Waste Not, Want Not: Choosing the Most Economically Impactful Configuration of Swine Waste Biogas Systems in Eastern North Carolina

Abstract

Eastern North Carolina is home to the densest industrial hog farming in the world, but from the perspective of renewable energy technologies this may be the equivalent of sitting on a gold mine. This research uses IMPLAN to estimate the economic impact of waste-to-energy system installation on hog farms in compliance with the NC Renewable Energy Portfolio Standards, comparing a centralized and decentralized configuration to maximize the benefit to the North Carolina economy as a whole.

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Introduction

Eastern North Carolina is home to the densest industrial hog farming activity in the world and by extension the highest concentration of hog waste. This waste is managed through a 'lagoon and spray' system: hog waste is stored in large open lagoons and as the lagoons fill the waste is spread onto fields where the high nitrogen content can be taken up by grasses. This practice places a high toll on neighboring communities which experience reduced environmental quality, negative health impacts and reduced property values due to odors and air and water pollution. These impacts are worsened by flooding which can cause lagoon breaches as was seen in 1999 when Hurricane Floyd hit eastern North Carolina.

From the perspective of renewable energy technologies however, Eastern North Carolina is sitting on a veritable gold mine. Through anaerobic digestion hog waste can be turned into biogas and burned to generate electricity. So-called waste-to-energy or biogas systems offer a solution that mitigates many of the negative impacts of hog waste management while at the same time bringing a new revenue stream to farmers and providing electricity from a non-petroleum source.

A 2013 report by Prasodjo et al., *A Spatial-Economic Optimization Study of Swine Waste-Derived Biogas Infrastructure Design in North Carolina,* analyzed multiple configurations of biogas systems to determine which system exhibited the lowest cost per kilowatt hour of electricity produced[1]. This research builds on Prasodjo et al.'s work, asking the question of which of the two least-cost configurations brings the most economic impact to North Carolina? Hog farming is a primary industry in eastern North Carolina, installation of waste-to-energy systems could have a transformative effect in this region bringing new economic activity as well as improved environmental quality.

Methodology

IMPLAN ("IMpacts for PLANning"), an industry standard input/output analysis software, was used to model economic impacts of the two configurations. The model estimates three types of impacts – direct, indirect and induced – in terms of jobs and economic output from a new economic activity by flowing the new spending through matrices of inter-industry spending relationships. Direct impacts are the jobs and output associated with the activity being modeled, in this 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 and induced impacts result from increased household spending resulting from the additional jobs created directly or indirectly by the modeled activity.

[1] 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

System Configurations

The two least-cost configurations from Prasodjo et al.'s study were modeled through IMPLAN to determine the economic impacts that would result from these two distinct waste-to-energy system configurations. These configurations are:

1. **Decentralized Electricity Production:** Biogas is captured on farm using in-ground ambient temperature mixed digesters and lightly conditioned. On farm microturbines are used to convert the conditioned biogas into electricity. Interconnection is required to enable electricity sales back to the grid. This configuration could be implemented in a distributed manner, farm by farm without a high need for coordination.

2. **Centralized Directed Biogas** – Biogas is captured on farm using in-ground ambient temperature mixed digesters and lightly conditioned. It is transferred via a newly installed low pressure pipeline to a new central hub facility for heavy conditioning and compression; from which point it can be injected into the existing natural gas pipeline and sent to an existing combined cycle natural gas power plant to generate electricity. This configuration would require significant planning and coordination to install pipeline networks and centralized hubs.

Scope

Under each configuration it was assumed that implementation would be phased to comply with the three phases of North Carolina's Renewable Energy Portfolio Standard. Prasodjo et al.'s work identified 127 farms in across 13 counties in eastern North Carolina best suited to participate in each REPS stage based on location and size (Prasodjo, 2013, pg 30). These farms and their associated energy production potential were used to determine costs and revenues at each REPS stage and IMPLAN scenarios were run to reflect the construction and operations activity in the appropriate event years. Table 1 summarizes the parameters for the twelve IMPLAN scenarios.

Table 1. 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

Analysis by Parts

For most industries the IMPLAN model utilizes a standard Social Accounting Matrix that captures the structure of a local economy and industry to industry spending relationships. Through these matrices the model estimates 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 an 'analysis by parts' was performed which separates the calculation of direct impacts from the modeling of indirect and induced impacts. Direct impacts were thus calculated through first-hand research of existing biogas systems and used as inputs to determine indirect and induced effects.

