Identifying Opportunities and Impacts for New Uses of Hog Waste in Eastern North Carolina

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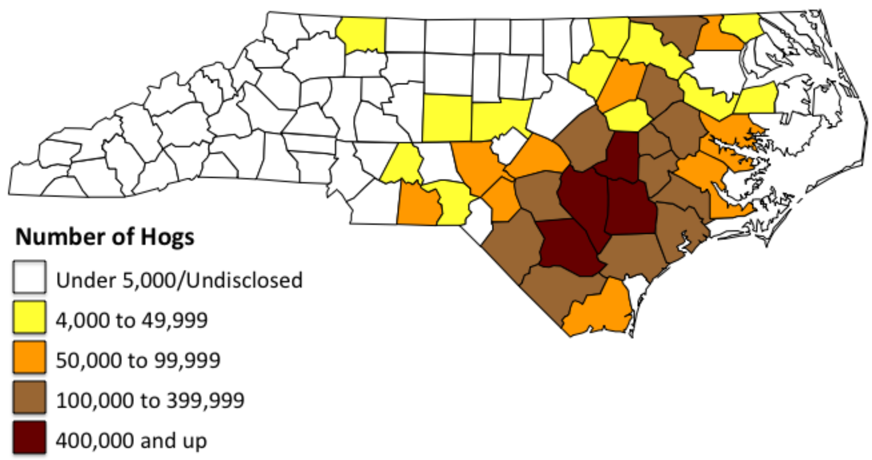
Task 1: Industry Overview and Public Health Issues

North Carolina's hog farms, as shown in Figure 1, are concentrated primarily in the southeastern part of the state. Hog farms range anywhere from small, family-run operations to large mechanized plants capable of processing up to 11 million sows a year. Hog industrial structure varies widely from state to state, and North Carolina's industry is built around a "contracted" system, which relies on independent farmers to focus on different stages in the hog farming and production process. In general, these stages are broken down into six different categories: research and development, hog farming, meat processing, finishing and packaging, product distribution, and retail (NC in the Global Economy). Of these various stages, hog farming is the most economically viable component for North Carolina.

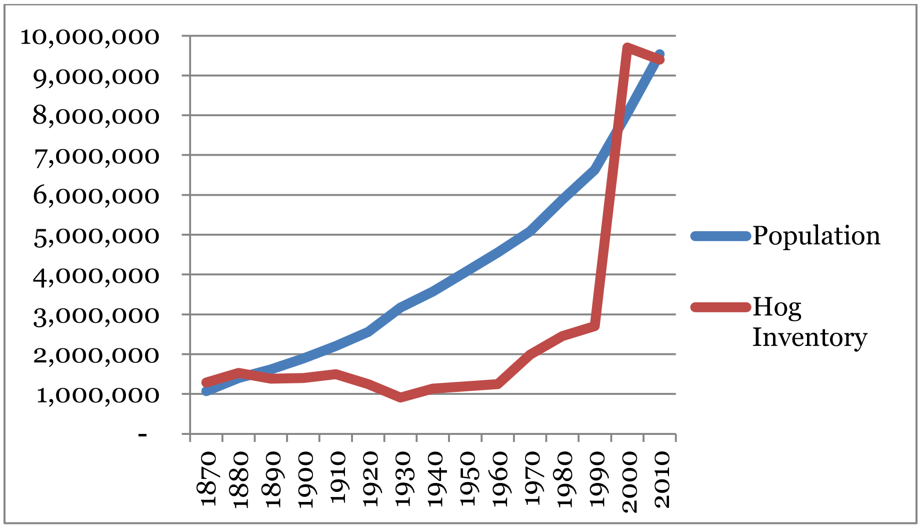
Figure 1: Inventory of Hogs by County



Source: USDA/NASS QuickFacts

Historically, North Carolina has consistently had a large number of hogs. Dating back to 1866, North Carolina has been home to hundreds of thousands of hogs. In some years, hogs have outnumbered the population of North Carolina. From 1866 to today, North Carolina's farms have had an inventory of at least one million hogs except for during nine years, 1924-1930 and 1934-1935. As shown in Figure 2, while the population of North Carolina has steadily grown, the growth in the number of hogs in North Carolina has been inconsistent.

Figure 2: Growth of North Carolina's Population and Hog Inventory

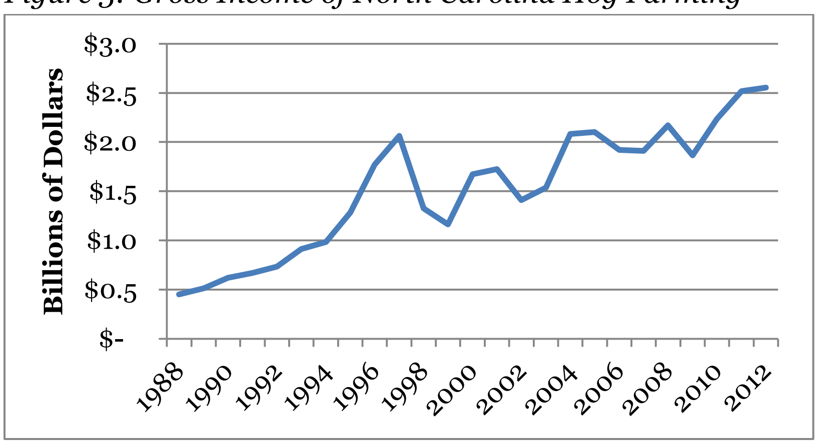


Source: Social Explorer Tables, Census Bureau and USDA/NASS QuickStats

From decade to decade, North Carolina's population has always increased with an average of 17% between 1870 and 2010. The hog industry has had four decades of negative growth with an explosive growth of 259% from 1990 to 2000. The average growth over a decade for hog industry is 25%.

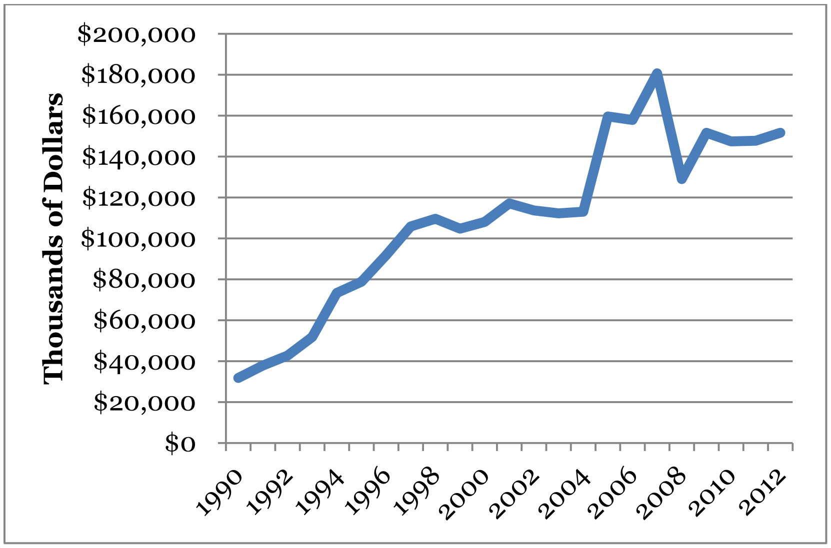
As the number of hogs increased in North Carolina, so did the gross income of farms and wages paid to farm workers. Gross income is defined as cash receipts and home consumption. These statistics are provided in Figures 3 and 4.

Figure 3: Gross Income of North Carolina Hog Farming



Source: USDA/NASS QuickFacts

Figure 4: Growth of Hog Farm Total Wages in North Carolina



Source: USDA/NASS QuickFacts

While the number of hogs has increased 762% from 1965 to 2007, the number of hog farms has drastically decreased by 96%. In 1965, North Carolina had an estimated 74,000 hog farms compared to an estimated 2,800 farms in 2007. Beginning in the 1970s and gaining significant momentum during the 1990s, hog farming transformed to become an industrial industry focused on efficiency. For example, the average number of hogs per farm increased more than 22,000% from about 16 in 1965 to 3,643 in 2007.

The growth of hog farming came began to slow in the late 1990s with environmental concerns associated with the hog waste. In 1997, North Carolina passed the Clean Water Responsibility Act 6, part of Bill 515 that placed a moratorium on the construction of farms with more than 250 hogs and the expansion of existing large farms.

Hog Slaughtering in North Carolina

The hog slaughtering industry in North Carolina has seen similar growth. Hog slaughtering is commonly measured by two statistics. In North Carolina, hog slaughtering increased 373% from 654 million pounds in 1990 to 3.1 billion pounds in 2012. The second statistic of slaughtering is number of heads slaughtered, which has increased 315% from 2.7 million in 1990 to 11.4 million in 2012.

Consolidation is another similar theme with hog farming and slaughtering. In North Carolina, the number of animal, except poultry, slaughtering establishments decreased from 52 in 2001 to 37 in 2012. This decrease of 29% has had little negative impact the number of employees working at these facilities. From 2001 to 2012, the number of employees only decreased 8% to 7,240 in 2012.

In 1992, the world's largest meat processing plant was constructed in Bladen County, which today boasts one of the highest concentrations of hogs per capita in the world. Until October 2013, Smithfield Farms dominated the hog production industry in North Carolina, but Shanghui

International Holdings Company recently purchased the company. This decision is likely to have a substantial impact on both North Carolina's hog economy and the U.S. hog industry at large, but the extent of its long-term effects remain unseen.

Comparison of Hog Industries in North Carolina, Iowa and Minnesota

North Carolina's hog industry, inclusive of farming and production, is large, but not the largest in the United States. Compared to Iowa, North Carolina's hog industry appears rather small. Iowa has more than twice as many hogs on its farms. North Carolina ranks second in the United States with inventory of hogs with Minnesota in third. Table 1 provides a more detailed comparison of hog farming (NAICS 1122).

Table 1: Comparison of Hog Farming in Iowa, Minnesota, and North Carolina

Measure	Iowa	Minnesota	North Carolina
Inventory of Hogs (Sept. 2013)	20.6 million	7.7 million	9.0 million
Number of Hog Farms (2007)	8,391	4,382	2,800
Number of Hogs per Farm	2,455	1,757	3,214
Hog Farming Employment (2012)	4,254	3,007	4,851
Avg. Number of Employees per Farm	0.5	0.7	1.7

Source: USDA/NASS QuickFacts and BLS QCEW

Not all hog farms are large-scale industrial farms. Independent growers continue to make up a large percentage of all hog farms. As shown in Table 2, in North Carolina, the number of independent grower establishments is increasing while they are decreasing in Iowa and Minnesota.

Table 2: Percent of Farms Classified as Independent Grower (2007)

State	Number of Farms in 2002	Number of Farms in 2007	Percent Change	Percent of all Farms in 2007
Iowa	7,548	5,242	-31%	62%
Minnesota	4,410	3,210	-27%	73%
North Carolina	1,166	1,233	6%	44%

Source: USDA/NASS QuickFacts

North Carolina's hog production, measured in pounds, ranks third in the United States behind Iowa and Minnesota. Table 3 provides a more detailed comparison of hog production in these three states (NAICS 311611).

Table 3: Comparison of Hog Processing in Iowa, Minnesota, and North Carolina

Measure	Iowa	Minnesota	North Carolina
Production Measured in lbs (2012)	10.3 million	4.0 million	3.9 million
Hog Processing Establishments (2012)	85	78	37
Pounds of Production per Establishment	121,176	51,282	105,405
Hog Processing Employment (2012)	17,295	5,293	7,240
Avg. Number of Employees per Establishment	203	68	196

Source: USDA/NASS QuickFacts and BLS QCEW

Workforce Profile

Wages

Average annual North Carolina wages for hog farm employees are slightly higher than in Iowa or Minnesota, reaching about $40,900 per year. However, North Carolina processing and slaughtering workers earn just $28,624 per year on average, which is about $1,500 to $3,300 less than what these workers earn in Iowa or Minnesota. More detailed wage data is provided in Tables 4 and 5.

Table 4: Wages in Hog Farming Industry

State	Hourly Wage	Annual Wage	Employment	Total Wages (Annual)
Iowa	$18.65	$38,782	4,254	$164,977,502
Minnesota	$18.96	$39,435	3,007	$118,581,101
North Carolina	$19.67	$40,903	4,851	$198,421,874

Source: BLS, Occupation and Education Survey, author analysis

Table 5: Wages in Hog Production Industry

State	Hourly Wage	Annual Wage	Employment	Total Wages (Annual)
Iowa	$14.49	$30,131	17,295	$521,108,039
Minnesota	$15.38	$31,981	5,293	$169,274,356
North Carolina	$13.76	$28,624	7,240	$207,238,032

Source: BLS, Occupation and Education Survey, author analysis

Occupational Breakdown

Of the ten main occupations that drive the U.S. hog farming industry, only three require some level of experience, and seven require either no or just short-term on-the-job-training, comprising 93% of positions. None of these occupations require more than a high school diploma. North Carolina leads the nation with 4,079 total employees across all occupations related to hog farming compared to Iowa and Minnesota's 3,577 and 2,528 employees, respectively. Also, 65% of farm workers have no experience at all before beginning work in the hog industry, whereas 31% have more than five years. More information about these occupations and education is provided in Table 6.

Table 6: Profile of Top 10 Occupations by Size for Hog Farming (NAICS 1122)

Occupation	Education	Experience Required	On the Job Training	Employment		
				IA	MN	NC
Miscellaneous Agricultural Workers	Less than HS	None	Short-term	2,030	1,435	2,315
Farmers, Ranchers, and Other Agricultural Managers	HS diploma or equivalent	More than five yrs	None	1,193	843	1,360
Bookkeeping, Accounting, and Auditing Clerks	HS diploma or equivalent	None	Moderate-term	80	56	91
First-Line Supervisors of Farming, Fishing, Forestry	HS diploma or equivalent	1 to 5 yrs	None	63	44	72
Animal Trainers	HS diploma or equivalent	None	Moderate-term	61	43	70
Heavy and Tractor-Trailer Truck Drivers	HS diploma or equivalent	1 to 5 yrs	Short-term	41	29	47
Landscaping and Groundskeeping Workers	Less than HS	None	Short-term	30	21	34
Production Workers, All Other	HS diploma or equivalent	None	Moderate-term	28	20	32
Secretaries and Administrative Assistants	HS diploma or equivalent	None	Short-term	26	18	30
Laborers and Freight, Stock, and Material Movers, Hand	Less than HS	None	Short-term	25	18	29

Source: BLS, Occupation and Education Survey, author analysis

U.S. animal slaughtering and processing production (except poultry) is centralized in Iowa with 17,295 workers, a number that more than doubles North Carolina's employment totals and triple Minnesota's. Of the ten main occupations in this industry, only one requires post-secondary education and at least one year of previous experience. The remaining roles are more likely to require moderate to long-term on-the-job-training, since they are more dangerous than farm positions and expose the worker to greater risk. However, 89%of these slaughtering and processing roles require no prior experience. More information about these occupations and education is provided in Table 7.

Table 7: Profile of Top 10 Occupations by Size for Hog Production (NAICS 311611)

Occupation	Education	Experience Required	On the Job Training	Employment		
				IA	MN	NC
Meat, Poultry, and Fish Cutters and Trimmers	Less than HS	None	Short-term	3,891	1,191	1,629
Slaughterers and Meat Packers	Less than HS	None	Moderate-term	2,886	883	1,208
Laborers and Freight, Stock, and Material Movers, Hand	Less than HS	None	Short-term	838	256	351
Packers and Packagers, Hand	Less than HS	None	Short-term	643	197	269
Production Workers, All Other	HS diploma or equivalent	None	Moderate-term	636	195	266
Packaging and Filling Machine Operators and Tenders	HS diploma or equivalent	None	Moderate-term	570	175	239
Helpers--Production Workers	Less than HS	None	Short-term	539	165	226
First-Line Supervisors of Production Workers	Post HS required	1 to 5 years	None	494	151	207
Maintenance and Repair Workers, General	HS diploma or equivalent	None	Moderate-term	400	122	167
Butchers and Meat Cutters	Less than HS	None	Long-term	379	116	159

Source: BLS, Occupation and Education Survey, author analysis

Education

Hog farm workers generally have low levels of educational attainment compared to the wider population, with 54% having achieved less than a high school degree as shown in Table 8. Additionally, 43% have received a high school degree or equivalent, with less than 3% of the remaining workers having any type degree beyond the high school level. The processing and slaughtering industry exhibits slightly higher levels of educational disparity, with 64% of workers having less than a high school diploma, 30% having a high school diploma or equivalent, and 6% of workers having degrees beyond the high school level. This difference can likely be attributed to the higher qualifications that are required in this industry for supervisory and managerial roles.

Table 8: Educational Requirements for Hog Industry

Education	Percent of Occupations	
	Hog Farming	Hog Production
Less than HS	54%	64%
HS diploma or equivalent	43%	30%
Post HS degree or award	3%	6%

Source: BLS, Occupation and Education Survey, author analysis

The majority of positions in the hog farming and production industries do not require significant prior experience. In farming, there is a wide gap between entry-level and skilled jobs, with 65% of positions requiring no experience, and 30% requiring at least 5 years. Only 5% of positions require between one and five years of experience.

An even smaller proportion of positions within the hog production industry require previous experience. Only 11% of positions require some experience, and none require more than 5 years (Table 9).

Table 9: Experience Requirements for Hog Industry

Experience	Percent of Occupations	
	Hog Farming	Hog Production
None	65%	89%
Less than 1 year	0%	4%
1 to 5 years	5%	7%
More than 5 years	30%	0%

Source: BLS, Occupation and Education Survey, author analysis

Table 10: On the Job Training for Hog Industry

On the Job Training	Percent of Occupations	
	Hog Farming	Hog Production
None	35%	4%
Short-term	60%	53%
Moderate-term	5%	40%
Long-term	0%	3%

Source: BLS, Occupation and Education Survey, author analysis

Economic Impact of the Hog Industry in North Carolina

The hog industry provides a substantial amount of employment and economic activity in the 11-county region in southeastern North Carolina where the vast majority of hog farming and processing activity in the state takes place. On an annual basis, we estimate that the hog industry employs approximately 4,581 people while hog processing employs another 7,240 people for the 11-county region. Using these estimates of employment, we used the economic impact modeling software, IMPLAN, to estimate the economic impact of the hog industry on the region as shown in Table 11.

Table 11: Employment Impact of Hog Industry in 11-county Region:

Impact type	Employment	Labor Income	Value Added	Output
Direct Effect	11,821	$200,188,759	$325,257,145	$574,541,200
Indirect Effect	1,341	$35,017,991	$58,366,375	$110,519,388
Induced Effect	1,314	$43,709,930	$80,931,381	$139,147,097
Total Effect	**14,477**	**$278,916,682**	**$464,554,902**	**$824,207,686**

Source: BLS, Occupation and Education Survey, author analysis

The hog industry in the 11-county region contributes to the employment of 14,477 people through direct, indirect and induced economic effects of the industry. Directly employed by the industry are 11,821 people, while the spending of those employees and hog farms result in another 2,655 jobs in the region. As such, over $278 million dollars in labor income is generated each year for the region from hog farming and processing. Overall, the industry in these 11 counties creates an output of $824 million, which illustrates its economic importance for the region and the state.

Some of the indirect and induced jobs are in industries such as maintenance and construction of non-residential structures, support industries for agriculture, wholesale trade, truck transportation, as well as other common services such as food and drink, real estate, medical care, child care, education and retail stores.

The tax revenue generated by this industry is also substantial. For example, $4,844,145 in state and local corporate tax comes from this industry in the 11-county region on an annual basis. Households generate another $7,165,202 in state and local taxes per year, while taxes on production and imports generate over $25 million.

Public Health Concerns of the Hog Industry

Over the past few decades, hog farms have become exponentially more productive as output has grown to produce unprecedented rates of return. Technological improvements to animal breeding, mechanical innovations, pharmaceuticals and higher usages of formulated feeds have brought greater efficiencies and profit to the industry. Meanwhile, farms are expanding in size, reaching ever-increasing economies of scale and spending less money and time than before to reach previous benchmarks. Accompanying this growing output, however, is a rising awareness of the impacts that increasing amounts of hog waste have on public health and the environment.

