PRESSON EXHIBIT NO. 1

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DOCKET NO. E-7, SUB 1264

REDACTED VERSION

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
Line No.	Renewable Resource	RECs only	Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs	Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs
[redacted]										

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
Line No.	Renewable Resource	RECs only	Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs	Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs
[redacted]										

REDACTED VERSION

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

Line No.	Renewable Resource	RECs only	EMF Period January 1, 2021 - December 31, 2021 Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs	September 1, 2022 - August 31, 2023 Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs
[redacted]										

REDACTED VERSION

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
Line No.	Renewable Resource	RECs only	Total Units *(A) (B)*	Total Cost per Unit	Total Cost	RECs	Total Units *(A) (B)*	Total Cost per Unit	Total Cost	RECs

[redacted]

REDACTED VERSION

Presson Exhibit No. 2
Page 5 of 9
March 1, 2022

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
Line No.	Renewable Resource	RECs only	Total Units *(A) (B)*	Total Cost per Unit	Total Cost	RECs	Total Units *(A) (B)*	Total Cost per Unit	Total Cost	RECs

[redacted]

REDACTED VERSION

DUKE ENERGY CAROLINAS, LLC
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Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
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[redacted]										

REDACTED VERSION

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

Line No.	Renewable Resource	RECs only	EMF Period January 1, 2021 - December 31, 2021: Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs	September 1, 2022 - August 31, 2023: Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs
[redacted]										

Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
Line No.	Renewable Resource	RECs only	Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs	Total Units (A) (B)	Total Cost per Unit	Total Cost	RECs

[redacted]

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Compliance Costs

			EMF Period January 1, 2021 - December 31, 2021				September 1, 2022 - August 31, 2023			
Line No.	**Renewable Resource**	**RECs only**	**Total Units** *(A) (B)*	**Total Cost per Unit**	**Total Cost**	**RECs**	**Total Units** *(A) (B)*	**Total Cost per Unit**	**Total Cost**	**RECs**
[redacted]										
218	Other Incremental (see Conf. Presson Exhibit No. 3 for Incremental Cost worksheet}				$ 1,291,990				$ 1,309,800	
219	Billing Period estimated receipts related to contract performance				[redacted]	Note 1			$ (100,000)	Note 1
220	Solar Rebate Program (see Conf. Presson Exhibit No. 3 for cost detail)				$ 1,908,249				$ 2,483,363	
221	Research (see Conf. Presson Exhibit No. 3 for Research cost detail)				$ 855,793				$ 915,000	
222	**Total Other Incremental and Research Cost**				**$ 4,056,032**				**$ 4,608,163**	
[redacted]										
224	EMF Period actual credits for receipts related to contracts - to Williams Exhibit No.4 - footnote (3)				$ (112,500)	Note 1				

Note 1: EMF Period contract receipts are not included in the under/overcollection calculation on Williams Exhibit No. 2, instead they are credited directly to customer class on Williams Exhibit No. 4. Estimated contract receipts are included in Billing Period total other incremental cost as a reduction in REPS charges proposed for the Billing Period.

Footnotes: [redacted]

REDACTED VERSION

Line No.	Incremental Cost Worksheet:	EMF Period January 1, 2021 - December 31, 2021	Billing Period September 1, 2022 - August 31, 2023
	Labor by activity:		
1	[redacted]		[redacted]
2	[redacted]	*$ 19,982*	[redacted]
3	[redacted]	*$ 191,744*	[redacted]
4	[redacted]	*$ 40,512*	[redacted]
5	[redacted]	*$ 24,634*	[redacted]
6	[redacted]	*$ 290,669*	[redacted]
7	[redacted]	*$ 21,713*	[redacted]
8	[redacted]	*$ 421,842*	[redacted]
9	[redacted]	*$ 1,011,096*	[redacted]
10	[redacted]	*$ 24,751*	[redacted]
11	[redacted]	*$ 24,751*	[redacted]
12	[redacted]	*$ 1,695*	[redacted]
13	[redacted]	*$ -*	[redacted]
14	[redacted]		[redacted]
15	[redacted]	*$ 35,000*	[redacted]
	[redacted]	*$ 519*	[redacted]
16	[redacted]	*$ 164,641*	[redacted]
17	[redacted]	*$ 41,000*	[redacted]
18	[redacted]	*$ 13,288*	[redacted]
19	[redacted]	*$ 254,448*	[redacted]
20	**Total Other Incremental Cost**	**$ 1,291,990**	**$ 1,309,800**
	Solar Rebate Program Cost Detail (recovery in REPS pursuant to G.S. 62-155(f)): (1)		
21	Annual Amortization of Incentives Provided to Customers, plus return on unamortized balance	$ 1,782,041	$ 2,286,644
22	Annual Amortization of Program Administrative Labor Costs, plus return on unamortized balance	[redacted]	[redacted]
23	Annual Amortization of Program Administrative Contract Labor & Other Administrative Costs, plus return on unamortized balance	[redacted]	[redacted]
24	**Total Solar Rebate Program Cost**	**$ 1,908,249**	**$ 2,483,363**