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 and these shares were then redistributed to pertinent industries based on research of existing systems.

Calculation of Inputs

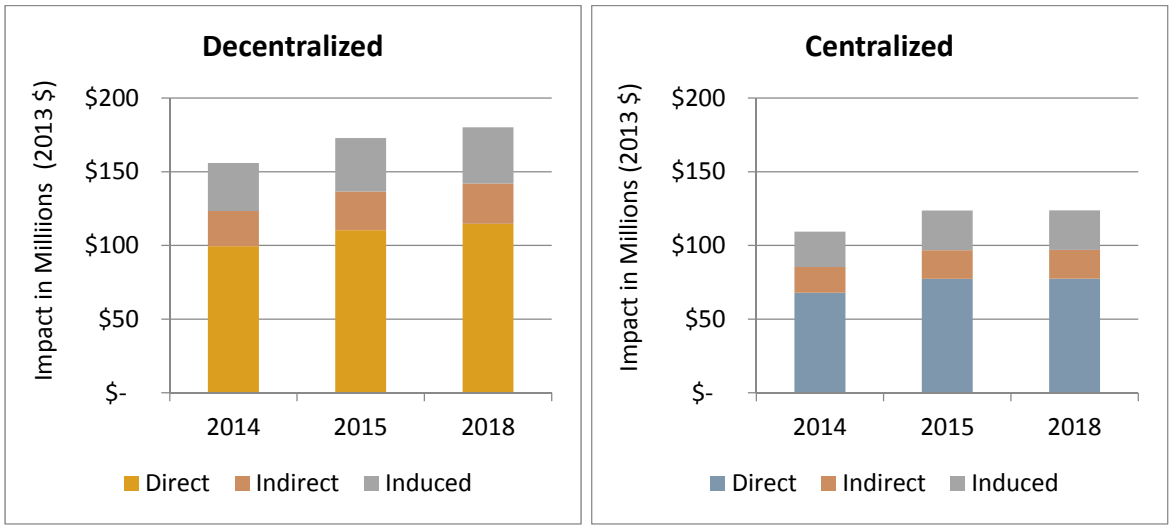
Cost data and system configurations were based on first-hand research of existing systems and figures provided in the Prasodjo et al.'s report. Potential electricity generation for each farm was calculated based on the number of permitted swine head and equipment was sized and priced based on this capacity. Revenues from electricity sales for each farm were calculated off of the capacity figure as well, and energy was valued at $103.31/MWh based on data from existing systems.

Results

Impact on Economic Output in North Carolina

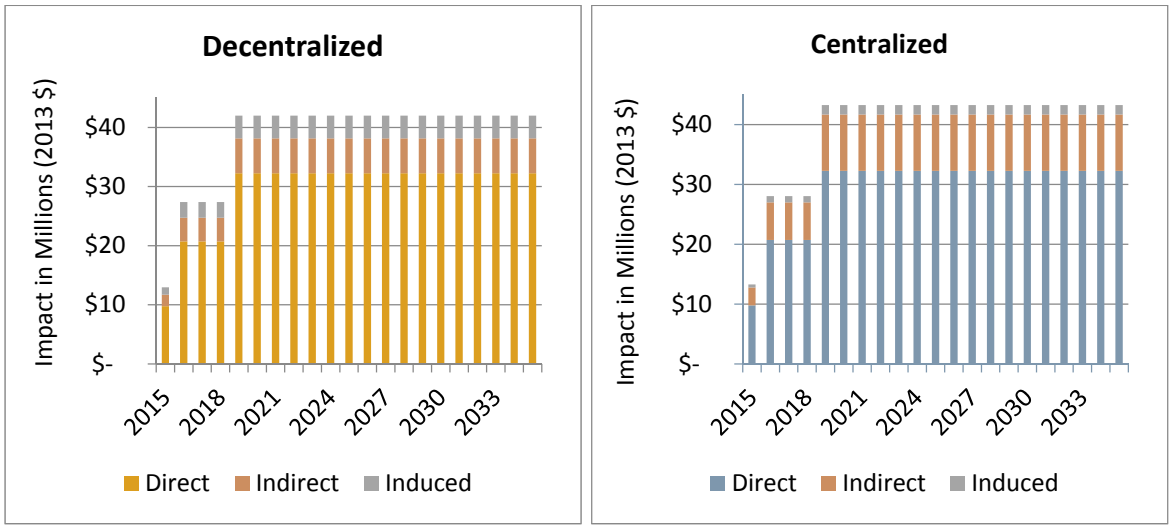
From the perspective of economic output, the decentralized scenario's construction phase has the highest one-time impact on the North Carolina economy with $155.9 million in new economic output in the first REPS stage, building to $180.1 for the construction of the final REPS stage. Construction of the centralized scenario has a lower impact with $109.3 million of new economic output in stage one building to $123.7 million in the second and third phases. Comparing the direct impact to the total impact, construction of the decentralized system has a multiplier of 1.57 versus 1.60 for the centralized system. For every dollar spent on system construction approximately $1.57 or $1.60 is spent elsewhere in the economy depending on the chosen configuration.