Although it remains an under-studied topic, a growing amount of the existing literature on the subject of public health and hog farming focuses on the many externalities of waste production. Waste is an issue of growing concern due to the number of contaminants it can transport away from farms, including pathogens like E. coli, growth hormones, antibiotics and inorganic chemicals. The growth of hog farms poses even greater threats to air and water quality due to the sheer volume of pollutants that have such profound public health implications. The remaining literature examines the full spectrum of hog farm impacts according to environmental, psychophysiological, and physical indicators. In many of these cases, the treatment and disposal of waste have tremendous implications for nearby communities.

Airborne Pollution

Odors are well-known and common by-products of hog farms, and are easily carried away from farm operations on dust and other airborne compounds. While the health risks to neighbors of factory farms has not been well-established, several pieces of literature suggest that malodorous gases and vapors from hog operations may have both physical and psychophysiological side effects on neighboring communities who breathe in these particles on a daily basis. In their study on environmental odors emanating from large-scale hog farms, Schiffman et. al. found that people living near these operations reported more tension, depression, anger, fatigue, confusion, and less vigor than control subjects (2000). Horton et.al. conducted a series of interviews with individuals living in predominantly African-American communities in southeastern North Carolina, who reported high rates of stress and negative mood (2009). Surveying children from several public schools in North Carolina, Mirabelli et.al. correlated high rates of wheezing to those schools' proximity to hog farms (2006).

Antibiotic Resistance

As the mechanization of hog farming techniques have scaled up in recent decades, so too has the use of nontherapeutic growth hormones. Over-use of these hormones supports the emergence of evolving microorganisms that are growing increasingly resistant to antibiotics. In a study by Chee-Sanford et.al, researchers identified Tetracycline-resistant genes in a hog farm, its neighboring manure lagoon, and in groundwater 250 meters downstream from the lagoon (2006). In a separate study, Chee-Sanford et.al. traced antibiotic-resistant genes from two hog farms into the local ground stream, underlining the potential risks of the widespread use of antibiotics for routine, non-therapeutic uses (2001). Voss et. al. have documented the potential for hog-to-human transmission of several drug-resistant diseases including penicillin and several strains of MSRA (2005). As pathogens grow more resistant to certain antibiotics, individuals are equipped with fewer defenses to overcome illness.

Water Contamination

Hog farms negatively impact surrounding water quality, and diseases caused by farm-borne pathogens can directly impact human health. For example, rural areas are much more likely to rely upon well water than urban or suburban populations. Because it is hard to inspect and regulate, contaminated groundwater puts rural populations at higher risk of nitrate poisoning. Nitrate poisoning has been linked to higher incidences of birth defects, hyperthyroidism, diabetes and cancer (Gilchrist, 2006). Contaminants from animal wastes can find pathways into the environment from leaky manure lagoons, through heavy rainfalls that cause lagoons to overflow, and runoff from the application of waste on fields (Burkholder, 2007). Campagnolo et. al. documented the presence of high levels of antimicrobial compounds in large-scale hog waste lagoons and proximate farms and suggest that waste sprayed onto these fields facilitate the spread of antimicrobial residues into the water stream (2002). Even at recommended rates of application, Stone et. al. discovered that contaminants can still reach nearby waterways through runoff or leaching through soils (1995).

Socioeconomic Status
In North Carolina, hog farms are heavily concentrated in the southeastern part of the state, especially in poor, rural and predominantly African-American communities. Because of their location, these hog farms disproportionately affect the health of individuals in surrounding areas. Several studies have examined the propensity for populations living in close proximity to these farms to be more susceptible to illness, stress, depression and physical injury. Unfortunately, these individuals are more likely to be poor, nonwhite, and less economically empowered to react against the political influences that determine policy in this arena. Wing, et. al. found that hog operations in North Carolina are five times denser in areas with the highest three-quintiles of nonwhites than in the lowest quintile (2000). Due to factors like low income, inadequate housing, low health status, and insufficient access to medical care, racial discrepancies compound the negative impacts that hog farms create (Donham, 2007).

Impacts on Immunocompromised Individuals
Certain individuals with weakened immune systems are at greater risk of experiencing adverse health effects if they live close to a hog farm. When parasites, bacteria or viruses from waste affect healthy people, these individuals are better-equipped to combating these pathogens. However, infants, pregnant women, children, the elderly and those taking medications that suppress the immune system are particularly vulnerable to illness due to their weakened immunological state (Burkholder, 2007).

Impacts on Worker's Health
An increasing amount of literature examines the impacts associated with working as an employee of a hog farm. Due to their close proximity the pollutants that these operations create, these individuals are especially vulnerable to their negative externalities. Farm workers report disproportionately high rates of occupational asthma, acute and chronic bronchitis, musculoskeletal injuries, hearing los and organic toxic dust syndrome (Heederik, 2007 & Mitloehner, 2008). The rising number of hogs in factory farms creates a large amount of waste, and dust particles carry animal skin cells, feces and bacteria, which lower indoor air quality and cause respiratory problems in workers (Wing & Wolf, 2000).

Task 2: Swine Waste and Swine Waste-to-Energy Systems

This section of the report examines legislative factors that influence the hog industry's disposal of waste and the creation of swine waste-to-energy systems, focusing primarily on North Carolina, with an exclusive focus on fecal waste as the main driver for change in North Carolina legislation. In the second half of this section, legislation that supported the creation of the swine waste-to-energy market is presented, as well as a brief overview of the role incentives play in creating swine waste-to-energy systems.

Federal Regulation of Swine Waste

The federal government has, to this point, been relatively silent on the issues of swine waste. This section provides some detail on regulation provided by the Clean Water Act and subsequent rule-making that affects the Clean Water Act.

At the federal level, swine waste has largely been unaddressed, save by the Clean Water Act (CWA) of 1972. The Act remains the primary federal law regulating water pollution and, for the first time, established water quality standards. Unfortunately, because swine waste is not as consistent in quality as synthetic fertilizer, hog producers may occasionally apply manure in excess of the land's agronomic requirement. (Key et al., 2011) The Act made it illegal to discharge pollutants from animal feeding operations (designated a 'point source' in the legislation) into navigable waters except in the case of a storm event. Land application areas, the area to which swine waste is applied, may not discharge except in the case of 'agricultural stormwater discharges.' North Carolina issued the new National Pollutant Discharge Elimination System (NPDES) permits out of what would eventually be the Department of Environment and Natural Resources (NCDENR) (Larick, 2013).

While the Act did recognize that concentrated animal feeding operations (CAFOs) were point sources for contaminants, and laid the groundwork for their regulation, the Act did not establish a threshold of hogs that would qualify a hog farm as a CAFO or otherwise define them. The act also did not define 'agricultural stormwater discharge' (Centner, 2011).

This lack of definition generally continued to leave CAFO oversight to the states, until the EPA developed two clarifying rules to specifically address animal feeding operations. In 1974, the EPA issued *Effluent Limiting Guidelines and New Source Performance Standards*, which created industry-specific operating water quality rules. In 1976, the agency added definitions that identified which animal feeding operations constituted a 'point source' and would be subject to NPDES standards. By the federal standards, an animal feeding operation (AFO) is defined as any livestock operation in which animals are fed or maintained for 45 or more days a year within a place of confinement that does not include normal growing season vegetation. Concentrated animal feeding operations (CAFOs) are defined by species-specific threshold numbers of animals; for swine, the federal level was set to 2,500 animals. However, the 1976 rules exempted operations that would only discharge in the event of a 24-hour, 25 year storm. All other CAFOs exceeding the threshold are prohibited from discharging into navigable waters unless the CAFO holds an NPDES permit issued by the EPA or by its authorized state agency (Sweeten et al., 2003).

The rules were not especially effective at protecting the country's waters. The 1998 Water Quality Inventory found that 40% of assessed waters were impaired, with agriculture a main contributor. (EPA, 2001) In 2003, the EPA updated its rules to include a provision that all concentrated animal feeding operations seek coverage under an NPDES permit: *NPDES and Effluent Limitation Guidelines and Standards for CAFOs Final Rule* (EPA, 2002). The 2003 rule also changed the definition of agricultural stormwater discharges to include any precipitation-related event (Centner, 2011).

The 2003 requirement that all CAFOs obtain an NPDES permit was successfully challenged in Waterkeeper Alliance v. EPA (2005). The *Waterkeeper* court held that CAFOs may not be responsible for agricultural stormwater, as long as the CAFO follows strong agricultural practices. Because most CAFOs argue that they only have agricultural stormwater discharges, many CAFOs are not federally required to apply for a discharge permit (Centner, 2011).

In the 2008 revision, CAFOs would be required to seek a permit if they intend to discharge or propose to discharge. In *National Pork Producers Council v. EPA* (2011), the National Pork Producers Council successfully challenged the NPDES permitting requirement for CAFOs proposing to discharge. The ruling allowed any CAFO found to accidentally discharge the opportunity to take steps to prevent additional discharges—*before* being required to secure an NPDES permit (Centner, 2011). The new revision essentially required a CAFO to be caught in the act of polluting before it would fall under EPA regulations—a requirement that could severely limit the EPA's ability to prevent CAFO-related discharges (Tomaselli, 2013).

The next major revision to the final rule occurred in 2011, following a settlement agreement reached between the EPA and the National Resources Defense Council, the Waterkeeper Alliance, and the Sierra Club. This rule would require all CAFOs to submit basic operational information to the EPA. The information would be used to evaluate NPDES program effectiveness, identifying and permitting CAFOs that discharge, and estimating pollutant loadings. After a comment period on the proposed information campaign that ended the beginning of 2012, the EPA chose to rescind the proposed registration program because the regulations would be burdensome for CAFOs. Instead, the EPA will enter into a collaborative arrangement with the Association of Clean Water Administrators to assist the agency in collecting information about the CAFOs. To gather the information, much of the data will come from organizations that include the USGS and state agencies (Federal Register, 2012).

The 2012 rule revision generally introduces requirements less stringent than what was in place at the state level (Lawson, 2013). The 2012 rule revision is also under review, pursuant to requirements put forth in section 610 of the Regulatory Flexibility Act of 1980 (EPA, 2013a).

North Carolina Regulation of Swine Waste

North Carolina has historically been seen as a state friendly to agriculture. The State passed one of the first right-to-farm laws in the country in 1979, with the "Agricultural Nuisance Standards" bill (Horne, 2000). Some research indicates that the State's relatively lax environmental regulation may have played a part in the hog industry's expansion in the state[1] (for more

[1] The degree of environmental regulation in the state seems to bear some responsibility for the shift in the structure of the swine industry (discussed in the first section of this report), and likely explains some of the shift in North Carolina. In an effort to quantify the full extent of this impact, a number of studies have made an attempt to identify key elements of environmental regulation across several state and conduct a comparison. Herath, Weesink, and Carpentier (2005) found that the degree of environmental regulation had a significant influence on the structure of the hog sector, with operations moving to areas where regulation was weaker.

information, see Herath et al., 2005; Roe et al., 2002; Metcalfe, 2001; Nene, Azzam, & Schoengold, 2009). During the early 1990s, Senator Wendell Murphy in particular was instrumental in passing further protections on the state's swine industry, including legislation that placed livestock under the protections of the right-to-farm law, removed counties' ability to zone out swine farms, and granted permission to the NC Pork Producers Association to collect a $.01/swine levy to support lobbying activity in the state.[2]

Federal law, as described in the previous section, largely left regulation to the states. In 1989, HB 480 created the Department of Environment, Health, and Natural Resources (DEHNR) by consolidating several other environmental programs. The new law required that any swine farm operator obtain a permit if they discharged pollutants to state waters. With SB 431 of the same year, waste lagoons were required to establish and maintain approved systems for monitoring and maintaining quality of water and air discharges. However, hog farms with fewer than 250 swine were deemed permitted without meeting any requirements; farms larger than 250 head were also deemed permitted provided the operation had a waste management plan that incorporated best practices (Blue Ribbon, 1996).

In 1995 Blue Ribbon Commission Study, initiated by the Studies Act of 1995, was written in response to the rapid growth in the number of swine and several high-profile lagoon failures. The study investigated adequacy of standards, adequacy of enforcement and compliance, and future research initiatives. This study generally found confusion around interpretation of the existing rules, long delays, lack of communication between relevant agencies, and vulnerability to the State water supply. The Commission issued a series of recommendations that clarified requirements for permitting. (Blue Ribbon, 1996) Starting in 1996, all farms with more than 250 head of swine were required to obtain permits, undergo regular soil sampling, and established standards for areas considered nonpoint sources of pollutants (i.e., farm to which waste was applied).

More protections were added in 1997 with the Clean Water Responsibility and Environmentally Sound Policy Act, which established a moratorium on new and expanded farms using the lagoon-and-spray method. This also restored partial zoning to counties for farms with many hogs. In 1999, the Clean Water Act increased civil penalties for violations of State water quality laws.

Hurricane Floyd was the triggering event for the most expansive study on the waste problem. In 1999 and 2000, agreements with Smithfield Foods and later Premium Standard Farms, formed the basis for what would commonly be called the 'Smithfield Agreement', providing research

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Metcalfe (2001) found that small hog feeding operations faced prohibitively high environmental costs in compliance with state requirements, while larger operations were not significantly affected by higher levels of state regulation. Kuo (2005) found that larger operations put downward pressure on prices for hogs, which causes smaller producers to leave the industry; but the regulatory burden was inconsequential. Nene, Azzam, & Schoengold (2009), find that the environmental burden affects output in the short run, but in the long run do not conclusively impact production.

[2] *The Raleigh Times* summarized some of this legislation in a Pulitzer-winning series on the hog industry in February of 1995.

funding for a team at North Carolina State University to conduct a detailed investigation into economically feasible systems for disposing of hog waste (Caldwell, 2004).

The Smithfield Agreement began a $17.1 million, six-year research effort to identify environmentally superior waste management technologies. 18 candidate technologies were put through various levels of testing, over the course of which all but four were eliminated. The final candidates combined solids separation with either a high solids anaerobic digester, centralized composting system, gasification system, or a fluidized bed combustion of solids system (Figure 5).

Figure 5: Environmentally Superior Technologies (four possible combinations)

solids separation / nitrification-decentrification / soluble phosphorous removal system			
in combination with one of the following technologies:			
high solids anaerobic digester	centralized composting system	gasification for elimination of swine waste solids with recovery of value-added products system	fluidized bed combustion of solids system

Source: Development of Environmentally Superior Technologies: Phase 3 Report (2006)

The economics subcommittee, unfortunately, was split on the question of whether these technologies were, in fact, economically feasible. Six of the committee members believed that the terms of the Agreement "require attention to both the true economic consequences of alternative technology adoption, as well as the financial consequences for persons affected" (Whisnant, 2005). Four of the committee members did not feel that economic costs (that is, uncaptured social benefits or uncaptured pollution costs) should be included in the definition of 'economic feasibility.' Instead, they argued that the cost of adopting this technology could lead to a reduction (12%) in the total swine population in the state. Ultimately, the group did not reach a consensus. In March of 2006, the agreements' principal designee, Dr. Mike Williams, announced that the research funded by the agreement was finished and that he would be leaving the project (Caldwell, 2006).

The Future of Swine Waste Management

In 2007, the General Assembly passed the Swine Farm Environmental Performance Standards. The law made the moratorium permanent on new and expanded farms using lagoon-and-spray, and required all new farms to follow the performance standards identified in the Smithfield Agreement. New farms must: eliminate direct discharge, seepage, or runoff; substantially eliminate ammonia emissions; substantially eliminate odor; substantially eliminate disease-transmitting vectors and pathogens; and substantially eliminate nutrient and heavy metals in soils and groundwater. (Perdue et. al., 2007) (Easley, 2000) A new farm could obtain a permit using technology not identified by the researchers at NC State, but only provided the new technology meets these standards (Larrick, 2013).

For existing farms, the performance standards are not as stringent. Currently, swine farm and waste management permits are managed by the Department of Environment and Natural Services. NCDENR issues two permits: a Swine Waste Management System General Permit (Permit Number AWG100000) and a Swine Waste Management System NPDES General Permit (NPDES Permit Number NCA200000). The General Permit applies to all hog farms in the state, where the second applies to waste collection systems, pipes and ditches used for transmission of the waste, lagoons and ponds, land application equipment, and all acreage used for waste application (Larick, 2013).

Both permits establish performance standards, maintenance requirements, monitoring and reporting requirements, inspections and entry, general conditions, and penalties. The NPDES permit, unlike the general permit, also includes a requirement for public notification (Larick, 2013).

The permits forbid any discharge from any existing animal feeding operation, except in the case of a 24-hour, 25-year flood. The Animal Feeding Operations Unit, within the Division of Water Resources at NCDENR, is responsible for annually inspecting the operations. With the passage of SB 205 in 2013, soil sampling is no long required annually, and is now only required once ever three years. Four counties are responsible for their own inspections under a pilot program that began in 1997: Columbus, Pender, Jones, and Brunswick. In these counties, the Division of Soil and Water Conservation conducts inspections, though the Division continues to work closely with NCDENR and often works out of the same local offices (Lawson, 2013).

NCDENR itself is also subject to several significant funding and organizational changes which make the operations more difficult, but do not as yet affect swine-related activity. In 2011, NCDENR's budget was cut by more than 12% (Kane, 2011). In July of 2013, the Division of Water Resources and the Division of Water Quality were merged, and the division that deals with stormwater pollution was moved to the Division of Energy, Mineral and Land Resources (Frank, 2013). The changes have resulted in steep staff reductions in the Division of Water Resources that will take effect in 2014. Keith Larick observes that, despite the cuts, NCDENR has been required to inspect every animal operation once a year, but the cuts will certainly make it harder to carry on with inspections. (Larick, 2013) To date, however, none of the cuts have affected the Animal Feeding Operations Unit (Lawson, 2013).

NCDENR is also under pressure to review rules and look for opportunities to remove regulation. As a result of the Regulatory Reform Act of 2013, NCDENR has been asked to review rules in all departments to identify rules that can be amended or repealed, the results of which may affect the Animal Feeding Operation Unit's practices in the future (Lawson, 2013).

Hog Waste-to-Energy Market

Hog waste-to-energy production is possible in no small part because of the federally-enacted Public Utility Regulatory Policies Act of 1978. This Act was designed to encourage electricity generation from renewable energy sources, and was designed to overcome utilities' reluctance to purchase electricity from non-conventional sources. This Act created a new category of electricity generators called 'qualifying facilities' and essentially required utilities to purchase all output from these facilities at the utility's full avoided cost.[3]

In 2003, a non-profit called NC Green Power was established to promote the use of renewable energy. The organization was formed by state officials, North Carolina's three investor-owned utilities[4], non-profit organizations, consumers, and renewable energy advocates; it was the first state-wide program to offer electricity customers the option to pay a premium for grid-tied energy generated by solar, wind, small hydroelectric, and biomass resources (La Capra Associates et al., 2006).

In 2006, the North Carolina General Assembly requested that the North Carolina Utilities Commission undertake a review of the costs and benefits of establishing a Renewable Energy Portfolio Standard (REPS) in North Carolina. At the time, 21 states had similar portfolio standards. REPS laws have been a useful mechanism for states interested in including renewable energy in the state's energy portfolio. This process is often difficult because most states follow an integrated resource planning (IRP) process that does not price well-known externalities, including environmental and health-related costs. The report regardless found that electricity from hog waste would result in job creation and a modest increase in energy production (La Capra Associates et al., 2006).

Following the report's recommendations, the General Assembly adopted the Renewable Energy Portfolio Standard with Senate Bill 3. North Carolina's REPS mandated that North Carolina utilities source 0.07%, 0.14%, and 0.20% of their commercial electricity from swine waste by 2013, 2015, and 2018 respectively. The law also has certain 'set-asides' for the use of solar energy, swine waste, and poultry waste. These options were chosen from a longer list of traditional renewable energy sources because these solutions are particularly well-suited to North Carolina (La Capra et al., 2006). To comply with the REPs, utilities must generate or obtain renewable energy certificates (RECs). Each REC represents one MWh of renewable energy generation. By year, this translates to approximately 270,000 MwH by 2018 (Prasodjo et al., 2013).