DUKE ENERGY CAROLINAS, LLC
Docket No. E-7, Sub 1264

Presson Exhibit No. 3
Page 2 of 2
March 1, 2022

REDACTED VERSION

Line No.	Incremental Cost Worksheet:	EMF Period January 1, 2021 - December 31, 2021	Billing Period September 1, 2022 - August 31, 2023
	(1) All annual Solar Rebate Program costs reflect amortization of incurred costs over 20 years, including a return on the unamortized balance.		
	Research Cost Detail:		
25	Astrape Battery Storage Effective Load Carrying Capability Study (Note 2)	[redacted]	
26	Bring Your Own Battery Study		
27	CAPER - Developing large DER Protection Guidelines and Settings for Mitigating System-wide Impacts across T&D Systems		
28	Coalition for Renewable Natural Gas Membership		
29	DC Meter Testing Project		
30	Distributed Generation Cost-of-Service Study		
31	Duke University - Loyd Ray Farms		
32	EPRI - Membership		
33	EPRI - Supplemental Projects		
34	NC State University's Future Renewable Electric Energy Delivery and Management ("FREEDM") Systems Center		
35	NCSU - Adopting DVAR to Mitigate PV Impact on a Distribution System		
36	NCSU - Adopting DVAR to Mitigate PV Impact on a Distribution System Phase 2		
37	NCSU – Feeder Anti-islanding Detection Using HIL Modeling and Simulation		
38	NCSU - Swine Lagoon Sludge Research Study		
39	NREL - Carbon-free Resource Integration Study		
40	Research Triangle Institute - Biogas Utilitzation in NC		
41	Smart Electric Power Alliance		
42	Southeastern Wind Coalition		
43	UNCC - Power Flow Analysis to Improve Integrated Volt/Var Control (IVVC) and Energy Efficiency Programs		
44	UNCC - Reliability Assessment for Utility PV Inverter System		
45	UNCC - Resilient Community Microgrids with Dynamic Reconfiguration to Serve Critical Loads in the Aftermath of Severe Events		
46	**Total Research Cost**	**$ 855,793**	**$ 915,000**
47	**Total Other Incremental Cost**	$ 1,291,990	1,309,800
	Projected credits for receipts related to contract amendments/liquidated damages, etc	$	(100,000)
	Total Other Incremental Cost and other credits	$ 1,291,990	1,209,800
	Total Solar Rebate Program Cost	$ 1,908,249	2,483,363
	Total Research Cost	$ 855,793	915,000
	Grand Total - Other Incremental, Solar Rebate Program, and Research Cost, other credits	**$ 4,056,032**	**4,608,163**
	EMF Period actual credits for receipts related to contracts - see **Note 1**	$ (112,500)	
	Net Other Incremental, Solar Rebate Program and Research Cost	**$ 3,943,532**	**4,608,163**

Note 1: EMF Period contract receipts are not included in the under/overcollection calculation on Williams Exhibit No. 2, instead they are credited directly to customer class on Williams Exhibit No. 4. Estimated contract receipts are included in Billing Period total other incremental cost as a reduction in REPS charges proposed for the Billing Period.

Note 2: Project completed in 2020. Charges relate to final invoices received in 2021.

DUKE ENERGY

Bring Your Own Battery Study Update

SUMMARY:
As variable renewable energy sources like wind and solar increase in market penetration, there is a greater need for grid flexibility to meet fluctuations in generation. Storage is a helpful companion for renewables such as wind and solar in that energy can be stored during high generation periods of time for use in future low generation periods of time. Residential customers in North Carolina are adopting residential battery storage technology at a growing rate and there is potential benefit to all Duke Energy customers in this technology for a variety of use cases. A technology study utilizing Renewable Energy Portfolio Standard (REPS) research funding will allow Duke Energy to study aggregation technology, battery discharge, customer usage patterns, and the customer experiences that could inform a future pilot or program filing.

STUDY UPDATE:
The study began work in Q3 of 2021 with the onboarding of an aggregator platform that receives battery data and controls existing batteries. Customer invitations to participate in the study were sent out in Q1 of 2022. The study will gather 12 months of data from 65 residential customers starting in Q2 of 2022. Duke Energy will report findings no later than May 2023.

- Aggregation Technology:
    - Aggregator platforms serve as an interface between different distributed energy resources (DER) by managing the cloud-to-cloud communication for the various original equipment manufacturers (OEM) and utilities.
    - Some commercially viable aggregators can manage the control and data collection for different devices including battery storage.
    - Aggregator platforms allow for customers to choose the battery storage system of their preference and then enroll their devices into a program with a utility.
    - For the purposes of this study, Duke Energy secured the services of an aggregator vendor, Virtual Peaker, that can control and collect data from battery storage OEMs: Generac and SolarEdge

- Battery Discharge:
    - This study could prove the technology efficacy and demonstrate the expected additional capacity that these devices could provide.
    - Controlling residential batteries through an aggregator is an unproven technology among Duke Energy customers.
    - Residential customers who have an approved interconnection agreement and have paired their solar generation with a Generac or SolarEdge battery system are eligible for the study. This includes customers who are leasing or financing their systems through Sunrun and PowerHome Solar.
    - There are different installation configurations of a residential battery storage system that could limit the amount of energy discharged from the battery. For the purposes of this study, we will not discharge a customer’s battery below a 50 percent state of charge at any time.
    - Duke Energy will not send a command (also referred to as an “event”) to customers’ battery systems to discharge if the 72-hour weather forecast calls for hurricanes, tropical storms, tropical depressions or even tropical disturbances near or approaching the area, allowing study participants to continue to use their battery storage systems as a backup energy solution.
    - Duke Energy will run up to 5 events per month over a 12-month period.
    - Customers will be given at least 2 hours’ notice prior to events via their preferred communication method.

