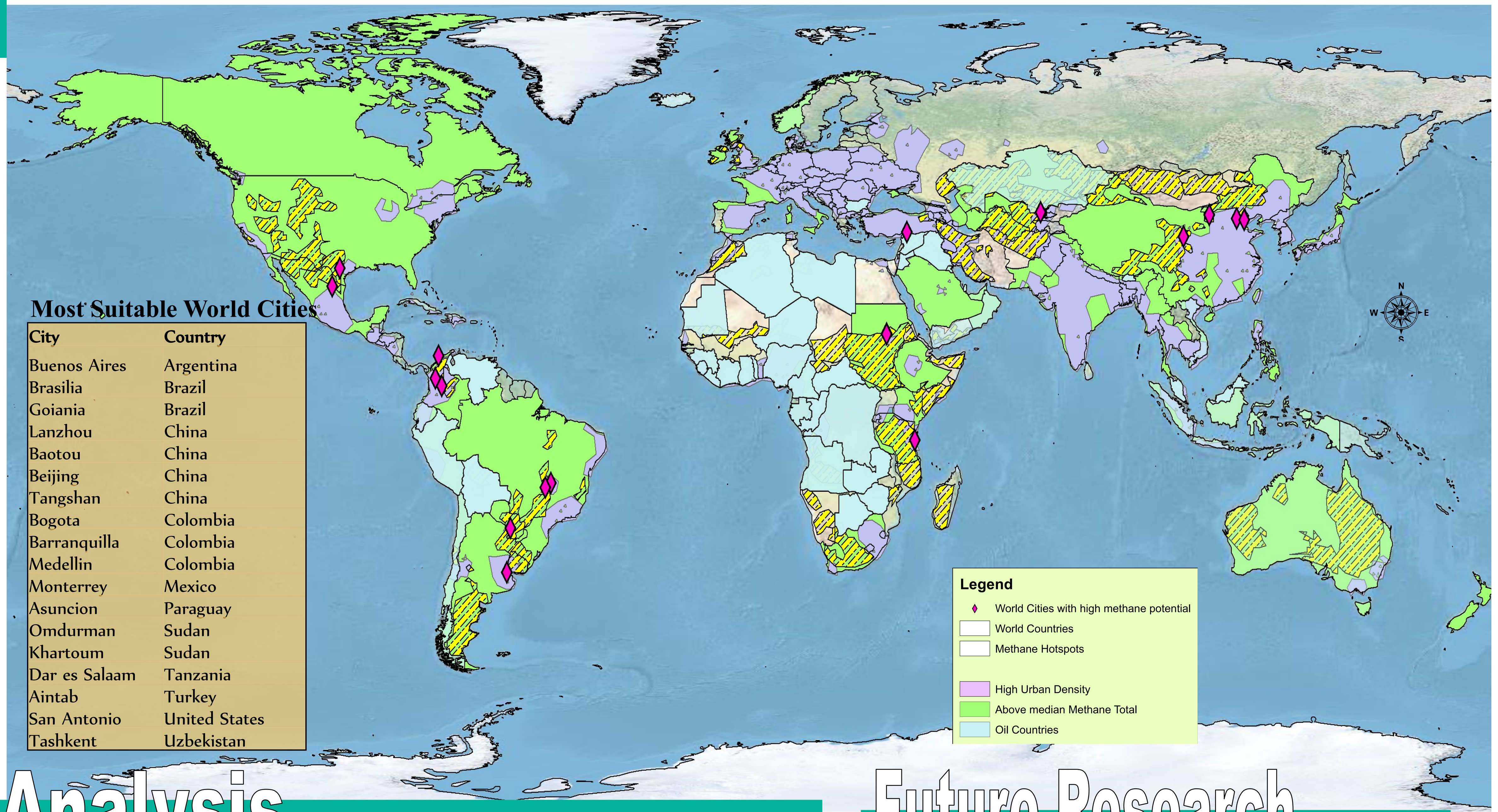
3.Select cities by location considering proximity (100 miles) to a methane hotspot. Later in analysis, smaller areas (less than 2000 square miles) will be eliminated.

4. Urban density was found by using the kernel density function on the ESRI World Cities map. Then the raster was classified according to natural breaks, the densest half were extracted, and polygons formed from the raster data. Select cities by proximity (100 miles) to "energy vulnerable" areas.

To right (Global map):

1. Same as above.
2. Countries classified by World Bank data on agricultural methane. Also, countries excluded by economies of oil dependence, also World Bank data.
3. Same as above, but proximity changed to kilometers.
4. Same as above, but proximity changed to kilometers.

US maps: North American Equidistant Conic
Global Maps: Plate Carrée



Most Suitable World Cities

City	Country
Buenos Aires	Argentina
Brasilia	Brazil
Goiania	Brazil
Lanzhou	China
Baotou	China
Beijing	China
Tangshan	China
Bogota	Colombia
Barranquilla	Colombia
Medellin	Colombia
Monterrey	Mexico
Asuncion	Paraguay
Omdurman	Sudan
Khartoum	Sudan
Dar es Salaam	Tanzania
Aintab	Turkey
San Antonio	United States
Tashkent	Uzbekistan

Results & Analysis

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.For the world, I separated the most suitable countries based on World Bank data estimating total country methane emissions due to agriculture. I assumed that the countries above the median level would be best suited for methane-to-energy operations.

The main layer of this analysis is the pasture intensity raster map from CEDAC/SIESIN. Using this map as a proxy for areas with the highest methane availability – keeping in mind that cows are the largest source of anthropogenic methane emissions in the world – methane-to-biogas siting suitability was primarily considered from this data. I reclassified and aggregated this raster several times to achieve a smoother effect, and shaped polygon "hotspots".

Using a kernel density function, I took the ESRI World Cities maps and created a raster of "dense urban zones" (high density of cities with more than 200,000 inhabitants) per that would be the most in need of alternative energy sources. Only a few of the cities identified within a close radius of the pasture hotspots also fall into 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 stocks. For global cities, I selected only 1,000,000+ inhabitant cities in countries that are not listed as oil dependent.

Also, according to (Hynes et al 2009) the methane to natural gas scheme works well if you can transfer the biogas directly into the natural gas infrastructure. While I managed to georeference the natural gas pipeline network of the US, there should be better quality data sets used to better correlate pipelines to biogas capture suitability.

Analysis
In this model, suitability is highly associated with available pasture land and the methane potential is considered by cow populations instead of manure availability or cattle density. However, I assume here that cities near these areas will serve as hubs 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 an analysis of the network of highly concentrated methane emission areas. This, in fact, may belie the most suitable locations for siting methane to biogas capture. In addition, a more refined vector map for natural gas pipelines would help the suitability analysis. With different types of operations considered, e.g. dairy vs. beef cows and industrial vs. pastoral systems, the results could vary significantly.

Surely, there are missing considerations in this analysis and questions that beg to be asked. Does methane-to-biogas actually work well for urban energy infrastructure or could it provide a greater return on investment 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?