The 2007 Swine Farm Environmental Performance Standards bill, in addition to the environmental requirements discussed earlier, also established a significant cost-share program designed to assist farmers converting to the new technology with the Lagoon Conversion Program. Until 2012, program grants would cover up to 90% of the cost of conversion; until 2017, it will cover 80% of the costs; after 2017 it will cover 75% of the cost. The program also established a Methane Capture Pilot program for up to 50 farms. The Program would cover utilities' avoided cost for purchasing decentralized biogas electricity production. Both programs were unfortunately very undersubscribed. 218 farms expressed interest in participating in the

[3] 'Avoided cost' is equal to the utility's current marginal cost of electric energy, and would require no change in rate charged to customers.
[4] Process Energy, Duke Energy, and Dominion North Carolina Power

Methane Capture Pilot Program, and roughly a quarter of those were eligible. Ultimately, the program retired without participation (NCDENR et. al., 2011). Only two Lagoon Conversion Program contracts have been fully implemented,[5] and one has been partially implemented[6] (Harris, 2012).

Senate Bill 3 is what Al Tank, co-founder and CEO of Revolution Energy Systems (RES), describes as "the star at the top of the tree" in North Carolina's market for renewable energy (Tank, 2013). RES manufactures patented anaerobic digester technology and is currently in the process of completing two projects to in North Carolina in cooperation with Murphy Family Ventures and Duke Energy. Tank believes that Senate Bill 3, with the support of developers and investors, has the potential to create millions of dollars of investment in North Carolina (Tank, 2013).

To date, the North Carolina Utilities Commission (NCUC) reports that State utilities have yet to meet the goals set forth in the renewable standard. In the two years since the requirements went into effect, utilities have appealed to the NCUC for an extension. Utilities claim that compliance is difficult because the technology is in early stages of development, modifications of the REPS requirements make their best course uncertain, and disagreements between developers and state utilities make it difficult to comply (NCUC, 2013). Anecdotal evidence suggests that the NCUC will almost certainly grant utilities an additional extension with no monetary penalty; utilities may be required instead to file tri-annual reports updating their progress on achieving the REPS requirements. Duke Energy already files these reports (Maier, 2013).

Waste-to-Energy Incentives

Tax incentives, cost share programs, technical assistance, and other programs also pay an increasingly large role in hog waste and waste-to-energy programs. At the federal level, a key piece of legislation is the periodically updated Farm Bill, which provides assistance to animal feeding operations through the Environmental Quality Incentive Program (introduced with the 1996 Farm Bill). (Metcalfe, 2000)

Al Tank, co-founder and CEO of Revolution Energy Systems (discussed earlier) highlights both the importance of this assistance and the ability to access information identifying them. When RES looked to expand into new markets, Tank developed a matrix of factors[7] that included information gathered from DSIREUSA.org, a website maintained by North Carolina State University with a database of renewable energy incentives and policies[8]. The database led the company to select North Carolina. Because no project qualifies for all of the incentives available, Tank explained that the detailed list simplified the task of comparing several combinations. (Tank, 2013)

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[5] Lloyd-Ray Farm in Yadkin County, and the Supersoils Centralized Composting Operation in Sampson County
[6] Tyndall Hog & Chicken Farm in Sampson County
[7] Other important factors included the presence of many utilities, a high concentration of livestock, the availability of feedstock, desire by the industry, a progressive utility in the form of Duke Energy, and proven technology.
[8] With funding from the NC Solar Center, the Interstate Renewable Energy Council, and the US Department of Energy (see http://dsireusa.org/about/ for more information)

Figure 6: Principle Incentives for hog waste-to-energy systems

Renewable Energy Equipment Manufacturer Tax Credit

- For commercial and industrial producers using biomass and anaerobic digestion.
- Applies to commercial and Industrial Users.
- Reimburses up to 25% of the cost of equipment used to construct/retrofit a renewable energy manufacturing facility.
- Set to expire January 1, 2014
- See HB 1829 (2010) for more information.

NC GreenPower Production Incentive

- May apply to electric producers using biomass, anaerobic digestion, or methane capture at any scale.
- When NC GreenPower issues an RFP, renewable energy producers may submit an application for payment.
- NC Green Power, in cooperation with local utilities and subject to voluntary contributions from NC electric customers, will pay production incentives based on the amount needed to make the technology approach economic feasibility.

Tennessee Valley Authority (TVA) - Green Power Providers

- For biomass systems between .5kW and 50 kW (primarily residential)
- TVA will enter into a 20 year contract with qualifying projects, purchasing up to 100% of output for ten years for retail electric rate + a premium
- $1,000 available to help offset costs of installation.

Tennessee Valley Authority (TVA) - Mid-Sized Renewable Standard Offer Program

- For mid-size producers (incl. government, nonprofit, schools, and others) using biomass or anaerobic digestion for energy production between 50kW-20MW.
- Long-term price contract between producer and TVA using a seasonal time-of-day average.B16

Renewable Energy Tax Credit (Corporate)

- For corporate producers using biomass, anaerobic digestion, or methane capture at any scale.
- Maximum of $2.5M credit per installation for all biomass installations used for a business purpose.

Source: DSIREUSA.org, captured November 26, 2013

Tom Butler, owner of Butler Farms, received a sizable grant administered by the North Carolina Department of Commerce through the now-defunct North Carolina Green Business Fund, which distributed funds provided by the American Recovery and Reinvestment Act of 2009. (Butler, 2013)

In order to meet the REPS requirements, Al Tank estimates that millions of dollars in investment will be necessary, and that development will be driven by large investment working to convert many farms. (Tank, 2013) The economic impact of converting the farms necessary to meet the REPS requirements will be discussed in more detail later.

Task 3: Real Estate Impacts of Hog Farms on Residential Properties and the Resulting Property Tax Loss for Local Governments.

Hog farms and their waste may present issues for adjacent properties. Problems could include odors, pathogens, insect vectors, water contamination, and greenhouse gases. These problems can have a number of adverse impacts on real estate values including diminished marketability, loss of use and enjoyment, and loss of exclusivity for private property owners. The literature indicates that proximity to hog farms diminishes real estate values for nearby properties. In addition to diminished private property values, local governments in jurisdictions with large concentrations of hog farms may miss out on additional property tax revenue due to these lower property values. As such, hog farms may have a serious real estate impact on residents and governments, which could possibly be mitigated through reforms to hog farm waste processing.

As part of our examination of the hog industry in North Carolina, we estimated the real estate impacts of hog farms in Sampson County, NC. Specifically, we investigated the impacts of proximity to hog farms on residential parcel values, and the associated potential loss of property tax income for local governments. The county provided us information on the assessed values for all residential parcels in Sampson County, as well as information on several variables that may also affect land and housing prices. With this information we built a hedonic price model to estimate the land value lost due to proximity to hog farms and their waste lagoons. Using the model's estimates, we calculated the amount of property tax lost by the local governments in Sampson County from properties near hog farms. Our analysis illustrates some of the impacts of hog farms on housing value and property tax revenue in eastern North Carolina.

Methodology

We collected information on a variety of characteristics for every residential parcel in Sampson County in order to measure the impact of hog farms on land values. We focused on residential parcels, as they are more consistently alike, whereas industrial or farm parcels have different uses. By illustrating the impact on residential parcels, the effects of hog farms on people can be better understood. Sampson County has the second largest concentration of hog farms in the state, and the county tax assessor's office provided us with data on all residential parcels in the county. After conducting a literature review on hedonic models and housing values, we asked for information on various factors that may affect housing prices, such as the square footage, number of bedrooms and bathrooms, age, heating and air system, construction type, and roof material. Additionally, we used GIS to map the residential parcels located within a ½ mile of hog farms in the county. This distance threshold is based on similar studies and reports using hedonic price models or other methods to measure the effects of hog farms. The hog farm data included information on the number of hogs per farm, the acreage, and the number of hog waste lagoons per farm, which allowed us to account for varying sizes of farms. Information on the parcels from the county was joined to information on local hog farms to provide a complete profile of each residential parcel in Sampson County.

Using information on the residential parcels and their proximity to hog farms, we built a hedonic price model to measure the effect of hog farms on residential parcels. Our model uses linear regression, which incorporates all of the variables mentioned above to see what effect they may have on the assessed value of residential parcels. We built a dummy variable to for identifying whether or not a parcel was within a ½ mile of hog farms. If the parcel was within a ½ mile of a hog farm, other information on the acreage of the hog farms and the number of lagoons and allowable animals was also included for those parcels. Additionally, we added a dummy variable to account for whether or not a house was a mobile home or not, as we assumed that could greatly affect value. Our hedonic price model then measured the over 12,000 residential parcels in the county and compared them to over 3,000 residential parcels located within ½ mile of hog farms, based on those variables that may affect housing prices. Each variable was tested in the model to see its statistical significance and if it was relevant to changes in the assessed value of residential property. The results of the hedonic model allowed us to understand which aspects of proximity to hog farms did or did not affect residential value and a sense of how much value may be lost.

To calculate the potential property tax loss from proximity to hog farms, we collected the property tax rates for Sampson County and its municipalities and applied those to the lost property value from hog farms. These calculations gave us an estimate of the amount of annual property tax revenue lost due to proximity to hog farm lagoons.

Real Estate Impact Results

The real estate hedonic model behaved largely behaved as expected. For example, a larger living area has a positive increase in the assessed value of a home, while having a mobile home results in a loss of between $74,478-$86,758 for a residential parcel. Additionally, an increase in total rooms results in an increase in the value of a residential parcel. The behavior of these standard variables and an R2 of nearly 0.56 indicate the model may be valid in explaining some the factors that affect housing value in Sampson County.

The hedonic model estimated that proximity to hog waste lagoons has a negative effect on the assessed value of residential properties. The data on residential parcels includes parcels that contain homes and also parcels that contain supplementary buildings, such as sheds, but do not contain houses. All of these parcels are considered residential, but we ran regressions on both types of parcels (with and without houses) since hog farms were likely to more adversely affect houses than parcels that simply had sheds or other unoccupied structures. Our results reflect this difference, as proximity to a lagoon results in a $10,382 decline per lagoon (range of 5,199.63-$15,563.23 loss per lagoon according to 95% confidence interval.) in the value of residential parcels with homes versus a $5,443 decline in for parcels without homes.

Table 12: Summary of effect of select variables on assessed value of residential parcels (with homes) in Sampson County

Variable	Statistical significance (P score)	Effect on assessed value($) per unit of variable	95% confidence interval
Living area	0.000	$21.39	$18.53-$24.25
Year built	0.000	$718.43	$637.39-$799.47
Mobile home	0.000	-$80,618	-$86,758- -$74,477.78
Total Rooms	0.000	$5,089	$3,284.25-$6,895.33
Full bathrooms	0.000	$42,296	$38,645.64-$45,947.20
Story Height	0.000	$26,105.58	$18,020-$34191.07
Bedrooms	0.217	-$1,415	-$3,663-$832.01
Lagoons (for parcels with houses)	0.000	-$10,382.43	-$15,563.23- -$5,199.63
Nearby farms	0.141	$5,920	-$1,955- $13,796
Allowable animals	0.707	$0.24	-$1.00-$1.47
R2 for model:	0.5584		

Other factors associated with hog farms did not show significant results for affecting housing values. For example, our variable that measured the number of allowed hogs nearby did not turn out to be statistically significant. The variable that measured whether or not a parcel was near a hog farm parcel also did not show statistical significance, though proximity to a hog farm parcel is assumed in other variables. Proximity to lagoons, however, was significant and resulted in substantial property value loss. Given how closely associated several of our variables for hog farms may be to each other, some multicollinearity may have occurred where the results of certain variables are closely intertwined. Our examination of the variable inflation factor (VIF) numbers for our variables confirmed this, as well. Proximity to lagoons, though, was statically significant and had a lower VIF score.

Property Tax Results

A loss of property value for residential parcels located near hog waste lagoons results in a loss of property tax revenue for local governments. Local governments collect property taxes for a parcel based on that parcel's assessed value. As our model showed, parcels with proximity to a hog waste lagoon were associated with a decrease in its assessed value, compared to those parcels that are not within ½ mile of a lagoon or lagoons. As such, local governments are collecting less property tax. Our analysis applies local county and municipal property tax rates to the lost value from proximity to lagoons. We used the results of our hedonic model to estimate the range of loss per lagoon using the 95% confidence interval range and applied that loss to each property, based on the number of lagoons nearby. Figure 7 is a rough estimate and combines county and municipal loss for a total figure.

Figure 7

Local governments	Annual property tax revenue lost ($)
Sampson County, Autryville, Clinton, Faison, Garland, Harrells, Newton Groce, Roseboro, Salemburg, Turkey	$450,000-$1.3 million Equal to $550-$1650 per lagoon
Entire 10-county region (Duplin, Sampson, Bladen, Wayne, Greene, Lenoir, Pender, Jones, Columbus)	$1.5 million-$4.6 million

While these numbers may not seem very large, this is still a substantial amount of money for local government budgets, such as those with significant numbers of hog farms within their jurisdictions. For example, in Sampson County, many functions and offices have total annual costs that are below or well within this range. The county's entire planning and zoning department, industrial development, mental health service, recreation department, 911 system, juvenile justice system, and numerous debt services (along with many other line items) all individually cost less than the amount of money lost each year in property tax revenue from lagoons. Also, this analysis applies to just one county in the region.

We extrapolated the effects of hog farms to the nine other counties in our study area. This 10-county region represents 78% of all hog production in the state and contains 7.3 million hogs with 794 hog waste lagoons. Using our same range for the amount of loss per lagoon ($5,199-15,563) we developed a rough estimate of the property tax revenue lost in the region of $1.5 million-$4.6 million annually. Many factors such as the differences in population density, hog farm density, and local tax rates can affect this estimate. Regardless, we estimate well over a million dollars and likely several million dollars in property tax revenue are lost for local governments in this 10-county region.

Conclusion:

- Proximity to hog waste lagoons results in an assessed property value loss of anywhere from $5,443-$15,563, depending on the type of residential parcel. Those parcels with homes on them average an assessed value loss of $10,382 per lagoon within a ½ mile of their property.
- The decrease in property value for parcels near lagoons results in an estimated $450,000-$1.3 million loss of property tax revenue for Sampson County and its municipalities on an annual basis with an estimated $1.5 million-$4.6 million for the entire 10-county region.

Task 4: Analysis of North Carolina's Swine Biogas Opportunity

Hog waste is commonly disposed in North Carolina through the "lagoon and spray" technique. Flushed out of the hog houses with water, the resulting liquid waste is captured in open-air lagoons and then irrigated over fields as a fertilizer. The high-nitrogen content of the fertilizer makes the crops inedible. This low-cost, low-value approach may allow farmers to deal with the steady flow of waste through their hog houses, but it misses a critical opportunity for value creation.

Technologies exist to capture methane gas released from hog waste and convert it into electricity or fuel. Referred to as "biogas," this byproduct of the waste decomposition process can generate revenue for farmers, increase on-farm efficiencies and provide renewable energy investment opportunities for utilities seeking to comply with North Carolina's REPS framework or for investors trading carbon offset credits in California's cap-and-trade market. Furthermore, biogas systems can mitigate odors and air pollutants from hog farming that are a nuisance to neighbors, as well as promote greater energy security for the state.

Task 4 of this project involved defining the most promising swine biogas system configurations for electricity production in North Carolina and their cost components (4.1), quantifying the state-wide energy output, greenhouse gas reduction, and economic impact of adopting these systems (4.2), finding opportunities for North Carolina businesses to participate in the value chain of these systems (4.3), and presenting a case for exploring transportation fuel applications of swine biogas (4.4).

Task 4.1: Most Promising Biogas System Configurations

Biogas is generated from hog waste through a process of anaerobic digestion. First, the waste is collected and moved into a covered vessel, such as flushing waste into a lagoon with a rubber tarp covering it. The organic matter in the waste decomposes anaerobically (without oxygen). Heating and/or mixing of the waste in the vessel can speed up the formation of methane. The biogas is then captured under the cover and transported via piping to a device that cleans it of impurities before it is sent to another gas use device. The uses of the biogas include combustion to form electricity or heat, conditioning and compression to pipeline quality, or conversion to compressed natural gas (CNG) for transportation fuel (EPA, 2013b).

When selecting which biogas recovery system would be most worthwhile to model, we wanted to identify existing practices and confirm what would best suit North Carolina's swine operations. Potential configurations included capturing the biogas with a covered lagoon or a complete mixed digester, and using the biogas for on-farm electricity production, centralized electricity production, centralized pipeline injection, or CNG.

The Environmental Protection Agency estimates there are 27 operational swine digester systems nationwide. County all livestock farms, there are 220. Currently, five hog farms in North Carolina are using anaerobic digestion to generate biogas for electricity or boiler fuel: Butler Farms, Black Farm, Loyd Ray Farms, Barham Farms, and Murphy-Brown LLC Kenansville Farm #2539. Four of these farms use a covered lagoon vessel; some include mixing. Nationwide, 11 of the operational swine digesters use an in-ground covered lagoon system, and 10 use an above-ground vessel with complete mixing (EPA, *Anaerobic Digester Database*, 2013c).

We spoke with four of the North Carolina hog farm operators using digesters and two swine biogas systems integrators about the design, installation, and operations of these systems. We also conferred with the authors of a study performed by Duke University to optimize the geographical layout and technology selection for these systems in North Carolina based on a lowest cost criterion (Prasodjo, et al., 2013).

From these discussions, we determined that the most likely digester technology to be scaled up across North Carolina's existing hog farms would be a covered, in-ground, ambient temperature, lined and mixed lagoon. This reflects the basic in-ground concept of four of the existing digesters in North Carolina, which would be practical for farms with lagoons to implement. However, the model makes some modifications to improve the efficiency of the digestion process, including lining the vessel and mixing the waste, which are incorporated into the Loyd Ray Farms system (the most recently installed digester in the state). These features were also mentioned as key elements for efficient bio gas production by other hog farm operators and systems integrators.

We selected on-farm electricity production and centralized pipeline injection as the two biogas applications to model based on the finding by Prasodjo et al. that these were the most cost-efficient applications. Capital costs, soft costs for design and installation, and the operating costs of these systems were drawn from the expense assumptions used by Prasodjo et al., tested against the actual costs and revenues realized by Butler Farms and Loyd Ray Farms.
We discarded CNG from our model because we did not find any swine biogas systems with that end application. However, we discuss the potential economic and environmental benefits of scaling up CNG in Task 4.3.

Task 4.2 Energy and Economic Impact Analysis of Swine Biogas Systems

Executive Summary
This analysis seeks to measure the relative economic impacts in North Carolina of two distinct swine waste to energy configurations that would meet the swine waste set-aside under North Carolina's Renewable Energy Portfolio Standard. In addition, we present the expected electricity generation and greenhouse gas reduction impacts of tapping into this renewable energy source. The two biogas configurations – Decentralized Electricity Production and Centralized Directed Biogas – were chosen as the leading configurations from the Prasodjo et al.'s April 2013 report, *A Spatial-Economic Optimization Study of Swine Waste-Derived Biogas Infrastructure Design in North Carolina*.

> **Decentralized Electricity Production** entails on farm biogas capture on 127 eastern NC farms utilizing mixed digesters. The biogas is then conditioned and burned in a microturbine to produce electricity on-farm that is sold to the electric grid. This configuration was modeled with six IMPLAN scenarios to capture the distinct construction and operations phases at each of the three REPS stages.
>
> **Centralized Directed Biogas** entails on farm biogas capture on 127 eastern NC farms utilizing mixed digesters. The biogas is then lightly conditioned and piped off the farm to one of 11 central hubs for heavy conditioning. From there it is injected into the

existing natural gas pipeline and sent to an existing combined cycle natural gas power plant. This configuration was modeled with six IMPLAN scenarios to capture the distinct construction and operations phases at each of the three REPS stages.