Bring Your Own Battery Study Update

- Customers may opt out of up to 5 events during the 12-month study.
- If customers opt out of more than 5 events, unenroll, move or otherwise become ineligible to participate, they will not receive the second $100 check.
- In event notifications, customers will be provided a link to opt out of an event.

- Customer Usage Patterns:
  - Utilizing the interval data available from these batteries, Duke Energy expects to model and forecast the expected additional capacity that these devices could provide.

- Customer Experience:
  - Designing a future pilot or program that centers on residential storage requires feedback from customers so that Duke Energy can design a program that meets the needs of all customers.
  - Study participants will receive $100 at the beginning of the study and $100 at the end of the 12-month period.

STUDY COSTS:

The costs for this program are $100,000 in DEC and $85,000 in DEP. These costs are allocated based on the total participants in each operating company. Funds are disbursed for 2021 and 2022 for aggregator vendor services.

PRESSON CONFIDENTIAL

EXHIBIT NO. 5

DOCKET NO. E-7, SUB 1264

CONFIDENTIAL – FILED UNDER SEAL

Economic Analysis of the US Renewable Natural Gas Industry

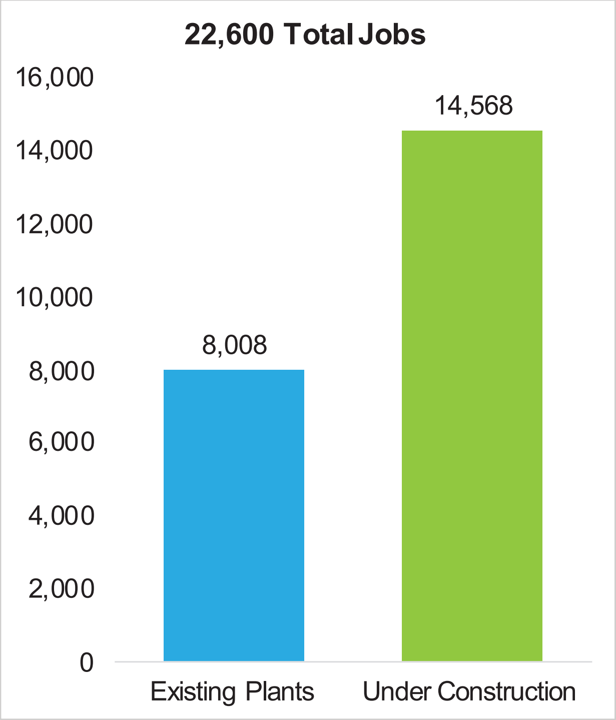
December 2021

THE COALITION FOR RENEWABLE NATURAL GAS

Contents

Renewable Natural Gas (RNG) is Estimated to Contribute 22,600 Jobs, $2.6B in GDP, and $5.4B in Total Business Sales for Operations and Capital Expenditures in 2021

These numbers include the direct, indirect, and induced effects of existing RNG facilities and facilities currently under construction. Construction jobs require the approval of additional RNG facilities to continue to contribute to the economy.



THE COALITION FOR RENEWABLE NATURAL GAS

RNG Has Potential to Grow into a Formative Green Industry

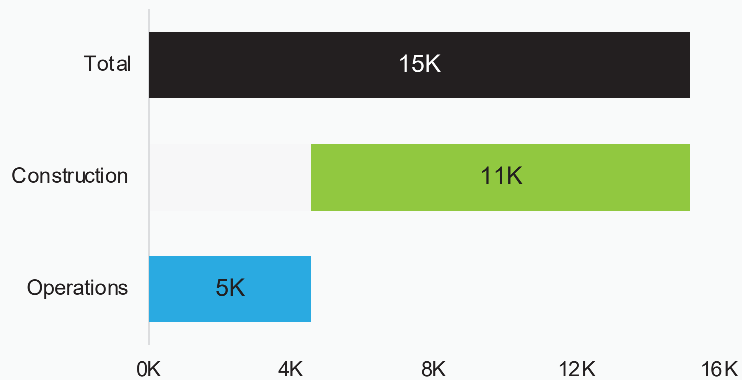
These numbers demonstrate the employment potential of RNG should it grow as expected based on RNG Coalition scenarios.