Figure 1. Impacts from construction on economic output in North Carolina



The impacts of construction are just a one-time effects. However, these systems are understood to have a useful life of 20 years, so looking at the operations phase there are continued benefits over the time period of 2015 to 2033. As with the construction impacts the magnitude of the effect increases as more systems come online in successive the REPS phases. Comparing between the centralized and decentralized configurations the new economic output from operations is slightly higher under the centralized configuration with $13.3 million annually of new output in stage one growing to $43.3 million by stage three versus $12.9 million and $40.2 million annually for the decentralized configuration in stage one and three respectively. Similarly the multiplier for the centralized configuration is 1.34 versus 1.31 for decentralized.

Figure 2. Impacts from operations on economic output in North Carolina

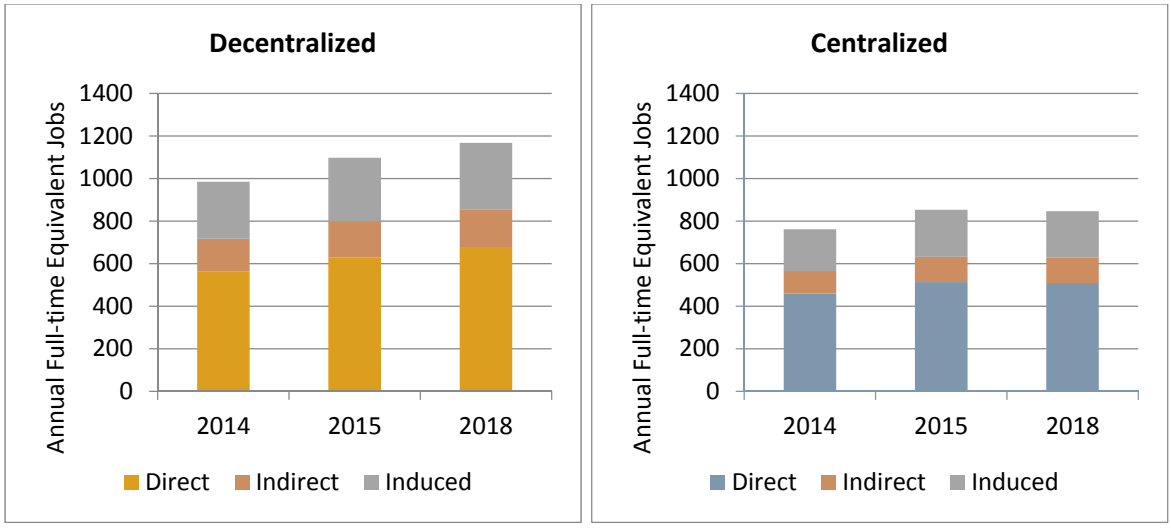


Impact on Employment in North Carolina

Turning to employment impacts the decentralized configuration appears to be the leading scenario with more jobs supported both during the construction phased and during operations. This make sense as this configuration has more distributed activity, whereas under the centralized configuration there are some efficiency gains as large equipment is located at centralized hubs and shared among farms.