The resulting impacts show that the decentralized electricity production configuration has higher employment impacts in North Carolina than the centralized configuration. In terms of economic output, the decentralized configuration leads with higher impacts during the three construction phases, however the centralized directed biogas configuration shows higher impacts during operations. Overall, impacts from these systems would be boosted by encouraging the establishment of industries that support the biogas industry in North Carolina, as will be discussed in detail in section 4.3 of this report, Value Chain Analysis.

System configurations were also analyzed through net present value and payback period calculations. From this perspective the centralized configuration shows a higher net present value and a shorter payback period, suggesting that despite its lower economic impacts overall this system may be more attractive for a private investor. Calculations were done to analyze the effect of projected increased tax revenues on the NPV and payback metrics to see what impact a potential public subsidy could have on the investment potential of these systems. It should be noted that the centralized configuration requires significant coordination in the planning and installation of shared infrastructure (pipe networks, central conditioning hubs), which is not required under the decentralized configuration. This suggests that public leadership, and potentially subsidy, will be necessary at some level to implement the centralized configuration.

Methodology

IMPLAN Software Description

IMPLAN ("IMpacts for PLANning") is an industry standard input/output analysis software used to model economic impacts. The software estimates three types of impacts in terms of jobs and economic output from a new economic activity: direct, indirect and induced. Direct impacts are the jobs and output associated with the activity being modeled, in our case the jobs created in building and running the new biogas capture systems. Indirect impacts result from increased inter-industry spending that results from the modeled activity. Induced impacts result from increased household spending resulting from the additional jobs created directly or indirectly by the modeled activity.

Scope

Each of these configurations, Decentralized Electricity Production and Centralized Directed Biogas was further broken down to reflect the phasing of system installation to comply with the three stages of the REPS framework discussed in the regulatory section of this report (section 2). Prasodjo et al.'s work identified 39 farms necessary for compliance in 2013, 46 in 2015 and 42 in 2018 (Prasodjo, 2013). These farms and their associated energy production potential were used to determine costs and revenues for each REPS stage and IMPLAN models were run to reflect these event years.

Finally, construction and operations for each of the three REPS stages were modeled separately. Thus while there are two overarching system configurations defined by Prasodjo et al. –

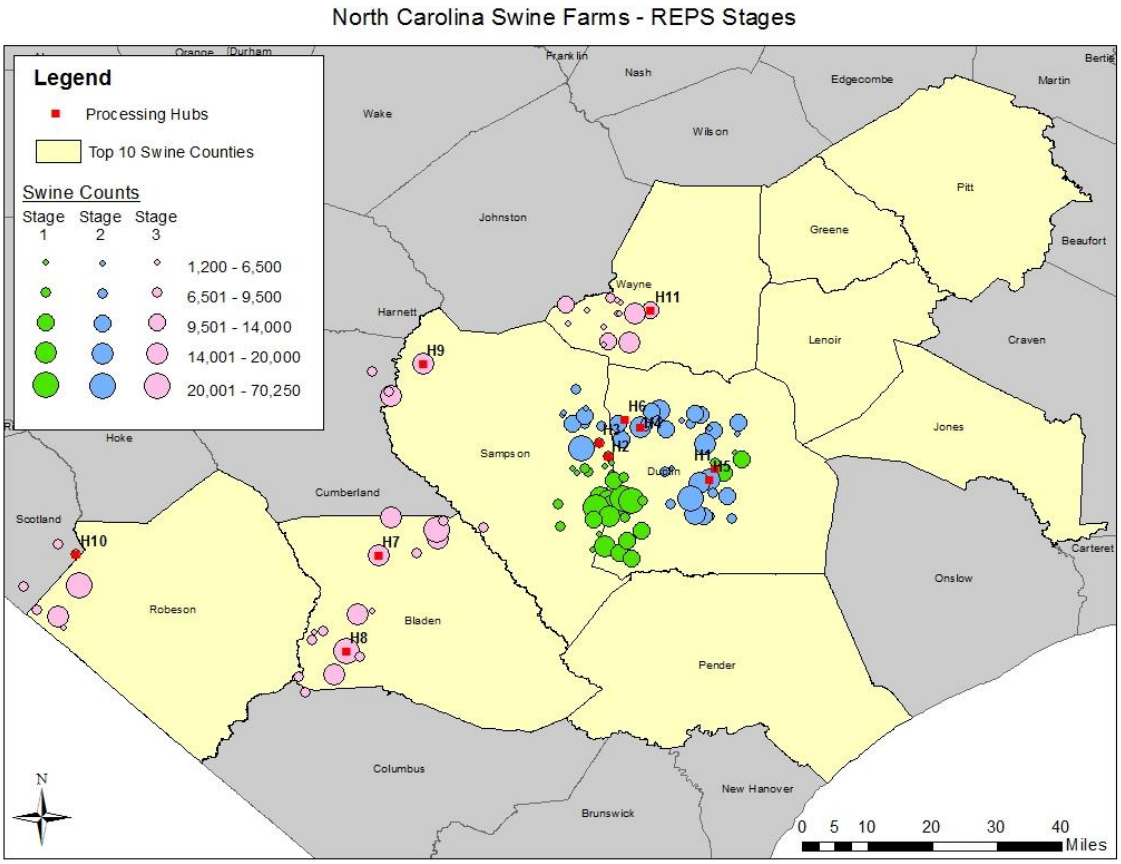
Decentralized Electricity Production and Centralized Directed Biogas – a total of twelve separate IMPLAN scenarios were run for this analysis. Table 13 summarizes the parameters for the scenarios modeled.

In total the 127 farms modeled cover 13 counties, including the top ten hog producing counties with the addition of Columbus, Cumberland and Scotland Counties (see Figure 8). The IMPLAN model was run at the statewide level to capture industry linkages that would benefit the state as a whole. Given that the REPS framework is a state-level policy, our team determined that it would be most pertinent to show the potential economic impacts of this policy at the state-level as well.

Table 13: Summary of IMPLAN Scenario Parameters

	Configuration 1: Decentralized Electricity Production			**Configuration 2: Centralized Directed Biogas**		
REPS Stage	**1**	**2**	**3**	**1**	**2**	**3**
Construction						
Event Year	2014	2015	2018	2014	2015	2018
# of Farms	39	46	42	39	46	42
# of Hubs	-	-	-	2	4	5
Operations						
Event Year	2015	2016	2019	2015	2016	2019
# of Farms	39	85	127	39	85	127
# of Hubs	-	-	-	2	6	11

Figure 8: Map of Farms Included in the IMPLAN Model by REPS Stage



Analysis

For most industries, the IMPLAN model utilizes a standard Social Accounting Matrix that captures the structure of a local economy including industry to industry relationships. Through these matrices the model can estimate how much activity is stimulated in an industry given a $1 increase in spending in another industry. When it comes to modeling biogas production however, there is no existent IMPLAN industry. To get to the impacts of this new industry our team performed an 'analysis by parts,' which essentially separates the calculation of direct impacts from the modeling of indirect and induced impacts. Direct impacts were calculated through first-hand research of existing biogas systems as discussed in detail in the preceding section 4.1 of this report.

To get to the indirect and induced impacts, a new industry-to-industry spending matrix – or "production function" – had to be defined for the new industry under each configuration. A production function expresses how much input is required from a given industry to produce a dollar of output in the primary industry, these figures are termed "spending coefficients." For the two configurations in this analysis, the production functions were created through adapting the existing industry spending pattern of electricity production (IMPLAN sector 31) based on research of existing biogas systems. Spending coefficients associated with fossil fuels and other industries not involved with electricity or biogas production from hog waste were set to zero;

these shares were then redistributed to pertinent industries. See Tables 14 and 15 for further detail on the changes made for each configuration's production function.

Table 14: Summary of Changes to Sector 31 Production Function for Configuration 1, Decentralized Electricity Production

Sector	Description	Configuration 1 Changes
3020	Oil and natural gas	Coefficient set to 0
3021	Coal	Coefficient set to 0
3032	Natural gas, and distribution services	Coefficient set to 0
3115	Refined petroleum products	Coefficient set to 0
3333	Rail transportation services	Coefficient set to 0
3335	Truck transportation services	Coefficient set to 0
3337	Pipeline transportation services	Coefficient set to 0
3375	Environmental and other technical consulting services	Increased coefficient by 50% of remaining share
3417	Commercial and industrial machinery and equipment repairs and maintenance	Increased coefficient by 50% of remaining share

Table 15: Summary of Changes to Sector 31 Production Function for Configuration 2, Centralized Directed Biogas

Sector	Sector description	Configuration 2 Changes
3020	Oil and natural gas	Coefficient set to 0
3021	Coal	Coefficient set to 0
3039	Maintained and repaired nonresidential structures	Coefficient set to 0
3115	Refined petroleum products	Coefficient set to 0
3333	Rail transportation services	Coefficient set to 0
3335	Truck transportation services	Coefficient set to 0
3014	Animal products, except cattle, poultry and eggs	Coefficient set to 35% of remaining share, local purchase set to 100%
3032	Natural gas, and distribution services	Increased coefficient by 52% of the available share, local purchase set to 100%
3337	Pipeline transportation services	Increased coefficient by 13% of the remaining share, local purchase set to 100%

Cost Data and System Components

All 127 farms were modeled with mixed digesters as the biogas capture method. Mixed digesters are more capital intensive to install than a covered lagoon system, however they are far more efficient at biogas capture. The cost for this system was calculated for each farm on a per-head basis, utilizing cost and swine head/farm figures provided in Prasodjo et al.'s study. These costs were assigned to seven different sectors to account for all the component parts and site work.

The microturbines were sized to the total potential energy production (KW) per farm based on mixed digester capture rate used by Prasodjo et al. with a 20% buffer. The light conditioning units were then sized based on the microturbine fuel consumption capacity. Equipment sizing options and costs were sourced from Prasodjo et al.'s study. This total cost was distributed as 30% installation and 70% equipment.

The final system cost of interconnection to the power grid was calculated as an average of $20,000 per farm (Butler, T, personal communication, October 28,2103) . This cost was distributed over power line construction (50%), metering equipment (25%) and other administration by the power company (25%).

Administrative and consulting costs for system design were calculated as 12% of the total capital expense, based on data from existing systems.

A similar method of equipment sizing was used for the eleven central conditioning hubs that would be installed under the centralized configuration. Equipment was scaled to the total potential biogas production of the specific farms connected to each hub. These hubs are assumed to be located on participating farms, additional site work costs for the heavy conditioning equipment were not added as these farms would be installing equipment for capture and light conditioning anyway.

For the low-pressure pipe network required under the centralized configuration, the pipeline lengths calculated by Prasodjo et al.'s OPTIMABiogas model were used as a baseline and scaled to the farms included in this analysis. Costs for installation and maintenance were taken directly from the Prasodjo et al. study as well and a 60/40 split was assumed between materials and installation.

Job Creation

For the decentralized electricity production configuration it was assumed that each farm would hire one part-time employee to manage the system. Tom Butler indicted in our interview that many hog farms are owned and operated by farmers whose main income is from an off-farm job; these farmers are able to manage the daily operations of their farm in just a couple hours before and after another job. However, with the addition of the mixed digester and generator additional oversight is needed that would necessitate bringing on another employee (Butler, T, personal communication, October 28, 2013).

This is not the case under the centralized directed biogas configuration however. This system is much more passive from the farm's perspective and on-farm management requirements are limited. The eleven centralized hubs for conditioning and injection would be managed by the natural gas utility and it was assumed that additional employees would not be needed to manage the oversight of these few facilities.

Revenues from Electricity Sales
Revenues from electricity sales for each farm were calculated based on the number of permitted swine head and the resulting energy production potential in MWh. Energy was valued at $103.31/MWh based on data from existing systems.

Summary of Inputs

Tables 16 and 17 below summarize the IMPLAN inputs for each configuration based on the preceding assumptions.

Table 16: Summary of IMPLAN Inputs, Configuration 1

	Configuration 1: Decentralized Electricity Production		
REPS Stage	**1**	**2**	**3**
Construction			
Administration	$10,781,403	$12,119,864	$12,967,113
Mixed Digesters	$17,942,026	$18,158,864	$20,688,277
Light conditioning	$27,038,000	$30,320,000	$33,536,000
Microturbine	$44,085,000	$51,600,000	$52,995,000
Power grid connection	$780,000	$920,000	$840,000
Operations			
Jobs	20	43	64
Electricity Sales	$9,770,698	$20,720,846	$32,268,947

Table 17: Summary of IMPLAN Inputs, Configuration 2

	Configuration 2: Centralized Directed Biogas		
REPS Stage	**1**	**2**	**3**
Construction			
Administration	$10,502,763	$11,817,944	$12,300,393
Mixed Digesters	$17,942,026	$18,158,864	$20,688,277
Light conditioning	$24,716,000	$27,804,000	$27,980,000
Low pressure pipeline	$4,113,856	$7,870,501	$8,114,415
Heavy conditioning	$10,100,000	$12,000,000	$11,900,000
Compression	$1,425,000	$1,650,000	$1,525,000
Operations			
Jobs	0	0	0
Electricity Sales	$9,770,698	$20,720,846	$32,268,947

If these inputs are analyzed alone as a stream of costs and revenues, the payback period on the systems is approximately 12 years for the decentralized configuration and 8 years for the centralized configuration. Additionally, the net present value (at a 7% discount rate) is $31.4 million for the decentralized configuration and $117.2 million for the centralized configuration. This calculation is highly sensitive to the discount rate; the 7% value was selected to remain consistent with Prasodjo et al.'s work. The additional impacts estimated by the IMPLAN model will help to give a sense of the public benefit anticipated and the level of public subsidy that could be justified to encourage capital investment in these systems by private actors. This is addressed in the following results section.

IMPLAN Analysis Results

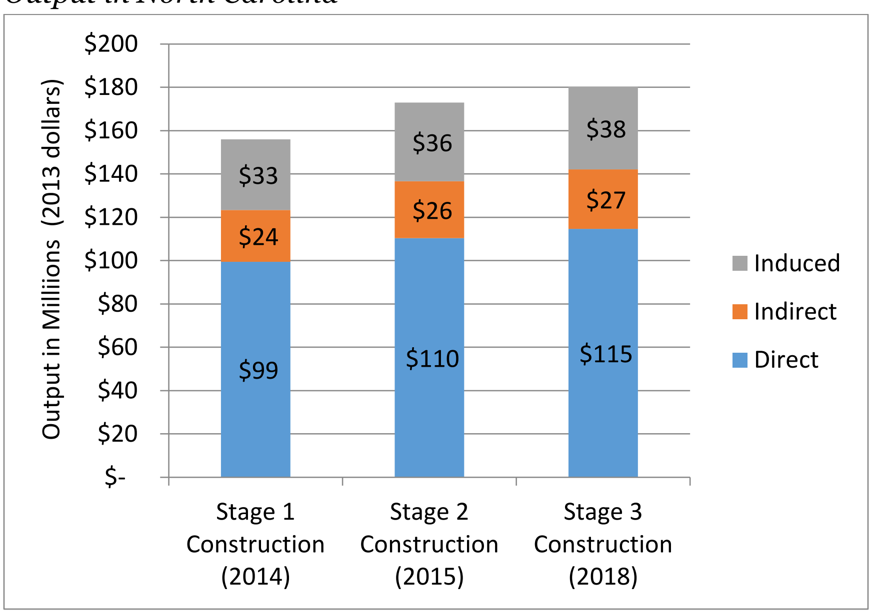
Configuration 1: Decentralized Electricity Production

The biggest impact of the decentralized electricity production configuration, in terms of jobs and output, is during the construction phase. Construction to prepare for stage one of the REPS has a projected total impact of $155.9 million in new economic output (in 2013 dollars). The direct impact is $99.4 million, resulting in a multiplier of 1.57 – for every dollar spent on constructing the decentralized biogas electricity production system $1.57 is spend elsewhere in the economy due to inter industry spending and increased household spending.

This impact increases in stage 2 to $172.8 million with 46 farms involved. In stage three there are 42 farms involved, however we see impacts increase again to $180.1 million; though there are fewer farms they are larger farms that have higher equipment needs for biogas capture and conditioning.

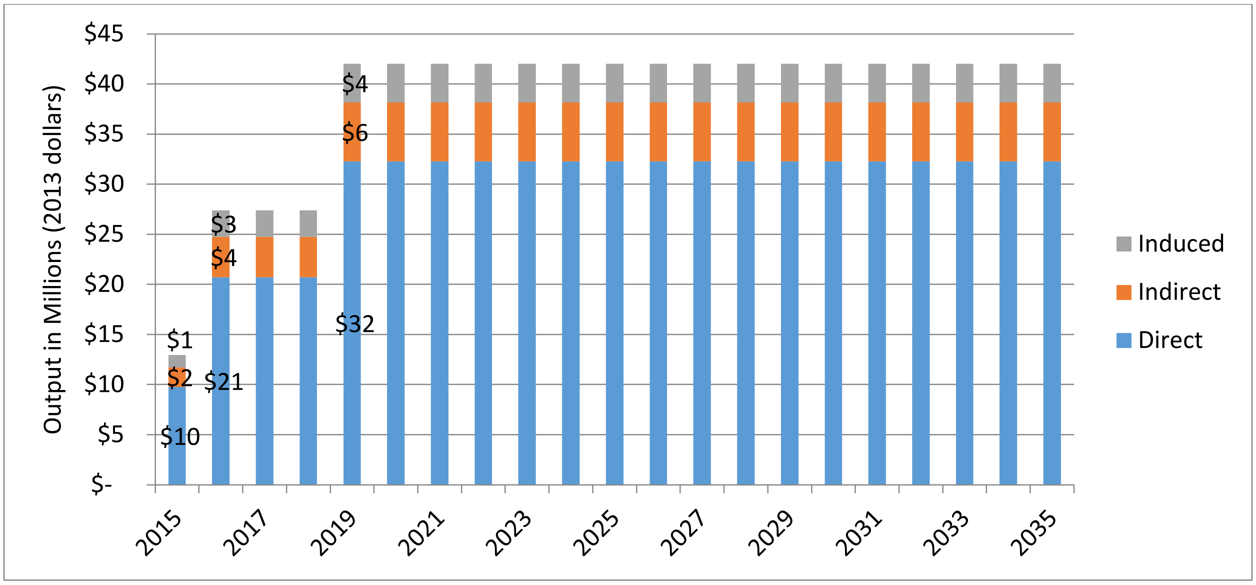
In each phase, approximately 34% of the total output goes to labor income versus value-added for producers.

Figure 9: Impact of Decentralized Electricity Production Construction Phases on Economic Output in North Carolina



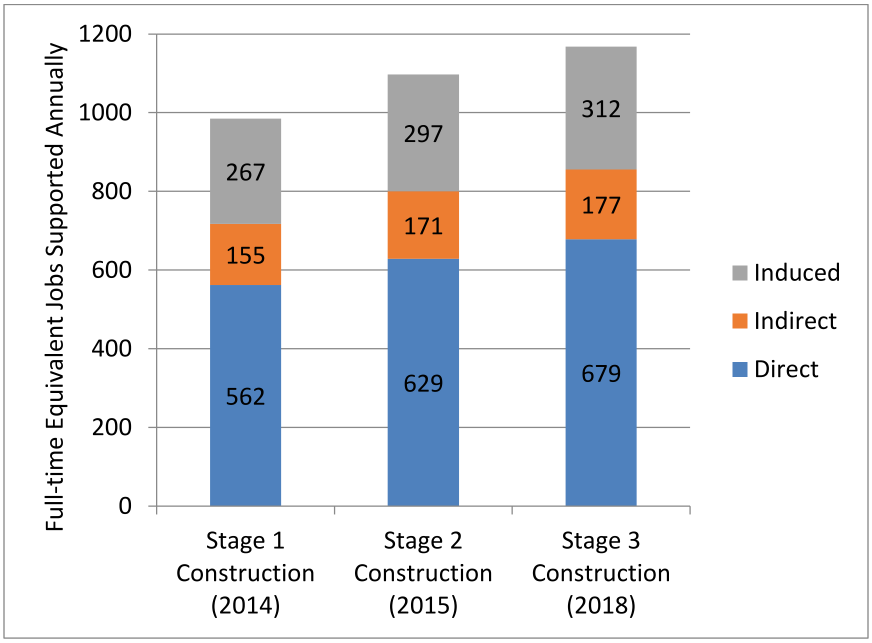
Looking at the operations impacts, these are minimal when compared to construction but they build overtime with the expansion of REPS and continue on an annual basis for the life of the biogas systems (~20 years). In the first stage the total impact is $12.9 million; this grows to $42.0 million by stage three operations in 2019. The majority of this impact is coming from the direct spending of new industry of electricity production from biogas; the multiplier of direct impacts to total impacts averages 1.31. Here the share of output that goes to labor income is lower than during the construction phases at approximately 16%.