12 Jobs created for every $1 million spent on RNG in 2021

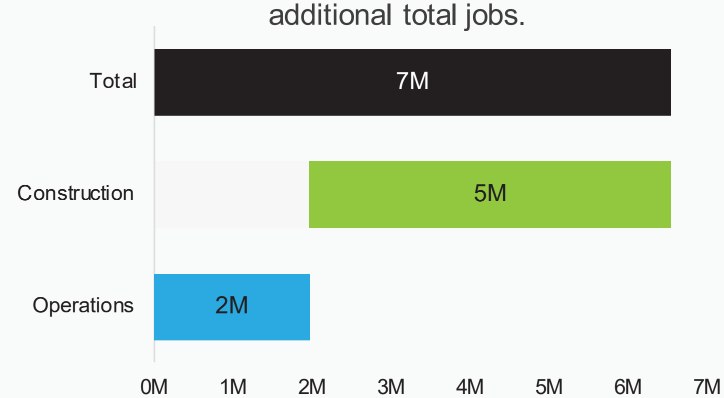
278 Jobs created per 1 million MMBTU of RNG in 2021

24 Jobs created per 1 million EGE[1] of RNG in 2021

Each additional **100 RNG facilities** creates an average 4,550 operations jobs and 10,634 construction jobs



If RNG Coalition's SMART [2] Initiative goal of **43,000 facilities** is met by 2050, this would create an estimated 6,528,938 additional total jobs.



1 Ethanol Gallon Equivalent

2 Sustainable Methane Abatement and Recycling Timeline

Employment Levels Vary Based on RNG Feedstock

A single Wastewater project creates an average of 141 total jobs, a single Livestock Waste project creates an average of 79 total jobs, a single Food Waste Project creates an average of 297 total jobs, and a single MSW project creates an average of 343 jobs.[3]

Adding an additional Wastewater project would create an average of 50 direct, 37 indirect, and 54 induced jobs – for 141 total jobs

Adding an additional Livestock Waste project would create an average of 25 direct, 22 indirect, and 32 induced jobs – for 79 total jobs

Adding an additional Food Waste project would create an average of 116 direct, 158 indirect, and 238 induced jobs – for 297 total jobs

Adding an additional MSW project would create an average of 115 direct, 94 indirect, and 134 induced jobs – for 343 total jobs

[3] Calculations are based on the average jobs per facility for each feedstock in 2021. Operations jobs ratios were calculated using current operation facilities in 2021 while construction job ratios were calculated using the number of facilities currently under construction in 2021. These numbers were provided by the RNG Coalition.

This Study Sets Out to Analyze the Current Economic Contribution of RNG to the US Economy in 2021

This report is comprised of four sections:

1. **RNG Overview**
   Introduces renewable natural gas (RNG)
2. **RNG Value Chain**
   Overview of the RNG value chain from waste collection to final use
3. **Expenditure Analysis**
   Calculates the spending associated with RNG 1) existing plants and 2) plants under construction
4. **Economic Impact**
   Estimates jobs, GDP, and sales associated with RNG 1) existing plants and 2) plants under construction

This study answers the following questions:

1. What is RNG and how is it produced?
2. What are the stages within the RNG value chain?
3. What are the costs of RNG?
4. What impact does RNG have on the U.S. economy?

THE COALITION FOR RENEWABLE NATURAL GAS

1 RNG Overview: RNG is a Clean, Affordable, and Reliable Waste-Derived Fuel that can be Used as Transportation Fuel for Vehicles, Generation of Electricity, and Thermal Heating Applications

RNG is a type of fuel that comes from a variety of waste sources. As that waste breaks down, biogas is captured through Anaerobic Digestion, Thermal Gasification, Pyrolysis, or Power-to-Gas technologies. The biogas is refined into biomethane (another name for RNG) after carbon dioxide, hydrogen sulfide, and other gases are removed. Crucially, biomethane is fully interchangeable with natural gas and can be used for local uses or injected into natural gas distribution systems. This report will cover the four feedstocks of Anaerobic Digestion, the most common RNG technology: Wastewater, Food Waste, Livestock Waste, and Municipal Solid Waste (MSW).

1 RNG Overview: Because of its Greenhouse Gas (GHG) Reducing Potential, RNG is Considered a Low-Carbon Fuel Under the Federal Renewable Fuel Standard and State Low-Carbon Fuel Standards

All sectors of the U.S. economy will need to decarbonize dramatically to reach mid- to long-term GHG emissions targets set by a growing number of states, enabling new business opportunities for RNG. RNG from organic wastes leads to GHG reductions in two ways:

1. Displacing the use of diesel in vehicles

RNG can facilitate the displacement of life-cycle GHG emissions from fossil fuel use in vehicles[6]

RNG reduces **660** million gallons of diesel consumed by heavy duty vehicles[5]

Filling approximately **3 million** semi trucks or **7.3 million** transit buses

Reducing **14,792** million pounds of CO_2 emissions

2. Reducing emissions from waste

Waste accounts for one third of U.S. methane production and 3 percent of total U.S. GHG emissions.[4] Food waste is often sent to a landfill where methane is released or burned (e.g., turned into carbon dioxide) which enters the atmosphere. Other types of organic waste are placed in an open lagoon and release methane. To produce RNG, these gases are captured and cleaned rather than being released directly into the atmosphere

[4]RNG's life-cycle net impact on GHG emissions also depends on the feedstock used, how much GHG would have otherwise been produced from fossil fuels, and how much methane escapes during RNG capture & upgrade