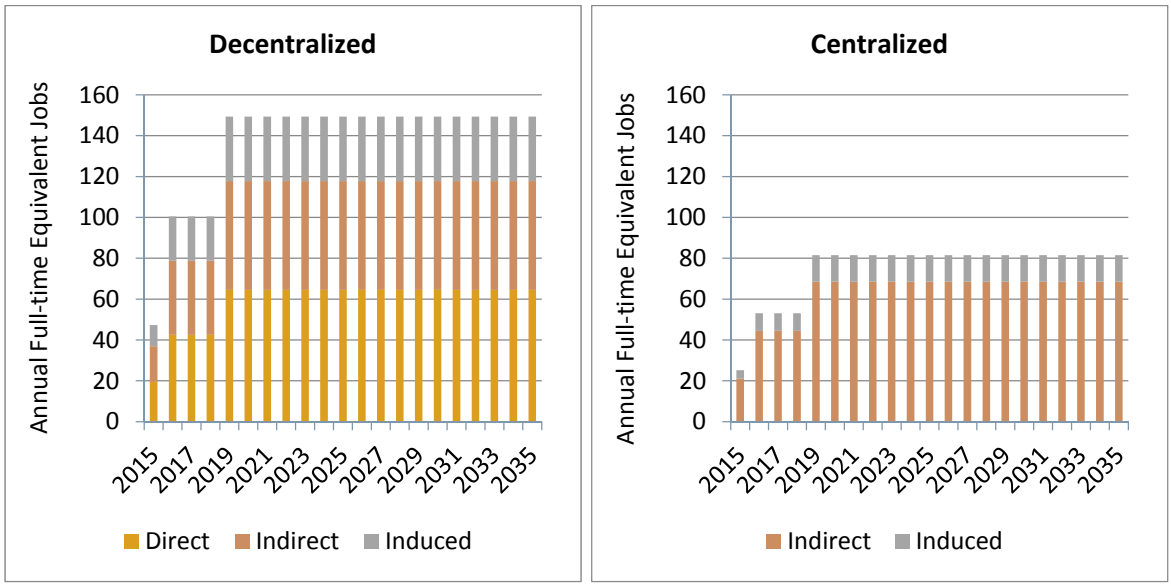
During construction, the decentralized configuration supports 980 full-time equivalent jobs, this impact grows to 1,160 by the third REPS stage. In contrast, the highest employment impact of the centralized configuration is 850 FTE jobs supported during the second REPS stage. The decentralized configuration has an average employment multiplier of 1.74 during construction, versus 1.66 for the centralized.

Figure 3. Impacts from construction on employment in North Carolina



The differences are starker during operations. By the third REPS stage the decentralized configuration is supporting a total of 149 FTE jobs annually versus only 77 under the centralized configuration. This translates into an average multiplier of 2.33 for the decentralized scenario – for every person directly hired to manage biogas systems approximately 2 FTE jobs are supported elsewhere in the economy. A multiplier cannot be calculated for the centralized configuration because it has no direct employment impact.

Figure 4. Impacts from operations on employment in North Carolina



State and Local Tax Impacts

Construction and operations of these systems would also entail new tax revenues for state and local government. The decentralized system leads again here, likely due to the greater employment impact this system brings and thus a larger income tax benefit for the state.

For both configurations the biggest impact comes from system construction which for the decentralized configuration is estimated to have a $22 million tax impact over the three REPS stages versus a $15 million impact for the centralized system. Once the systems are in operation the annual impacts build with each REPS stage; for the decentralized configuration this impact is $185,000 annually in stage one (2015) growing to $575,000 annually by stage three (2019). The centralized configuration brings $174,000 of new tax revenue annually in stage one and builds to $551,000 annually by stage three.

Table 2. Estimated New State and Local Tax Revenue from Installation and Operation of Biogas Systems Fulfilling the NC REPS Set-asides

	Decentralized	Centralized
Construction (total for all stages)	$22 million	$15 million
Operations - Stage 1 (2015)	$185K /year	$174K/year
Operations - Stage 2* (2017)	$389K/year	$364K/year
Operations - Stage 3* (2019)	$575K/year	$551/Year

*Stage two and three figures are cumulative

Conclusion

The IMPLAN analysis gives some insight into which system configuration would bring the most economic impact to the state of North Carolina as a whole, but the results are mixed displaying a classic tradeoff between efficiency and jobs. The decentralized configuration leads in almost all measures except for economic impact during operations. Much of this is due to the fact that the decentralized configuration is less efficient than the centralized, requiring dispersed construction and operations activity on each farm. This may be a benefit from the standpoint of economic impacts but from the farmer's perspective it poses a higher cost and does not benefit from the coordination and economies of scale that the centralized configuration brings.

The best solution here may in fact be a blended approach. The decentralized system can be phased in and connected to a central system of pipes later down the road as these systems are proven and become more widely known. Such an approach will allow time for more biogas supporting industries to locate in North Carolina, which will further boost economic benefits to the state by keeping more of the spending and employment locally. Additionally a blended approach gives state and local government the opportunity to see these systems in operation and understand the benefits to their regions, paving the way for the coordination action required for the centralized infrastructure and public support of system construction.