Figure 10: Impact of Decentralized Electricity Production Operations on Economic Output in North Carolina, 2015-2035



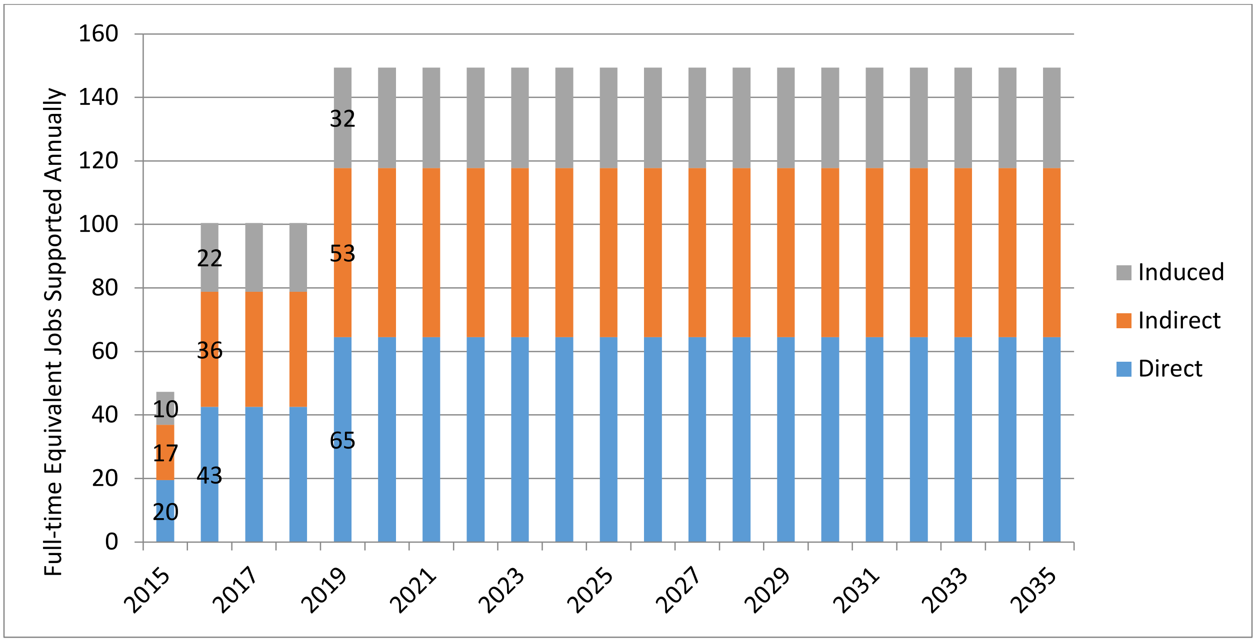
The employment impacts calculated by IMPLAN represent full-time equivalent jobs on an annual basis. The direct jobs are new jobs created by the biogas industry, the indirect and induced jobs are job supported by the biogas industry elsewhere in the economy. Looking at the employment impacts for the decentralized electricity production configuration, the trends are similar to the impacts on economic output. The construction phase supports the highest number of jobs relative to the operations phase, and the number of jobs supported grows with successive REPS stage. The multiplier in terms of employment however is higher than that for output; for the construction phases the multiplier averages 1.74.

Figure 11: Employment Impact of Decentralized Energy Production Construction Phases in North Carolina



The operations phase shows a lower employment impact than construction but a higher multiplier, here the total employment impact tops out at 149 full-time equivalent jobs for the third REPS stage and the multiplier averages 2.33. For every person hired directly for operations of the biogas electricity production system, approximately 2 jobs are supported elsewhere in the economy.

Figure 12: Employment Impact of Decentralized Energy Production Operations in North Carolina, 2015-2035



State and Local Tax Impacts

Construction and operation of the decentralized energy production configuration would also entail new tax revenues for state and local governments. IMPLAN estimates the new tax revenues that would be generated from personal taxes and taxes on production. These estimates are summarized in Table 18.

Table 18: Summary of Estimated New State and Local Tax Revenue, Decentralized Electricity Production

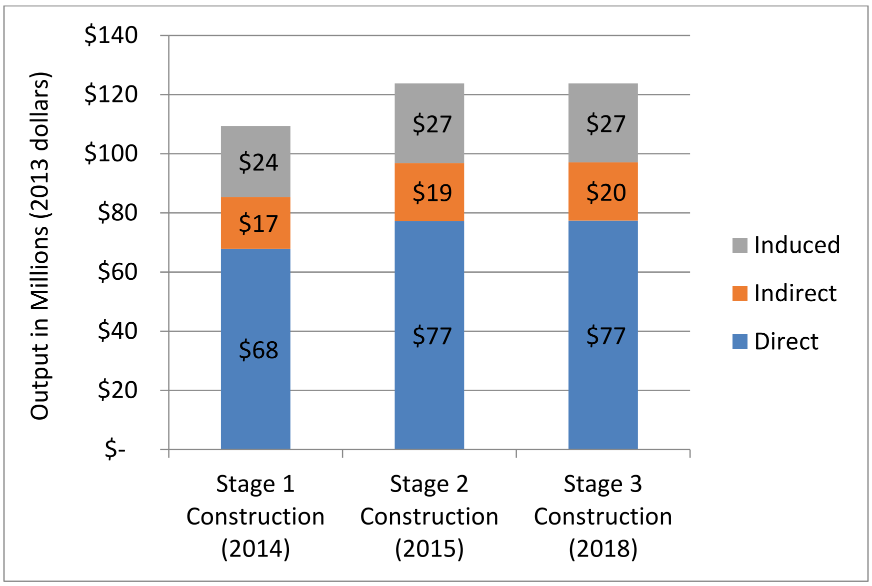
Phase	Impact Year	Annual New Tax Revenue
Construction - Stage 1	2014	$6,653,000
Construction - Stage 2	2015	$7,435,000
Construction - Stage 3	2018	$7,837,000
Operations - Stage 1	2015	$185,000
Operations - Stage 2	2016-2018	$388,000
Operations - Stage 3	2019-2035	$575,000

Considering these new tax revenues along with the revenues generated from electricity sales shortens the payback period of the construction investment to 11 years from 12 years. The net present value (at a 7% discount rate) of this revenue stream over 20 years is increased 74% from $31.4 million based on the electricity sales revenues alone to $54.8 million with the inclusion of the new tax revenues. This assumes that these tax revenues would flow back to private investors in some form as a subsidy to incentivize investment in swine waste to energy systems.

Configuration 2: Centralized Directed Biogas

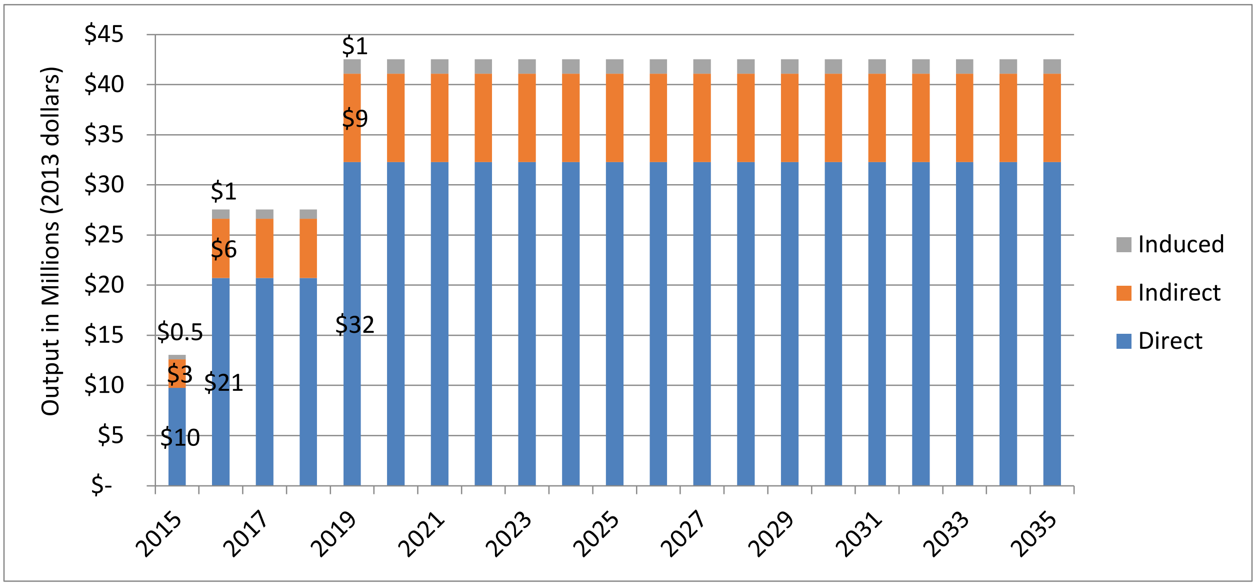
Under the centralized directed biogas scenario, the highest impact in terms of economic output is seen the construction phases. Stage two and three's construction have the highest impact with $123.7 million in total economic output each while stage one construction shows $109.3 million of impact. These three phases each show a multiplier of 1.60; for every $1 spent on constructing the centralized system, $1.60 is spent elsewhere in the economy. During construction phases, 35% of the output impact is captured in labor income.

Figure 13: Impact of Centralized Directed Biogas Construction Phases on Economic Output in North Carolina



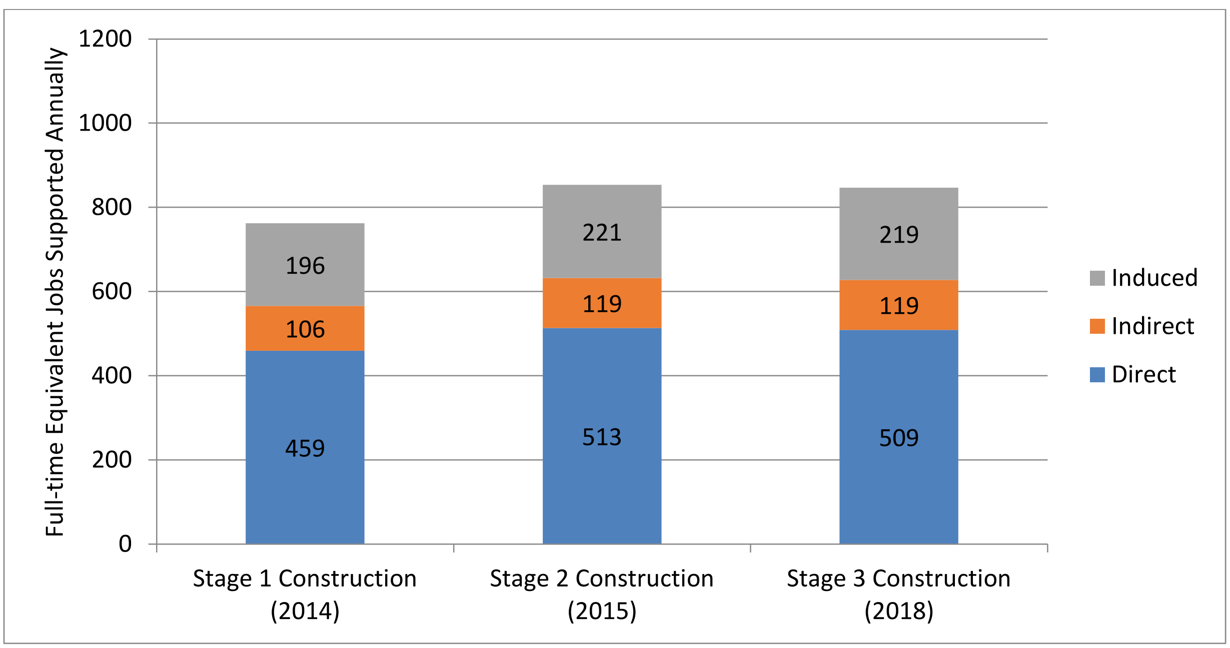
Under the operations phases, the impacts are lower however these continue on an annual basis for the life of the systems. The impact grows with each successive REPS stage, from a total impact of $13.3 million in stage one to $28.1 in stage two and $43.3 million in stage three. The multiplier here is lower than during construction, at an average of approximately 1.34 for the operations phases. Approximately 6% of the total output is captured in labor income.

Figure 14: Impact of Centralized Directed Biogas Operations on Economic Output in North Carolina



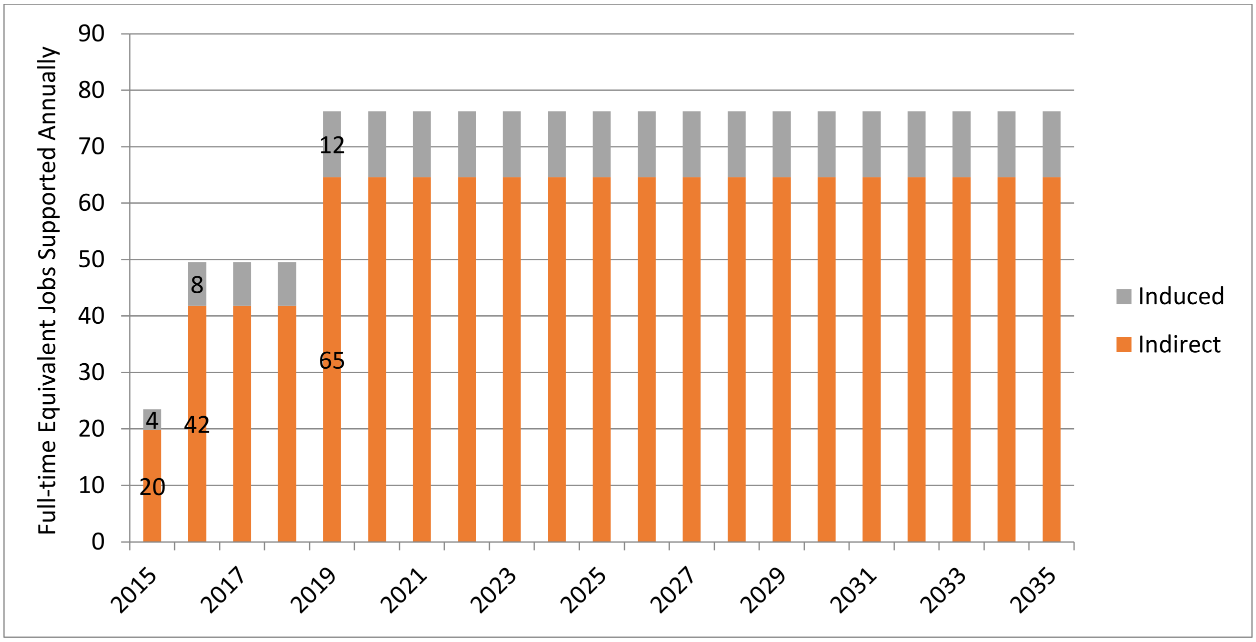
The employment impacts of the centralized configuration are again greatest during the construction phases. The biggest impacts are seen in construction for stages two and three with a total employment impact of 853 and 847 respectively; stage one has the lowest impact of the three construction phases with 762. Each phase exhibits an employment multiplier of 1.66.

Figure 15: Employment Impact of Centralized Directed Biogas Construction Phases in North Carolina



During operations the employment impacts fall significantly but the impacts continue for the life of the systems. No jobs are directly created by the centralized system and thus all employment impacts from operations are indirect or induced, caused by increased inter-industry spending or increased household spending. The highest impact is seen in phase three with 77 total jobs. Because there are no direct jobs created, a multiplier cannot be calculated.

Figure 16: Employment Impact of Centralized Directed Biogas Operations in North Carolina



State and Local Tax Impacts

Construction and operation of the centralized directed biogas configuration would also entail new tax revenues for state and local governments. These estimates, summarized in Table 19, are lower than the impact estimated under the decentralized scenario. This difference is linked to the lower employment impacts of the centralized scenario which results in a lower impact from personal taxes.

Table 19: Summary of Estimated New State and Local Tax Revenue, Centralized Directed Biogas

Phase	Impact Year	Annual New Tax Revenue
Construction - Stage 1	2014	$4,720,000
Construction - Stage 2	2015	$5,337,000
Construction - Stage 3	2018	$5,334,000
Operations - Stage 1	2015	$173,000
Operations - Stage 2	2016-2018	$364,000
Operations - Stage 3	2019-2035	$551,000

Considering these new tax revenues along with the revenues generated from electricity sales does not affect the payback period of the construction investment, remaining at 8 years. The net present value (at a 7% discount rate) of this revenue stream over 20 years is increased 15% however from $117.2 million based on the electricity sales revenues alone to $134.9 million with the inclusion of the new tax revenues.

Electricity Generation and Greenhouse Gas Reductions

In addition to the economic impacts, we wanted to provide a brief synopsis of the environmental impacts accrued as a result of transitioning to this renewable energy source. At stage 3 REPS compliance, the 127 farms in our model would produce an estimated 1.07 billion kilowatt-hours of electricity annually under an ideal scenario without considering operational inefficiencies in the equipment. This calculation is based on the number of permitted swine head per farm and conversion constants used by Prasodjo et al and is independent of the system configuration selected. Getting electricity from this source as opposed to fossil fuels entails a projected reduction in greenhouse gasses of 756,000 tons of carbon dioxide. This is roughly equivalent to eliminating the carbon dioxide emissions from powering 34,257 average U.S. homes, or the greenhouse gas reduction from taking 142,882 passenger cars off the road per year according to the EPA Greenhouse Gas Equivalencies Calculator[9].

Table 20: Annual potential energy and greenhouse gas reduction

REPS Stage	Number of Farms	Electricity * (kWh)	GHG Reduction (CO_2e tons)
1	39	324,296,000	229,000
2	85	687,739,000	485,000
3	127	1,071,029,000	756,000

Conclusion

Comparing the impacts of these two configurations, decentralized electricity production and centralized directed biogas, we can conclude:

- **The employment impacts for both construction and operations are highest under the decentralized configuration** which requires more construction activity and on farm oversight during operations. The centralized configuration benefits from some economies of scale which lowers the employment impacts during both the construction and operations phases.
- **Total economic output is impacted most strongly by the construction of the decentralized system.** Again, this configuration is less efficient in that equipment and installation is required on every single farm rather than concentrating some of this activity at central hubs and therefore more revenues are generated for industries involved in the production and installation of system components.