[5]Total RNG volume as of 2021 converted from RNG in Ethanol Gallon Equivalents (EGE) to Diesel Gallon Equivalents (DGE) using conversions found at: https://nhcleancities.org/2017/04/can-compare-energy-content-alternative-fuels-gasoline-diesel/

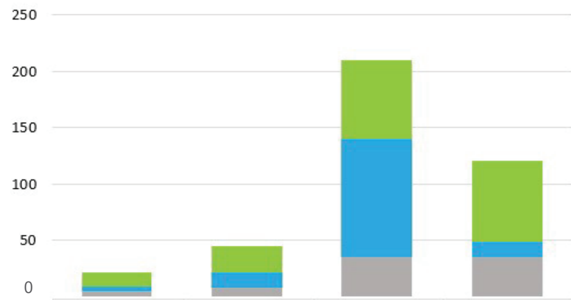
[6]World Resources Institute, 2015

1 RNG Overview: State of RNG Supply

RNG capacity in 2021 is nearly 74 trillion BTU's. RNG equates to nearly 870 million gallons of ethanol gallon equivalent (EGE) or 660 million gallons of diesel gallon equivalent (DGE). At the mid-point of 2021, there are 176 operational RNG facilities and 220 facilities that are under construction or planned. The agriculture sector has the most projects under construction for collecting and upgrading biogas into RNG.[7]

Status of RNG Facilities by Feedstock

(project counts)



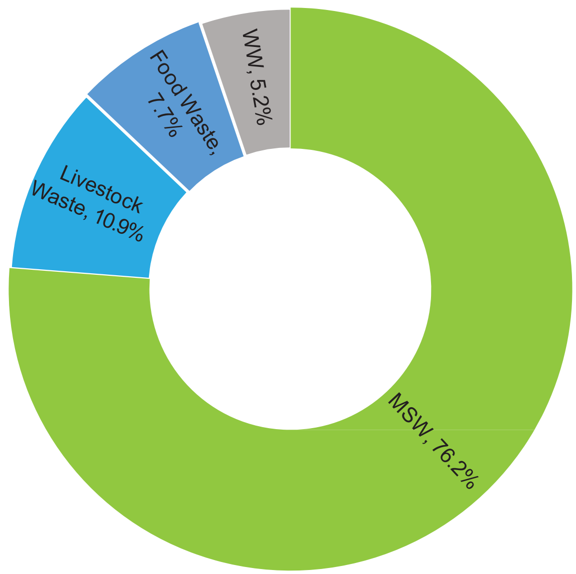
	Food Waste	WW	Livestock Waste	MSW	Total
Operational	13	23	70	72	178
Under Construction	4	14	105	14	137
Planned	5	8	35	35	83
Total	22	45	210	121	398

[7] 2021 RNG volumes and operational facility data are provided by the RNG Coalition

1 RNG Overview: The Vast Majority of RNG Comes from Municipal Solid Waste

Nearly 74 trillion British thermal units (BTU) of biomethane will be produced from waste in 2021. Of this, three quarters could come from municipal solid waste.[8]