[9] http://www.epa.gov/cleanenergy/energy-resources/calculator.html

- **However, the centralized configuration shows the highest impact in terms of economic output under the operations phases.** The centralized configuration exceeds the decentralized configuration in terms of economic output in every stage of operations by 3%. This implies that there is more leakage under the decentralized configuration. Environmental and technical consulting services and commercial and industrial machinery and equipment repairs and maintenance, two industries that feature strongly in the production function for the decentralized configuration, display an IMPLAN local purchasing percentage of 50%. Encouraging the establishment of these firms in North Carolina would increase the operations impact under the decentralized configuration, keeping more of the revenues generated from electricity production in the state.
- **The centralized configuration shows a higher net present value than the decentralized configuration.** Looking solely at the stream of costs and revenues (electricity sales) used as inputs for the IMPLAN analysis, the net present value at a 7% discount rate is higher for the centralized configuration at $117.2 million versus $31.4 million for the decentralized configuration. This suggests that without public subsidy the centralized configuration is a more profitable investment than the decentralized, despite its overall lower economic impacts demonstrated through the IMPLAN analysis.
- **New tax revenues are generated under each scenario which could help to build a framework for public support of system construction.** The estimated state and local tax impact was largest under the decentralized scenario. Adding these benefits into the analysis of the revenue stream from these systems increases their NPV with the centralized configuration maintaining the highest value. This assumes that these tax revenues would flow back to private investors in some form as a subsidy to incentivize investment in swine waste to energy systems. Under the decentralized configuration the NPV is increased 74% from $31.4 million to $54.8 million and the payback period is shortened from 12 years to 11 years. For the centralized configuration the NPV increases 15% from $117.2 million to $134.9 million and the payback period remains 8 years. The centralized configuration in particular will need higher-level leadership and coordination which could be justified by viewing these projected tax revenues as the basis for public involvement in system installation.
- **Overall, impacts on employment and economic output in North Carolina will be boosted by encouraging the establishment of firms that support the biogas industry in North Carolina.** Under both configurations significant leakage is occurring which is lowering the economic value captured by the North Carolina economy. The more firms that support biogas production that are located in North Carolina the higher the local capture of impacts will be. The following value chain section of this report, section 4.3, will quantify this leakage and explore industry-based strategies that could be employed to increase North Carolina's value capture.

Task 4.3: Biogas Value Chain Analysis

At a high level, the economic impact estimates from our IMPLAN model are compelling. But there is more to the story. Swine biogas production involves numerous businesses contributing various goods and services to the process. Together they create the "value chain" that turns a waste into a renewable source of energy. This value chain is an invisible, but dynamic connection between industries that determines how each dollar spent on a biogas system circulates through the economy. The swine biogas value chain is in a fledgling state. Our IMPLAN model contemplates the economic impacts of scaling up swine biogas in North Carolina based on the existing composition of the value chain in the state. But if North Carolina wants to reap more of the economic benefits from swine biogas, it can try to upgrade its position in the value chain.

In this section, we will map the swine biogas value chain and its primary industries. We will identify which industries North Carolina hosts and which ones it appears to be leaking outside the state. We will then prioritize the industries to make the focus of an import substitution strategy based on those that would have the highest potential economic impact and those that would find a complementary supplier network already in the state.

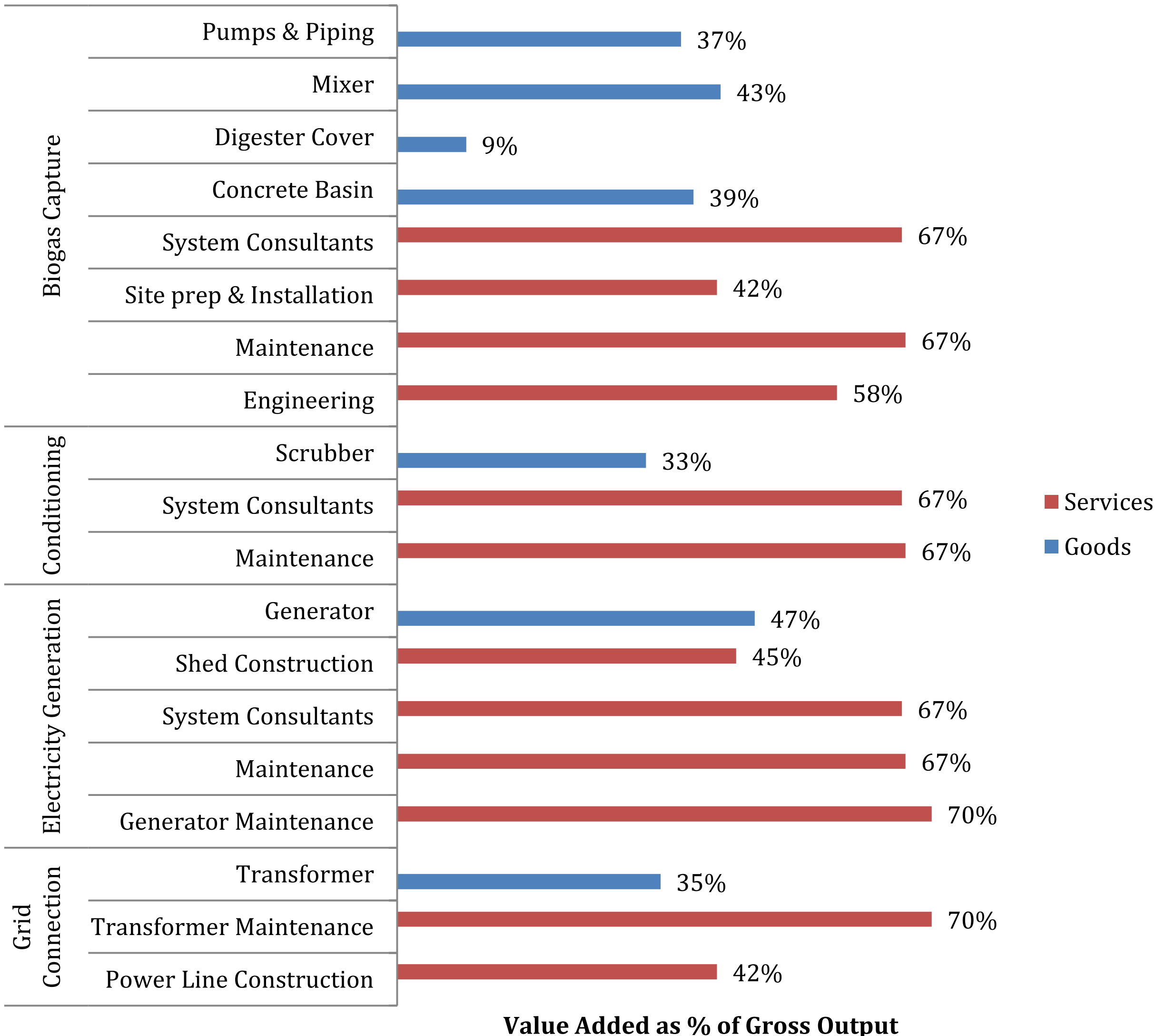
Value Chain Map

The biogas value chain is straightforward regardless of the configuration. Decentralized and centralized both have four stages that start with biogas capture and conditioning (see Figures 17 and 18). Beyond that point they differ, as the biogas in the decentralized configuration stays on farm where it produces electricity that is connected to the grid. In the centralized configuration, the biogas is sent via a low-pressure pipeline network to a hub for heavy conditioning and compression before being injected into the natural gas pipeline.

At each stage, the goods and services—and the industries that produce them—are the primary components of the value chain. One way to compare the relative importance of these industries in the value chain is by their "value added": their gross output less intermediate inputs, including raw materials, energy, components, and services. We can identify the value added of each industry in the biogas value chain using the IMPLAN model we constructed in task 4.2. The industry spending pattern reveals how much of each $1 in gross output from the industry goes towards intermediate inputs. The residual is the value added. Figures 19 and 20 provide the value added as a % of gross output for the primary goods and services industries.

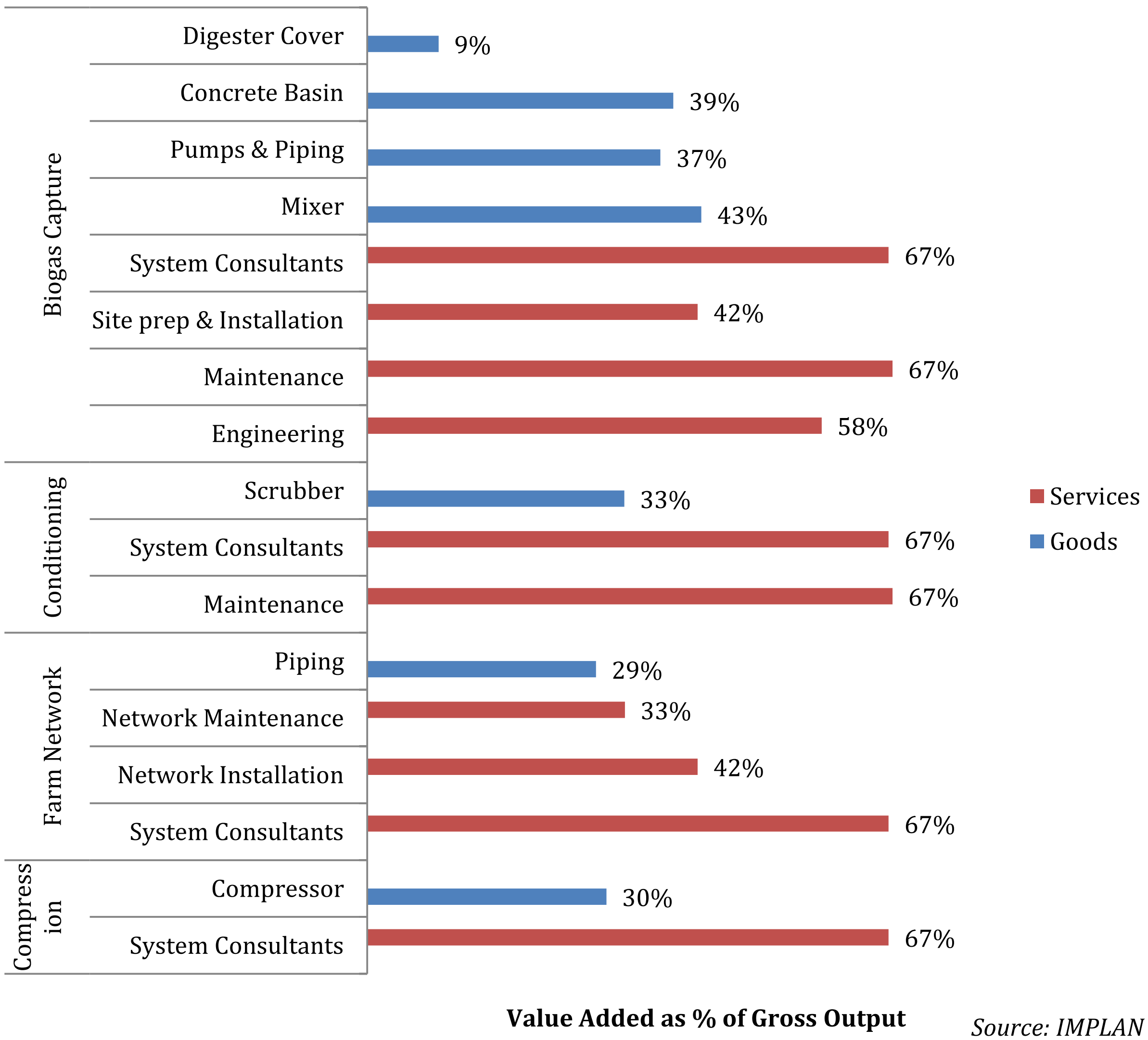
In nearly every instance, the service industries offer a higher value added than the goods-producing industries. This is not a surprising result. However, it points to the critical role that services such as system consultants play throughout the process in the design of the system, while industrial machinery repair and maintenance is critical to the installation and operations of the systems (see Appendix 2 for a cross-walk between the goods and services and their NAICS codes and descriptions).

Figure 17: Decentralized Electricity Production – Value Added by Stage and Offering



Source: IMPLAN

Figure 18: Centralized Pipeline Injection – Value Added by Stage and Offering



Source: IMPLAN

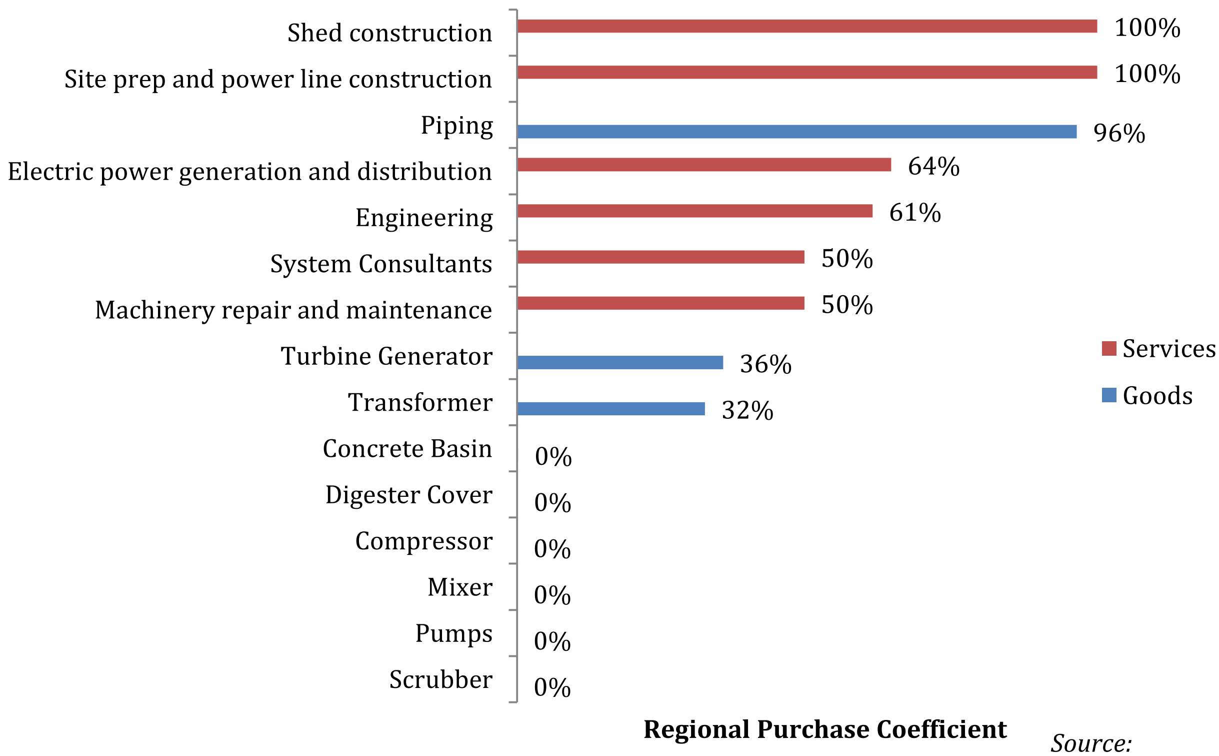
Industries in North Carolina – Direct Leakage

Of particular concern to North Carolina is not only which industries in the biogas value chain have a high value-added, but also which ones are located in the state. These "local" industries will create jobs, pay wages, and earn profits locally. The more purchasing that happens locally in the biogas value chain, the more local economic activity will be supported. If a business in the value chain is not located in North Carolina, then a dollar spent on that good or service is considered to be "leaked" outside the region.

One way to identify the presence of North Carolina firms in the biogas value chain is by the regional purchasing coefficient for each industry. The RPC is IMPLAN's estimate of how much each commodity that a given industry purchases will be bought from local suppliers. IMPLAN generates the RPC from a model of inter-regional trade flows. An industry's "leakage" from a region is 1 – RPC for that industry in that region. This metric has its limitations. It assumes that substitutable commodities will be purchased locally, as else constant. However, variations in quality of substitutable goods or services could make the buyer value each differently and instead choose to purchase outside the region. Furthermore, buyer behavior is not always rational, and it is possible that a buyer would purchase the more expensive or inferior product for any number of cultural, personal, or logistical reasons. That said, the regional purchase coefficient is one of the best approximations we have for local purchasing and, thus, leakage.

If we rank the primary biogas value chain industries according to their RPC, a picture emerges (see Figure 19). North Carolina hosts a significant share of the key services, reflected by high RPCs. However, the state is leaking most of the dollars associated with the major capital expenses, such as generators, transformers, scrubbers, compressors, and the components of the digester. This finding comports with what we observed of biogas system installations at Butler Farms, Black Farms, and Loyd Ray Farms, where equipment manufacturer labels revealed importing from around the country.

Figure 19: Biogas Value Chain Industries – Local Purchasing



Source:

Import Substitution Targets

North Carolina could capture a larger share of the direct, indirect and induced economic impacts of swine biogas if it participated in more of the industries of the value chain. Given the premise of our analysis is a hypothetical roll-out of swine biogas across 127 hog farms (less than 6% of all hog farms in the state) with potential for expanding even further, the scale-up is far enough out in the future that it is not unreasonable to suggest the state could broaden its coverage of the value chain. Such an outcome would be achieved through "import substitution":

finding commodities that are currently bought outside the state and bringing production into North Carolina. As a very early step in an import substitution strategy, we propose two criteria for selecting target industries:

1. that would have the highest potential direct economic impact, and
2. that have a supply chain already in the state

Criterion #1: Highest Direct Impact

One might consider the industries with the lowest RPC (i.e. the highest leakage) to be those with the greatest potential impact on economic output if they were brought into the local economy. However, we must consider the dollar weight of each industry in the value chain; some capture a much larger share of the total project cost. Multiplying the direct cost of each commodity by 1 – RPC gives us the dollar leakage by industry for each system configuration (see Figures 20 and 21 below). Clearly the big capital expenses—the generators and the scrubbers—emerge as high potential targets, with roughly $64 million to $69 million in direct output each, if 100% of the leakage was capture locally. But so do two service industries: machinery repair and maintenance ($24-$36 million) and the system consultants ($18 million). The significant value added by these service industries and their involvement in multiple stages of the value chain make them key anchors in swine biogas production.

Figure 20: Decentralized Electricity Production – Direct Dollar Leakage

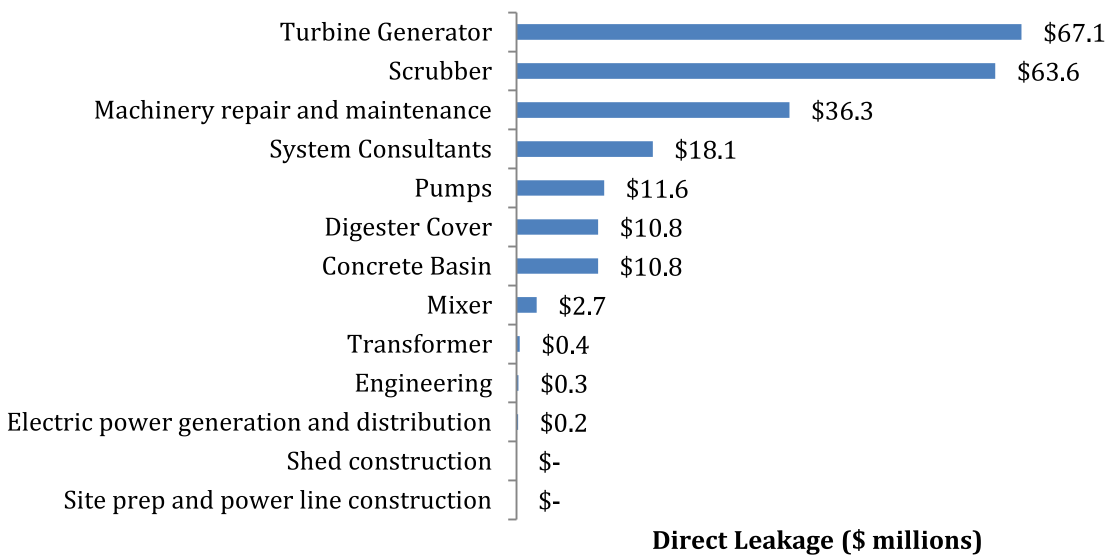
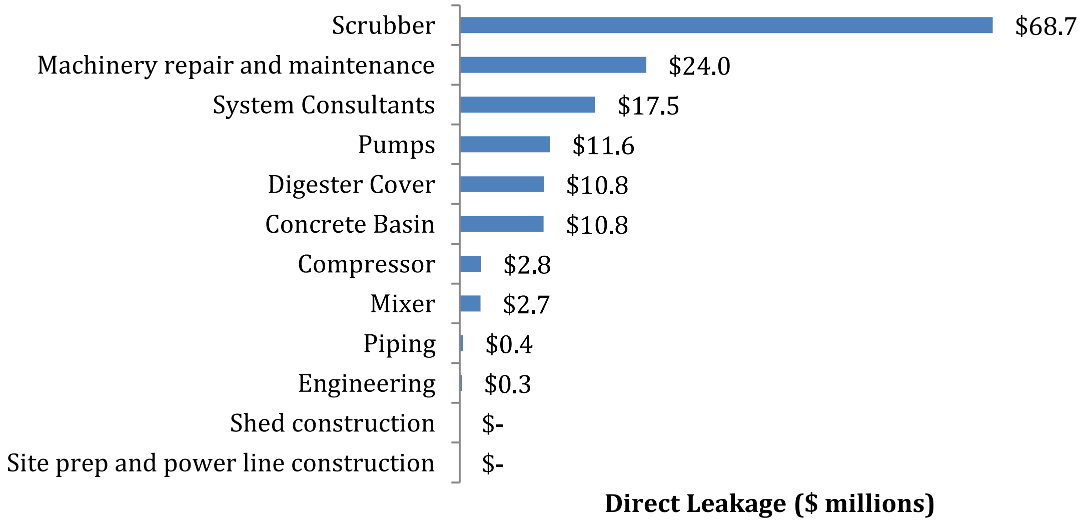


Figure 21: Centralized Pipeline Injection – Direct Dollar Leakage



Criterion #2: Local Supply Chain

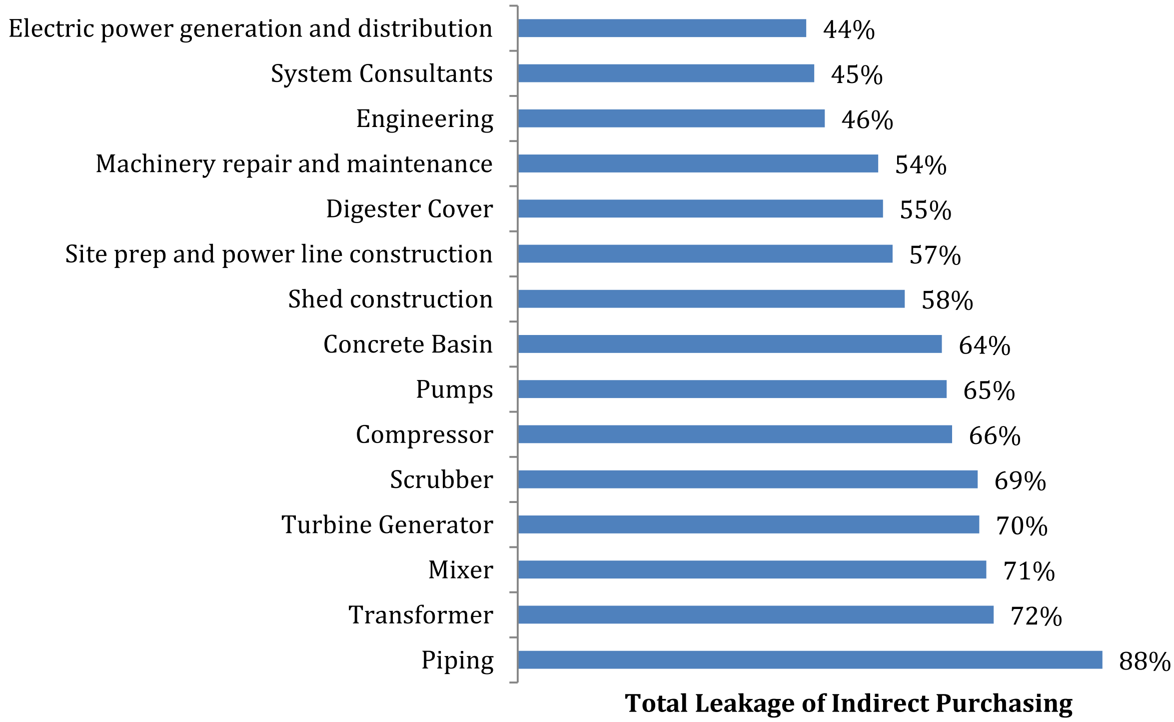
An import substitution strategy built around high direct impact targets would be deceptively simple. Although turbine generators and scrubbers might seem like the most worthwhile industries to target, their respective supply chains play a large role in the total economic impact they have on a region. So, another dimension to the state economy that we need to measure is indirect leakage: the dollars that a primary industry spends with suppliers outside of North Carolina. Capturing all the direct output of an industry without any of the indirect spending will significantly reduce the overall multiplier of the industry. Thus, a low indirect leakage is desirable.

Indirect leakage plays another role in import substitution: Without a strong base of local suppliers, any business will be reluctant to set up shop. Therefore, the success of capturing major goods-producing industries in North Carolina will depend in part on touting or strengthening the local supply chain for those industries. A lower indirect leakage from biogas industries reflects a deeper existing local supply chain.

Figure 22 below ranks the primary industries by their associated indirect leakage (lowest first, since low leakage is preferred). We can immediately see that two of the industries from our first screen of direct output effects also have relatively low indirect leakage: system consultants (44%) and machinery repair and maintenance (54%). Meanwhile, the generators and scrubbers have relatively high indirect leakage, 70% and 69% respectively.

An interesting case is that of pipe manufacturing. With a high regional purchase coefficient (96%) it is not surprising that it did not register as an import substitution target from a direct output standpoint. However, in terms of indirect spending, it has the highest total leakage. Thus, North Carolina is currently not capturing the full economic benefit of spending on piping because so many of the intermediate purchases leave the state.

Figure 22: Biogas Value Chain Industries - Indirect Dollar Leakage



Suggested Industry Targets

Over the time frame in which swine biogas may roll out across North Carolina hog farms, there is an opportunity for shifting the value chain landscape to capture more economic benefits for North Carolinians through import substitution.

Seeking a combination of high direct output impact and low indirect leakage, we identified the following four industries as primary targets for an import substitution strategy:

1. System consultants ($18 million in direct output potential, 45% indirect leakage)
2. Machinery repair and maintenance ($24-$36 million, 54% indirect leakage)
3. Scrubber manufacturing ($64M-$69 million, 69% indirect leakage)
4. Turbine generator manufacturing ($67 million, 70% indirect leakage [for decentralized system])

Note that of these industries, scrubber manufacturing is the only one without a significant presence in the state, according to regional purchase coefficients. Therefore, the state is not starting from scratch. We prioritize systems consultants ("integrators") and the technicians that install, maintain and repair the machinery because they add value regardless of the biogas infrastructure configuration. Given their presence in North Carolina, part of the import substitution strategy may simply be enhancing awareness of the swine biogas opportunity. Our research revealed only one biogas systems integrator operating within the state. Many of those who have set up the first on-farm systems are based outside North Carolina. As service industries, both the system integrators and machinery technicians may also be easier to create or attract to North Carolina in the near term than manufacturing establishments.

Task 4.4: Transportation Fuel Applications of Swine Biogas

Using biogas produced from swine farms in electricity production is only one application of the potential energy utilization that exists on these farms. Although compliance with the North Carolina Renewable Energy and Efficiency Portfolio Standard is desirable, only 0.2% of retail electricity sales must be derived from swine waste by 2018. Meeting this standard can be accomplished with as few as 127 farms, which is far less than the number of permitted facilities that exist in North Carolina.

The biogas produced in the remaining farms can be utilized as transportation fuel. Converting biogas produced from swine farms to compressed natural gas (CNG) can result in a 4% decrease of gasoline consumption in North Carolina. This is a reduction of 10.3 million metric tons of CO_2 emissions. CNG costs less than diesel and gasoline and has the potential to expand existing industries in the state. Transportation fuel harvested, processed and distributed locally also increases energy security and improves disaster response.

Biogas produced by anaerobic digesters in swine operations must be further processed before it can be used as a transportation fuel. The gas is further purified and compressed to increase the volumetric energy density as described in the centralized directed biogas scenario. In 2010, 4,336 million gallons of motor gasoline were consumed in the state (EERE, 2013a). Swine farms in North Carolina that produce at least 7,500 mmbtu annually have the potential to produce a total of 19.5 million mmbtu (Prasodjo et al., 2013). Converting this energy into CNG for transportation vehicles would result in 169 million gasoline gallon equivalents (GGE) or a 4% reduction in gasoline consumption statewide.

Policy Incentives and Regulations

Integrating CNG into the transportation mix is currently driven by federal and state policies. There are several policies and regulations that facilitate the integration of compressed natural gas into the national and local/state fuel mix. Per Table 21 many of these policies apply to fleet operators and fueling infrastructure owners.

Table 21: Federal and Local/State Incentives and Regulations for NGVs (EERE, 2013b)

	Vehicle Owner or Driver	Fleet Purchaser or Manager	Fueling or TSE Infrastructure Owner	Alternative Fuel Producer	Alternative Fuel Dealer	Alternative Fuel Purchaser	AFV Manufacturer or Retrofitter
Number of Incentives: (X) = Federal, X = State							
Grants	1	1	1	1	1	1	1
Rebates	1	1	1	(1)		1	
Tax Incentives	1 (5)	1 (6)	1 (5)	1 (2)	(1)	1 (1)	
Loans and Leases	(2)	(2)	(2)	(2)		(2)	(2)
Exemptions	1 (1)	1 (1)					
Other Incentive	(1)	(2)	(2)	(2)			(2)
Number of Regulations: (X) = Federal, X = State							
Fuel Use		1 (1)	1 (1)			1 (1)	
Driving or Idling		1 (1)	(1)			(1)	
RFS				(1)			
Air Quality		(1)					
Other	(1)	(2)	(1)	(1)	(1)		(2)

Renewable Fuel Standard (RFS)

The Renewable Fuel Standard (RFS) is derived from the Energy Policy Act of 2005. To reduce the consumption of petroleum in the US, transportation fuel providers are required to include a specific volume of renewable transportation fuels in their product each year, peaking to 36 billion gallons by 2022. Generally, these requirements were met by blending 10% of ethanol into gasoline (E10), which is regular octane gasoline. This concentration of ethanol in gasoline is approved for all vehicles by the federal government and will not void new or existing automobile warranties. However, this is not true for concentrations higher than 10%.

The 10% concentration limit creates a "blend wall" that is dependent on the amount of gasoline that is projected to be consumed domestically that year. 2013 estimates are 133 billion gallons of gasoline, resulting in 13.3 billion gallons of renewable fuel that can be used to comply with the RFS. However, the 2013 required volume is 16.55 billion gallons, a balance of 3.25 billion gallons short of the compliance. It is anticipated that fuel providers will bridge the 3 billion gallon gap by trading renewable identification numbers (RINs).

Barriers to Implementation

There are several barriers to integrating compressed natural gas (CNG) in the North Carolina transportation fuel mix. Unlike motor gasoline and diesel, the support industries for natural gas vehicles (NGV) are not ubiquitous. However, various private firms, government agencies, and nonprofit organization in North Carolina are currently collaborating to establish those industries.

Fueling Infrastructure

CNG retail infrastructure in North Carolina is relatively scarce. There are zero LNG fueling stations and only 17 CNG fueling stations in the state. A majority of these fueling stations are owned and operated by government agencies or natural gas provides such as PSNC or Piedmont Natural Gas and may not be publicly accessible (EERE, 2013b). In contrast, there are hundreds of conventional fueling stations accessible to the public in the state.

Natural Gas Vehicles (NGVs)

NGVs utilizing CNG should be used for fleets that have high-mileage requirements in a limited area and are fueled from a central location. Fleets that travel long distances should utilize liquefied natural gas (LNG). However, the availability of new NGVs is a major issue. Although the passenger NGV portfolio has increased, there is a limited selection relative to conventional fuel vehicles. Since 2010, there have only been 11 new light-duty NGV models available in the market. In contrast, for heavy-duty applications, there are 55 dedicated CNG vehicles, 27 LNG vehicles, and one hybrid-CNG vehicle available on the market (EERE, 2013b). Additionally, there are at least 367 EPA-certified CNG-compatible after-market vehicles (NGVAmerica, 2013).

Certified Mechanics and Equipment

To service CNG vehicles, specialized knowledge of the technology and vehicles are required. Existing vehicles can be converted to consume CNG. Although conversion kits are available, they must be EPA certified (EPA, 2013d). Installers, maintenance shops and fueling station upgrades must also obtain certification to comply with NFPA 52 (EERE, 2013b). The certification process can be expensive and complicated. Local standards are still in development and training is not widespread.

Economic Benefits

There are also economic benefits to transitioning to compressed natural gas vehicles. Figure 23 illustrates the lower cost of CNG compared to gasoline and diesel. Table 22 indicates the annual cost savings and GHG reductions for specific vehicle classes.

Figure 23: U.S. Average Retail Fuel Prices (EERE, 2013b)

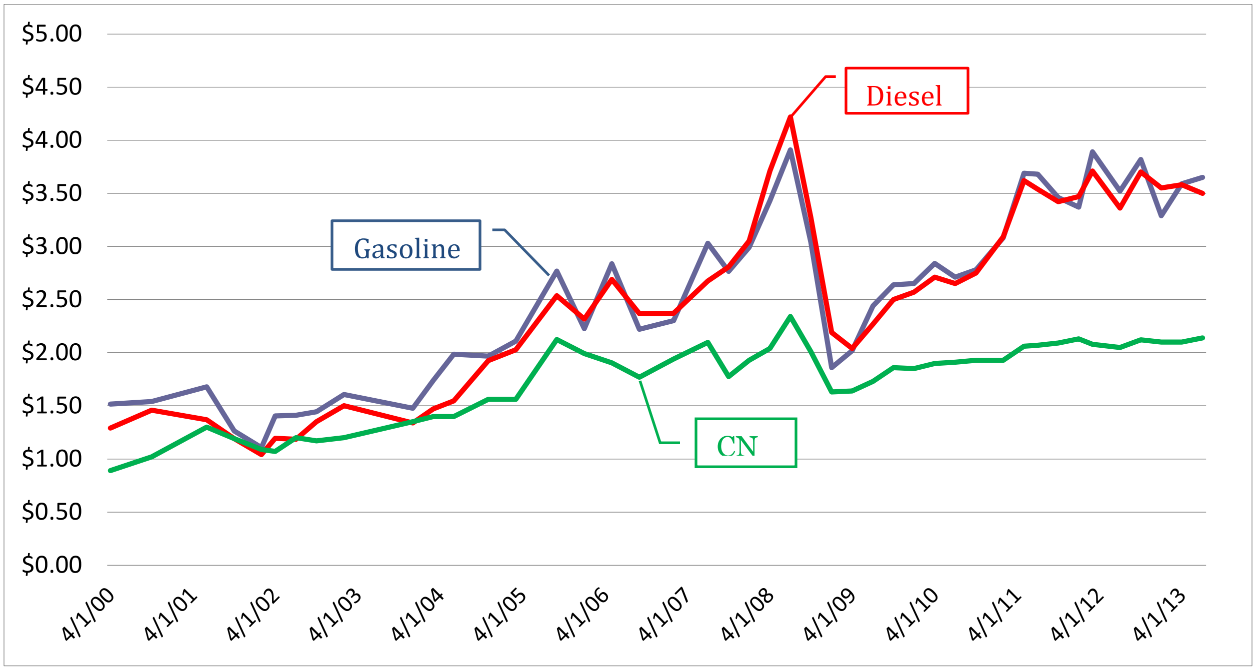


Table 22: GHG reductions due to replacing a gasoline vehicle with a compressed natural gas vehicle (EERE, 2013b)

	Petroleum Reduction (gal/yr)	**GHG Reduction** (tons CO_2/yr)	**Fuel Cost Savings** ($/yr)
Midsize gas car	479	1	$723
Small gas van	540	1	$815
Large gas pickup	653	1	$986
Small gas SUV	520	1	$786

Employment Opportunities

Compressed natural vehicles (CNGs) have spawned a diverse range of employment opportunities in North Carolina. There are several planning and policy related organizations (e.g. North Carolina Solar Center, Advanced Energy, Triangle Clean Cities, Centralina Clean Cities and the Land-of-Sky Clean Vehicles Coalition), that are dedicated to integrating alternative fuels such as CNG into the transportation fuel mix. Due to the advanced technology inherent in CNG vehicles, other primary-related jobs include certified CNG mechanics, manufacturing specialized vehicle components, construction to install fueling stations and other infrastructure. Secondary industries include the financial sector for trading offset credits.

Secondary Advantages

Integrating CNG into the North Carolina fuel mix has several secondary advantages. A locally-sourced transportation fuel increases energy security and facilitates disaster relief and recovery efforts. CNG costs less than diesel or gasoline and releases less greenhouse gas emissions.

Transitioning to CNG can expand existing industries (e.g. labor and automotive parts) and create new ones (e.g. carbon offset trading).

Energy security
North Carolina is one of the most energy-insecure states in the country. In 2011, it produced only 22% of the total energy that was consumed in the state (EIA, 2013). The primary electricity fuel is coal and nuclear. Coal is imported via rail from West Virginia and Kentucky. The primary transportation fuel is petroleum. Petroleum is imported via the Colonial and Plantation pipelines from the Gulf Coast refineries. The Transcontinental Gas Pipeline Company (Transco) is the primary source of natural gas to North Carolina.

Disaster Preparedness
Major disasters due to extreme weather have been declared 14 times in North Carolina since 2000 (FEMA, 2013) and have resulted widespread power outages. These power outages significantly impact the transportation sector. Without electricity, the pumps at pipeline transfer stations no longer function and transportation fuel cannot be distributed to retailers. Additionally, the pumps at retail fueling stations no longer distribute fuel to paying customers without electricity. In 2009, North Carolina received a grant from National Association of State Energy Officials (NASEO) to create state and local energy assurance and emergency preparedness plans. These plans emphasize a diversification of transportation fuels to mitigate any interruption of the petroleum supply chain. In fact, 29 of the 39 state energy plans reviewed by NASEO have goals to develop alternative transportation fuels and 22 energy plans have provisions to utilize CNG as a transportation fuel (NASEO, 2013).

Hurricane Sandy
CNG has been proven as a resilient fuel source and critical back-stop for other transportation fuels in disaster-affected areas. Hurricane Sandy resulted in gasoline and diesel rationing. Eleven days after landfall, 21% of conventional retail fueling stations in affected areas had no fuel (Bluestein, 2013), but all the CNG stations remained operational. In Atlantic City, CNG Jitney minibuses assisted with the evacuation and CNG refuse trucks in Oyster Bay were used in clean-up efforts. National Grid and the Long Island Power Authority used CNG cars and trucks to conduct infrastructure repairs (EERE, 2013b). “It’s also important to diversify our fueling options for our fleets, especially after the crippling gas shortage during a superstorm” says Paul Power, assistant director of operations for the Center for Emergency Medical Services (CEMS). CEMS owns over 100 emergency vehicles and consumes $1.1 million annually in diesel and gasoline. Although converting ambulances to CNG adds approximately $20,000 to cost of the $115,000 vehicle, this is recovered over the life of the ambulance in fuel savings and decreased maintenance costs (Olt, 2013).

Greenhouse Gas (GHG) Reductions
In 2011, the transportation sector accounted for 28% of U.S. greenhouse gas (GHG) emissions second only to electricity generation (EPA, 2013e). Transitioning to a locally produced fuel such as compressed natural gas (CNG) is a strategy that private firms and government agencies are using to reduce GHG emissions. Stakeholders in the Triangle Region transitioned 107 vehicles to CNG for a 212 ton reduction of CO_2 emissions (TCCC, 2012). Converting the methane from

swine farms in North Carolina that produce at least 7,500 mmbtu of biogas annually results in a total reduction of 10.3 million metric tons of CO_2 (Appendix 1). Other strategies to reduce GHG emissions include increasing fleet operational efficiency, reducing vehicle miles travelled, investing in mass transit, and increasing fuel economy by using new technologies.

Offset Trading

Converting biogas to CNG for transportation qualifies for participation in the national Renewable Identification Number (RIN) market and the California cap-and-trade market in 2015. In addition to the NC REPS framework, these markets may create additional demand for biogas offset credits that could spur CNG production.

Renewable Identification Numbers (RINs)

RINs are certified numerical designations assigned to each gallon of biofuel produced and are used to track compliance with the Renewable Fuel Standard (RFS). Unused RINs can be banked and used to comply with the RFS in the following year. They are tradable and increase in value as the cost of biofuel production infrastructure increases and decrease in value as biofuel market prices increase from increased consumer demand.