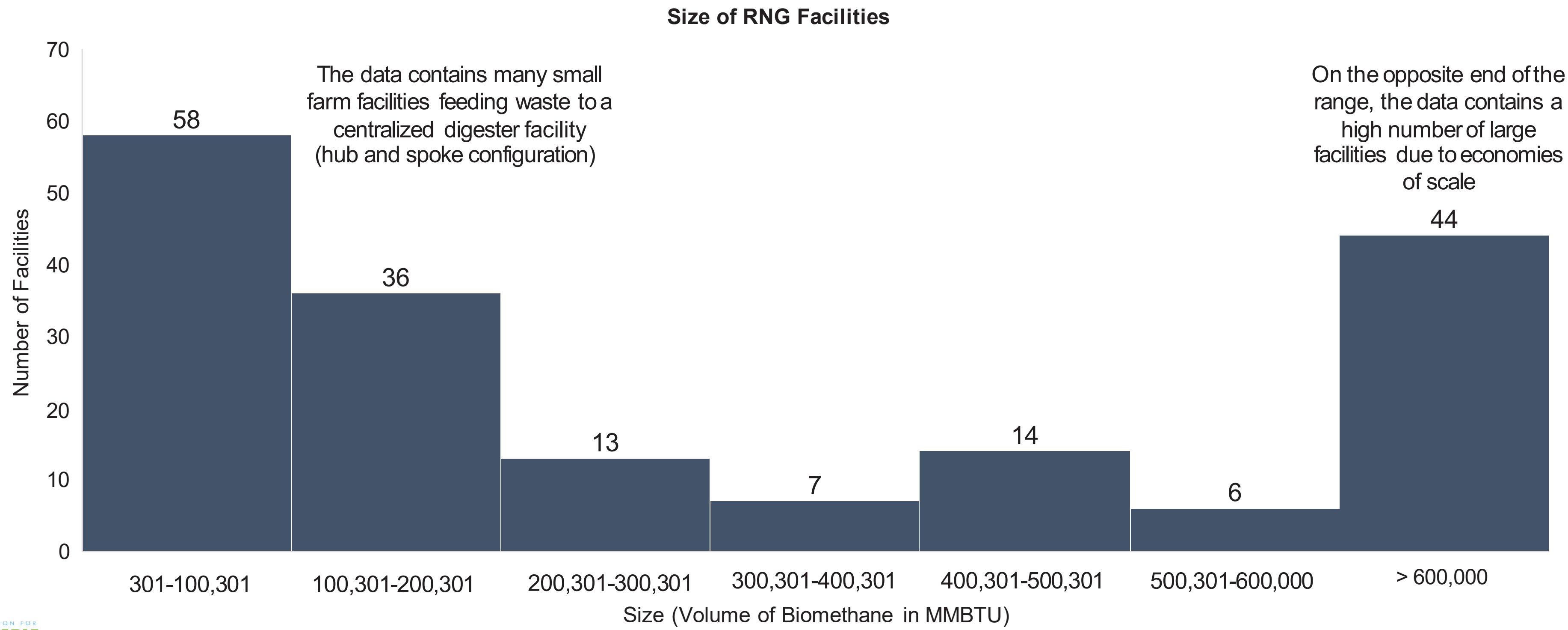
2021 RNG Volume by Feedstock



[8] Data provided by the RNG Coalition and the Argonne National Laboratory (ANL)

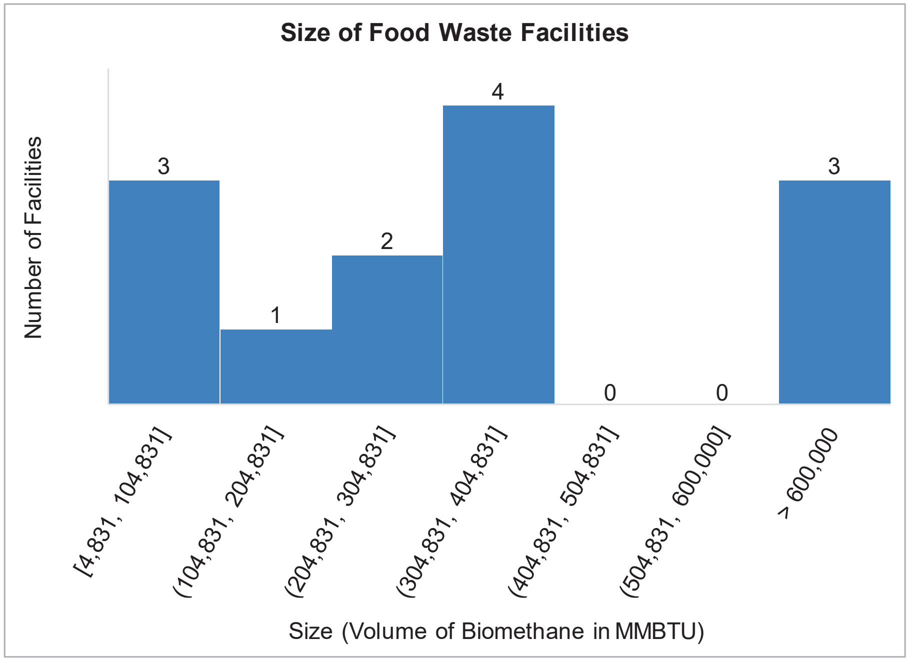
1 RNG Overview: RNG Facilities Vary in Size

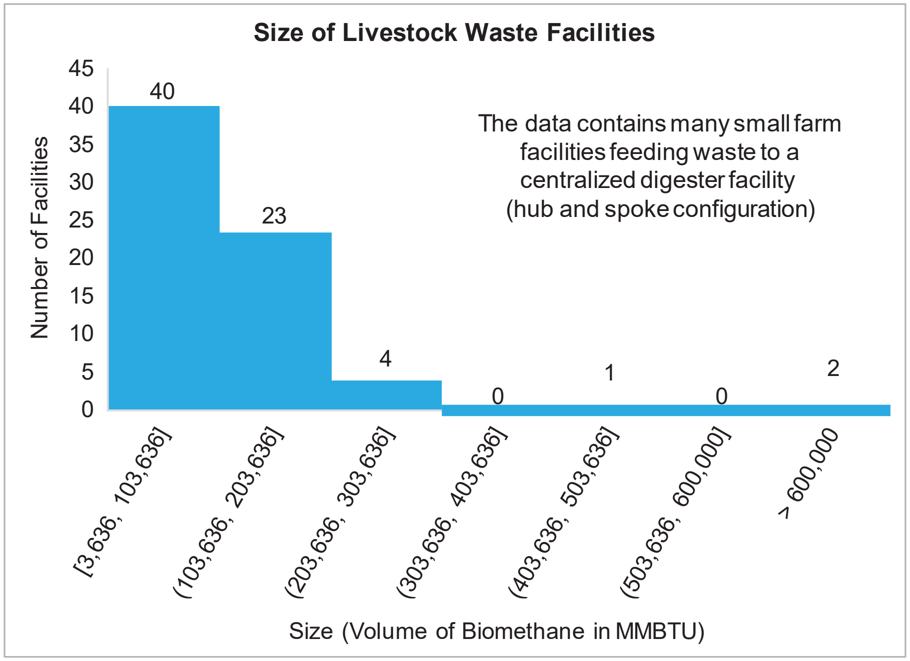
The distribution of the size of RNG facilities looks like an inverse normal distribution because of two reasons; small farms use a hub and spoke configuration for the disposal of agricultural waste, and – on the other end of the spectrum – larger dedicated facilities bring economies of scale at sizes greater than 600,000 MMBTU.