CNG derived from hog waste would fall under the "Advanced Biofuel – D5" category. In response to the impending “blend wall”, proposed changes to the RFS would allow trading RINs from CNG produced from anaerobic digesters. Progressive Fuels Limited, an independent broker in the wholesale physical biofuel markets, has projected that the price of D5 RINs will increase by more than 70% in 2014 (see Table 23).

Table 23: D5 Advanced Biofuel RIN Pricing for 2012 to 2014 (PFL, 2013)

Year	Bid (cents/RIN)	Ask (cents/RIN)
2012	21	23
2013	23	25
2014	32	36

*Prices are based on D5 – sugarcane

With the penetration of alternative fuel vehicles in the market, investment in public transportation, and the increase of fuel economy in new vehicles, it is likely that domestic gasoline consumption may decrease, leading to reduced production. The gap between the “blend wall” and the RFS compliance volume will only increase. As a result, it is anticipated that RINs will become vital for transportation fuel suppliers to comply with the RFS.

California Cap and Trade Emissions Market

The California cap and trade emissions market is a key component of the Global Warming Solutions Act of 2006, also known as AB 32. Cap-and-trade sets a limit of GHGs for regulated organizations. This cap is reduced approximately 3% each year, starting in 2013. The goal of this legislation is to reduce carbon emissions to 1990 levels by 2020. Currently, organizations that emit more than 25,000 metric tons of carbon dioxide (i.e. refineries, cement plants, and utilities) or the equivalent in methane, refrigerants, and other gases annually are regulated. This is roughly equivalent to the emissions created by 5,000 passenger vehicles or electricity for

3,000 homes (EPA, 2013f). In 2015, transportation fuel distributors (e.g. oil companies, airlines, ground transportation industries) will be required to comply with AB 32 (CARB, 2013).

There are several ways a regulated organization can comply with emission reductions: (1) Reduce operational emissions, (2) Purchase additional allowances in quarterly auctions or from other polluters who have reduced their emissions and are willing to sell their emission allowances, (3) Purchase offsets which will fund environment projects in the US that reduce or absorb GHGs. Since transportation fuel distributors will be not regulated until 2015, there are no available standards to review. However, assuming that transportation fuel distributors will be regulated similarly to large emitters, biogas from swine operations would fall under compliance option three under the current enforcement standards.

Further Research

Strong federal and state policies exist to create a new CNG for transportation industry in North Carolina. Several government agencies, nonprofits, and academic organizations are currently coordinating to educate the public and deploying the infrastructure. However, no studies exist investigating the impact of CNG for transportation on existing industries or the potential to create new industries in North Carolina. We recommend further research be conducted to gauge the potential impact of this technology on the state economy.

Appendix

1. Transportation Calculations

Greenhouse gas reduction calculations (Darmawan Prasodjo et al., 2013; EPA, 2013g)

$$\frac{0.1\ mmbtu}{1\ therm} * \frac{14.47\ kg\ C}{mmbtu} * \frac{44\ g\ CO_2}{12\ g\ C} * \frac{1\ metric\ ton}{1{,}000\ kg} = \frac{0.05306\ metric\ tons\ CO_2}{therm}$$

Farms in North Carolina that have the potential to create produce at least 7,500 mmbtu/year of biogas can be converted to:

$$19.5\ million\ mmbtu * \frac{1\ therm}{0.1\ mmbtu} = 195\ million\ therm$$

This is a GHG reduction of approximately 10.3 million metric tons of CO_2.

$$195\ million\ therm * \frac{0.05306\ metric\ tons\ CO_2}{therm} = 10.3467\ milion\ metric\ tons\ of\ CO_2$$

2. Cross-walk of Value Chain Industries by Configuration, Stage, Category, Offering, and NAICS Code

Configuration	Stage	Category	Offering	Industry	NAICS
Both	Biogas Capture	Goods	Digester Cover	Resin and Synthetic Rubber Manufacturing	32521
Both	Biogas Capture	Goods	Concrete Basin	Other Concrete Product Manufacturing	32739
Both	Biogas Capture	Goods	Mixer	All Other Fabricated Metal Product Manufacturing	33299
Both	Biogas Capture	Goods	Pumps & Piping	Pump and compressor manufacturing	33391
Both	Biogas Capture	Services	System Consultants	Environmental Consulting Services	54162
Both	Biogas Capture	Services	Engineering	Engineering Services	54133
Both	Biogas Capture	Services	Site prep & Installation	Water and sewer line and related structures construction	23711
Both	Biogas Capture	Services	Maintenance	Commercial and Industrial Machinery and Equipment Repair and Maintenance	81131
Both	Conditioning	Goods	Scrubber	Air purification equipment manufacturing	333411
Both	Conditioning	Services	System Consultants	Environmental Consulting Services	54162
Both	Conditioning	Services	Maintenance	Commercial and Industrial Machinery and Equipment Repair and Maintenance	81131
Centralized	Compression	Goods	Compressor	Air and Gas Compressor Manufacturing	333912
Centralized	Compression	Services	System Consultants	Environmental Consulting Services	54162
Centralized	Farm Network	Goods	Piping	Plastics Pipe and Pipe Fitting Manufacturing	326122
Centralized	Farm Network	Services	Network Installation	Oil and Gas Pipeline and Related Structures Construction	23712

Centralized	Farm Network	Services	Network Maintenance	Pipeline Transportation of Natural Gas	48621
Centralized	Farm Network	Services	System Consultants	Environmental Consulting Services	54162
Decentralized	Electricity Generation	Goods	Generator	Turbine Generator Set Manufacturing	333611
Decentralized	Electricity Generation	Services	Shed Construction	Industrial Building Construction	23621
Decentralized	Electricity Generation	Services	Generator Maintenance	Electric Power Transmission, Control, Distribution	22112
Decentralized	Electricity Generation	Services	System Consultants	Environmental Consulting Services	54162
Decentralized	Electricity Generation	Services	Maintenance	Commercial and Industrial Machinery and Equipment Repair and Maintenance	81131
Decentralized	Grid Connection	Goods	Transformer	Power, Distribution and Transformer Manufacturing	335311
Decentralized	Grid Connection	Services	Power Line Construction	Power and Communication Line and Related Structures Construction	23713
Decentralized	Grid Connection	Services	Transformer Maintenance	Electric Power Transmission, Control, Distribution	22112

References

Blue Ribbon Study Commission on Agricultural Waste. (1996) http://ncleg.net/Library/studies/1996/st10736.pdf

Bluestein, L. (2013, April 23). *Webinar on the Role of Alternative Fuel Vehicles in Emergency Preparedness*. Retrieved from http://www1.eere.energy.gov/cleancities/toolbox/webinar_emergency_preparedness.html

Burkholder, J., et al. (2007). Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality. *Environmental Health Perspectives*, 115(2): 308–312.

Butler, T. (2013) Conversation with Adrienne Heller on October 25.

Caldwell, D. (2004) Two waste management technologies may be alternatives for swine industry. *Magazine of the College of Arts & Life Sciences, North Carolina State University*. Raleigh: NC. http://www.cals.ncsu.edu/agcomm/magazine/fall04/n_waste.htm

Caldwell, D. (2006) End of an era. *Perspectives Online: The Magazine of the College of Arts and Life Sciences*. *Spring*. http://www.cals.ncsu.edu/agcomm/magazine/spring06/end.html

Campagnolo, et. al. (2002). Antimicrobial Residues in Animal Waste and Water Resources Proximal to Large-scale Swine and Poultry Feeding Operations. *Science of the Total Environment*. 299(1-3): 89-95.

CARB. (2013, November 7). Cap-and-Trade Program. *California Air Resources Board*. Retrieved November 7, 2013, from http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

Centner, T. J. (2011). Addressing water contamination from concentrated animal feeding operations. *Land Use Policy*, *28*(4), 706–711.

Chee-Sanford, J. (2006). Distribution of tetracycline- and tylosin-resistance genes in bacteria from soils exposed to swine effluent.

Chee-Sanford, et. al. (2001). Occurrence and diversity of tetracycline resistance genes in lagoons and groundwater underlying two swine production facilities. *Applied and Environmental Microbiology*, 67(4), 1494-1502.

Donham, K. (2007). Community Health and Socioeconomic Issues Surrounding Concentrated Animal Feeding Operations. *Environmental Health Perspectives*, 115(2): 317–320.

Easley, M. F. (2000) The Smithfield Agreement. http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/agreement.pdf

EERE. (2013a). Energy Consumption by Transportation Fuel in North Carolina. *Clean Energy in my State*. Retrieved October 15, 2013, from http://apps1.eere.energy.gov/states/transportation.cfm/state=NC

EERE. (2013b). Fuels and Vehicles. *Alternative Fuels Data Center*. Retrieved September 29, 2013, from http://www.afdc.energy.gov/

EIA. (2013, June 13). State Energy Data System (SEDS): 1960-2011 (Complete). *North Carolina State Profile and Energy Estimates*. Retrieved October 15, 2013, from http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=NC&CFID=11889080&CFTOKEN=22c869ce0990561c-87266869-25B3-1C83 546AADC35866B68D&jsessionid=8430ec437ac750aad4a0249464757b35b3a4#Production

EPA. (2013a). National Pollutant Discharge Elimination System: State Program Status. US Environmental Protection Agency. http://cfpub.epa.gov/npdes/statestats.cfm

EPA. (2013b). AD 101: Biogas Recovery Systems. AgSTAR Program. Available: http://www.epa.gov/agstar/anaerobic/ad101/index.html

EPA. (2013c). Anaerobic Digester Database. AgSTAR Program. November. Available: http://www.epa.gov/agstar/projects/index.html.

EPA. (2013d). Alternative Fuel Conversion. *On-road Vehicles and Engines*. Retrieved October 15, 2013, from http://www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm

FEMA. (2013, October 29). Major Disaster Declarations. *Disaster Declarations for North Carolina*. Retrieved April 19, 2012, from http://www.fema.gov/disasters/grid/state-tribal-government/51

EPA. (2013e). Transportation. *Sources of Greenhouse Gas Emissions*. Retrieved September 28, 2013, from http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html

EPA. (2013f). Greenhouse Gas Equivalencies Calculator. Retrieved October 15, 2013, from http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

EPA. (2013g). Calculations and References. *Clean Energy*. Retrieved October 15, 2013, from http://www.epa.gov/cleanenergy/energy-resources/refs.html

EPA. (2001). Proposed Regulations to Address Water Pollution from Concentrated Animal Feeding Operations. Washington DC. EPA 833-F-00-016

EPA. (2002). Concentrated Animal Feeding Operations. Clean Water Act Requirements. What are the federal requirements for Swine CAFOs? EPA 833-F-02-007. http://www.epa.gov/npdes/pubs/cafo_brochure_swine.pdf

EPA. (2002) EPA State Compendium: Programs and Regulatory Activities Related to Animal Feeding Operations. US Environmental Protection Agency, May 2002. http://www.epa.gov/npdes/pubs/statecom.pdf

Federal Register / Vol. 77, No. 140 / Friday, July 20, 2012 / Proposed Rules http://www.gpo.gov/fdsys/pkg/FR-2012-07-20/pdf/2012-17772.pdf

Frank, A. (2013) DENR merges state water programs; cuts may result. *Raleigh News & Observer,* August 1. http://www.newsobserver.com/2013/08/01/3076533/denr-merges-state-water-programs.html#storylink=cpy

Frank, J. (2013) Skvarla crafts new DENR mission statement, raising Sierra Club questions. *Raleigh News & Observer,* January 9. http://projects.newsobserver.com/under_the_dome/skvarla_crafts_new_denr_mission_statement_raising_sierra_club_questions#storylink=cpy

Gilchrist, M. (2006). The Potential Role of Concentrated Animal Feeding Operations in Infectious Disease Epidemics and Antibiotic Resistance. *Environmental Health Perspectives*, 115(2): 313–316.

Harris, P. (2012) Annual Report to the Environmental Review Commission of the North Carolina General Assembly on the Implementation of the Lagoon Conversion Program. Division of Soil and Water Conservation. http://www.ncleg.net/documentsites/committees/ERC/ERC%20Reports%20Received/2012/Department%20of%20Agriculture/2012-October%20Lagoon%20Conversion%20Rpt.pdf

Heederik, Dick. (2007). Health Effects of Airborne Exposures from Concentrated Animal Feeding Operations. *Environmental Health Perspectives,*115(2):298-302.

Herath, D., Weersink, A., & Carpentier, C. L. (2005). Spatial dynamics of the livestock sector in the United States: Do environmental regulations matter? *Journal of Agricultural and Resource Economics*, 45–68.

Horne, J. (2000) Rural Communities And CAFOs: New Ideas For Resolving Conflict. *Kerr Center for Sustainable Agriculture:* Poteau, OK. http://www.kerrcenter.com/publications/CAFO.pdf

Horton, R. A., et. al. (2009). Malodor as a trigger of stress and negative mood in neighbors of industrial hog operations. *American Journal of Public Health. 3*(S3), S610-S615.

Kane, D. (2011) Budget slashes safeguards for a healthy environment. *Raleigh News &*

Observer, June 12. http://www.newsobserver.com/2011/06/12/1267667/budget-slashes-safeguards-for.html

Key, N., & Sneeringer, S. (2011). Climate change policy and the adoption of methane digesters on livestock operations. *USDA-ERS Economic Research Report*, (111).

La Capra Associates, GDS Associates, and Sustainable Energy Advantage LLC. (2006) Analysis of a Renewable Portfolio Standard for the State of North Carolina. http://energync.org/assets/files/2006%20La%20Capra%20Analysis.pdf

Larick, K. (2013) Conversation with Adrienne Heller, September 27.

Lawson, C. (2013) Conversation with Adrienne Heller, October 30.

Maier, A. W. (2013) Conversation with Adrienne Heller, October 2.

Metcalfe, M. (2000). State legislation regulating animal manure management. *Review of Agricultural Economics*, *22*(2), 519–532.

Mirabelli, et al. (2006). Asthma Symptoms Among Adolescents Who Attend Public Schools that are Located Near Confined Swine Feeding Operations. *Pediatrics*,118(1):e66–e75.

Mitloehner, F. (2008). Worker Health and Safety in Concentrated Animal Feeding Operations. Journal of Agricultural Safety and Health, 14(2), 163-187.

NASEO. (2013). *An Overview of Statewide Comprehensive Energy Plans: From 2002 to 2012*. Arlington, VA. Retrieved from http://www.naseo.org/Data/Sites/1/naseo_39_state_final_7-19-13.pdf

National Pork Producers Council v. EPA, 635 F.3d 738, 742 (5th Cir. 2011).

Nene, G., Azzam, A. M., & Schoengold, K. (2009). Environmental Regulations and the Structure of US Hog Farms. Presented at the 2009 Annual Meeting, July 26-28, 2009, Milwaukee, Wisconsin, Agricultural and Applied Economics Association.

NCDENR-Division of Soil and Water Conservation and the NC Utilities Commission. (2011). Joint report to the environmental review Commission and the Joint Legislative Utility Review Committee On the Implementation of the Swine Farm Methane Capture Pilot Program. http://www.ncuc.commerce.state.nc.us/reports/MCPP_Joint_Report_2011.pdf

NGVAmerica. (2013). *Available NGV Aftermarket Conversion Systems*. Washington D.C. Retrieved from http://ngvamerica.org/about_ngv/documents/availablevehiclesandconversions_130920_final.pdf

North Carolina Environmental Management Commission Department of Environment and Natural Resources: Swine Waste Management NPDES General Permit. http://portal.ncdenr.org/c/document_library/get_file?uuid=a63f6515-e3ad-48c0-ac6b-e69505c51d81&groupId=38364

North Carolina Environmental Management Commission Department of Environment and Natural Resources: Swine Waste Management General Permit. http://portal.ncdenr.org/c/document_library/get_file?uuid=3e065d07-8269-46a9-858d-d425fb3d3327&groupId=38364

North Carolina in the Global Economy. (2007). Hog Farming in NC. Duke University. http://www.soc.duke.edu/NC_GlobalEconomy/hog/overview.shtml

North Carolina Utilities Commission (NCUC). (2013) Annual Report Regarding Renewable Energy And Energy Efficiency Portfolio Standard In North Carolina.

Olt, B. (2013, April 13). First-of-its-Kind Natural Gas-Powered Ambulance Debuts on Long Island. *News Room*. Retrieved October 15, 2013, from http://www.northshorelij.com/hospitals/news/natural-gas-ambulance

Perdue, B., Hackney, J. and Easley, M. (2007) Swine Farm Environmental Performance Standards. Senate Bill 1465. Ed. General Assembly of North Carolina. Raleigh, NC 2007. Vol. S.L. 2007-523.

PFL. (2013, November 22). PFL MARKETS DAILY. Retrieved from http://www.progressivefuelslimited.com/Web_Data/pfldaily.pdf
TCCC. (2012, October). Clean Fuel and Advanced Transportation Options. Triangle Clean Cities Coalition. Retrieved from http://www.trianglecleancities.org/Data/Sites/4/media/cfat-options-2012-final-102612.pdf

Prasodjo, D, Vujic, T, Cooley, D., Yeh, K., & Lee, M. (2013) A Spatial-Economic Optimization Study of Swine-Waste Derived Biogas Infrastructure Design in North Carolina. Durham, NC: Duke University, Duke Carbon Offsets Initiative. http://nicholasinstitute.duke.edu/sites/default/files/publications/ni_r_13-02.pdf

Proposed Regulations to Address Water Pollution from Concentrated Animal Feeding Operations. March 2001. US EPA. Washington DC. EPA 833-F-00-016

Roe, B., Irwin, E. G., & Sharp, J. S. (2002). Pigs in space: Modeling the spatial structure of hog production in traditional and nontraditional production regions. *American Journal of Agricultural Economics*, *84*(2), 259–278.

Schiffman, S. S., et al. (2000). Potential Health Effects of Odor from Animal Operations, Wastewater Treatment, and Recycling of Byproducts. *Journal of Agromedicine*, 7(1), 7-7.

Stith, P. and Warick, J. (1995) For Murphy, good government means good business. *Raleigh News and Observer*, February 22.

http://www.pulitzer.org/archives/5897

Stone KC, et. al. (1995). Water Quality Status of a USDA Water Quality Demonstration Project in the Eastern Coastal Plain. *Journal of Soil and Water Conservation*. 50(5):567–571.

Sweeten, J., Miner, R., & Tengman, C. (2003). Fact sheet# 1 A Brief History and Background of the EPA CAFO Rule. http://infohouse.p2ric.org/ref/16/15140.pdf

Tank, A. (2013) Conversation with Adrienne Heller, October 25. North Carolina Utilities Commission. (2013) Annual Report Regarding Renewable Energy And Energy Efficiency Portfolio Standard In North Carolina.

Tomaselli, P. M. (2013). Paving the Way: Are Half Measures in Animal Factory Farm Legislation Ethical? *S. Tex. L. Rev.*, *54*, 513–615.

USDA, "Unified National Strategy for Animal Feeding Operations." United States Department of Agriculture and the Environmental Protection Agency, 1999.

Waterkeeper Alliance, Inc. vs. EPA, 2005. Fed. Reporter 3d 399, 486– 524.

Whisnant, R. (2005) Memo: Economic Feasibility Determinations. December 1. http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase3report06/pdfs/Appendix%20D.pdf

Wing, S. et al, (2000). Environmental injustice in North Carolina's hog industry. Environmental Health Perspectives, 108(3): 225–231.

Wing, S. and Wolf, S. (2000b) Intensive livestock operations, health, and quality of life among eastern North Carolina residents. *Environmental Health Perspectives*, 108(3): 233–238.

Voss A, et.al. (2005). Methicillin-resistant *Staphylococcus aureus* in Pig Farming. Emerging Infectious Diseases. 11(12), 1965-1966.

Vukina, T., Roka, F., & Palmquist, R. B. (1996). Swine odor nuisance. *Voluntary Negotiation, Litigation, and Regulation: North Carolina= s Experience, CHOICES, First Quarter*, 26–29.