1 RNG Overview: Food Waste and Livestock Waste Facilities are Predominantly Smaller-Scale

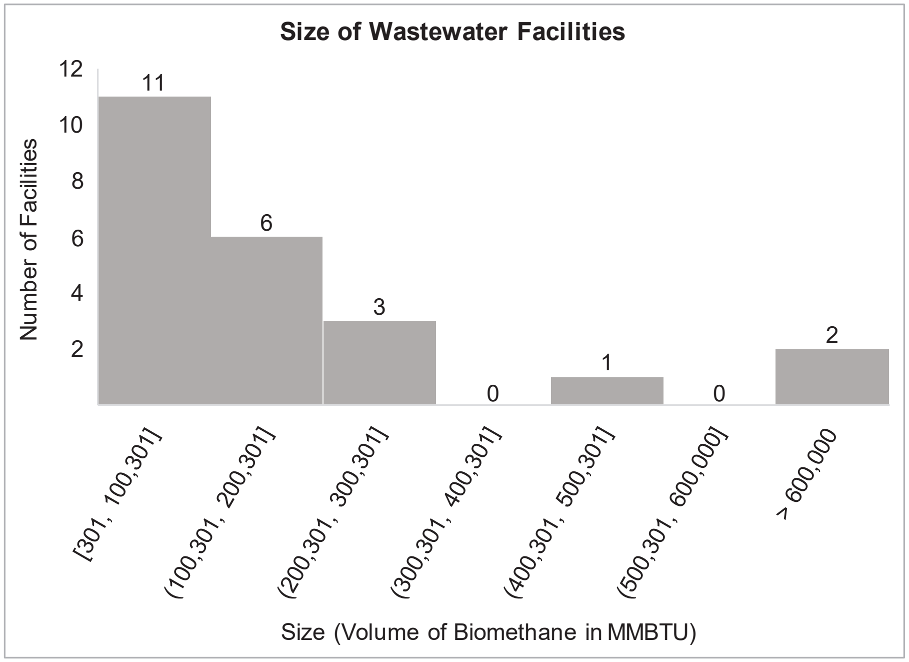
Below are the histograms for Food Waste Facilities and Livestock Waste Facilities showing the facility counts that fall within a range of MMBTU volume by feedstock. For Food Waste, facilities varied widely in size while most Livestock Waste Facilities fall within 100,000 MMBTU's of RNG.

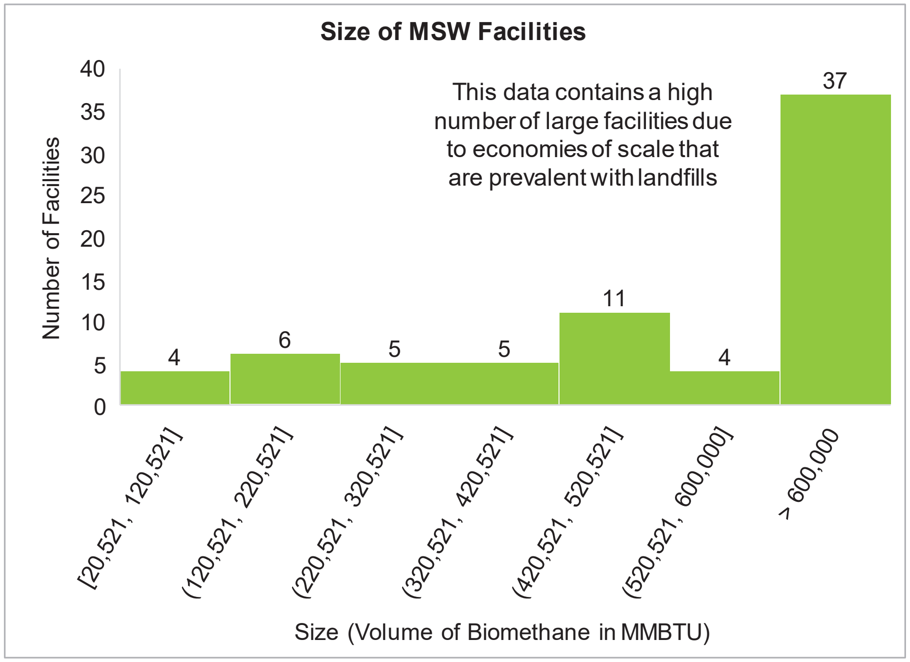




1 RNG Overview: Wastewater Facilities are Smaller in Size, MSW Facilities are Largest

Below are the histograms for wastewater facilities and MSW facilities showing the facility counts that fall within a range of MMBTU volume by feedstock. For wastewater, most facilities fall within 100,000 MMBTU's of RNG whereas the majority of MSW facilities produce over 600,000 MMBTU's of RNG.





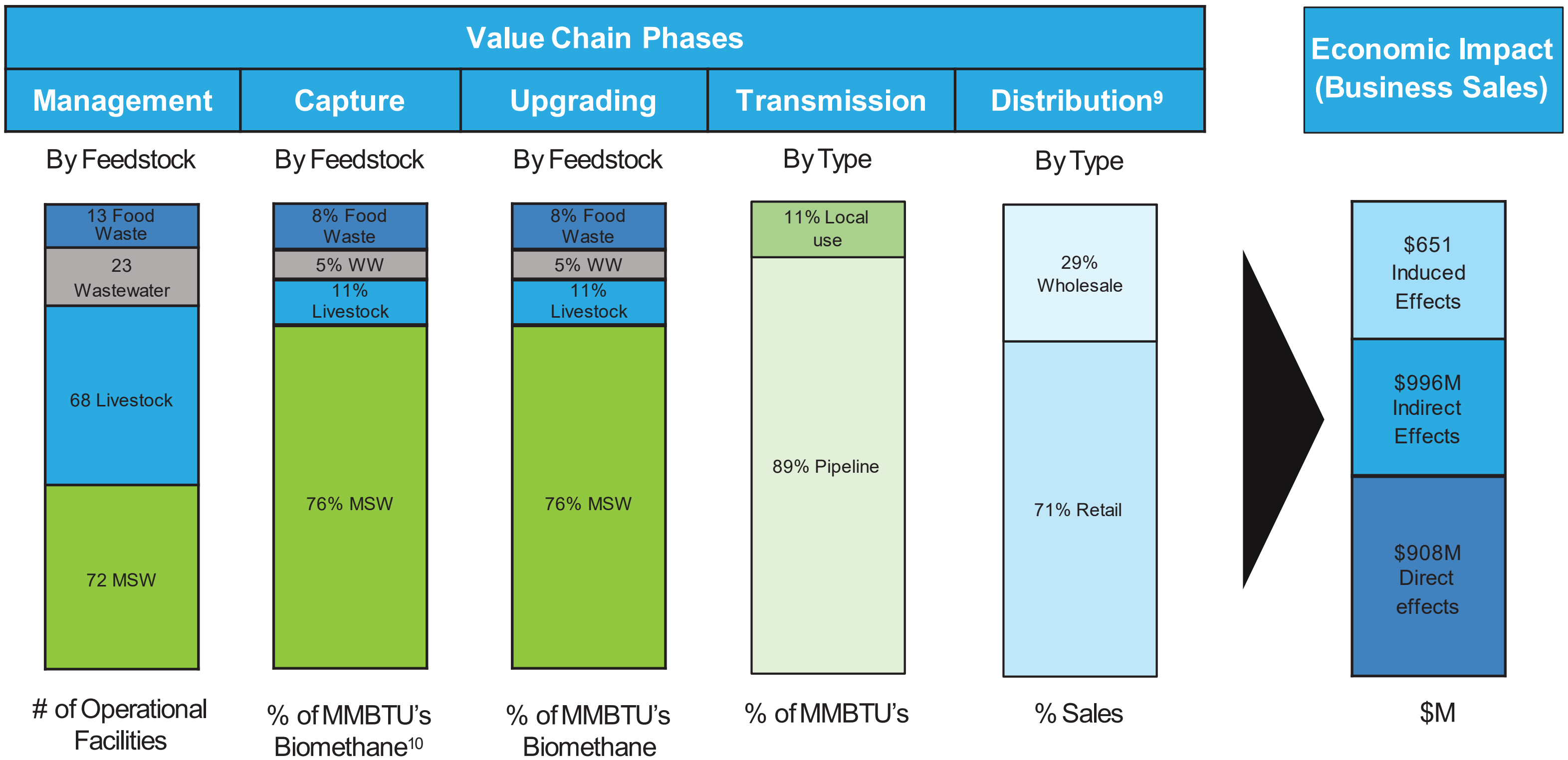
2 RNG Value Chain: The RNG Value Chain Comprises 6 Stages

Each stage of the value chain plays a role in the capture and upgrade of RNG ranging from management (waste collection) to distribution. A portion of RNG is transported via local pipeline for local usage while the remaining portion is injected into the natural gas pipeline system. The value chain is important to understanding the operation costs associated with RNG which is used to calculate its economic impact.

		Value Chain Phases					
Size	**Description**	**Management**	**Capture**	**Refinement**	**Transmission**	**Distribution**	**End Use**
Small Ops (aggregate waste to larger facility)	On/Off site anerobic digestion (hub & spoke)	Collection of waste	Anerobic digestion of waste (on-site or off-site)	Biogas is upgraded to biomethane by removing $C0_2$, H_2S, and other trace gasses	Use of local pipeline or injection of RNG into the natural gas pipeline network	Vehicle fuel is distributed to end users via local pipeline or through wholesale / retail channels	Vehicle fuel, electricity generation, home heating and industrial uses
Large Ops (on-site capture)	Onsite anerobic digestion (pipeline)		Anerobic digestion of waste (on-site)				

2 RNG Value Chain: Each Stage of the Value Chain Creates Economic Impact

This diagram details the different components associated with each phase of the value chain and how they ultimately feed into the economic impact of the RNG industry.

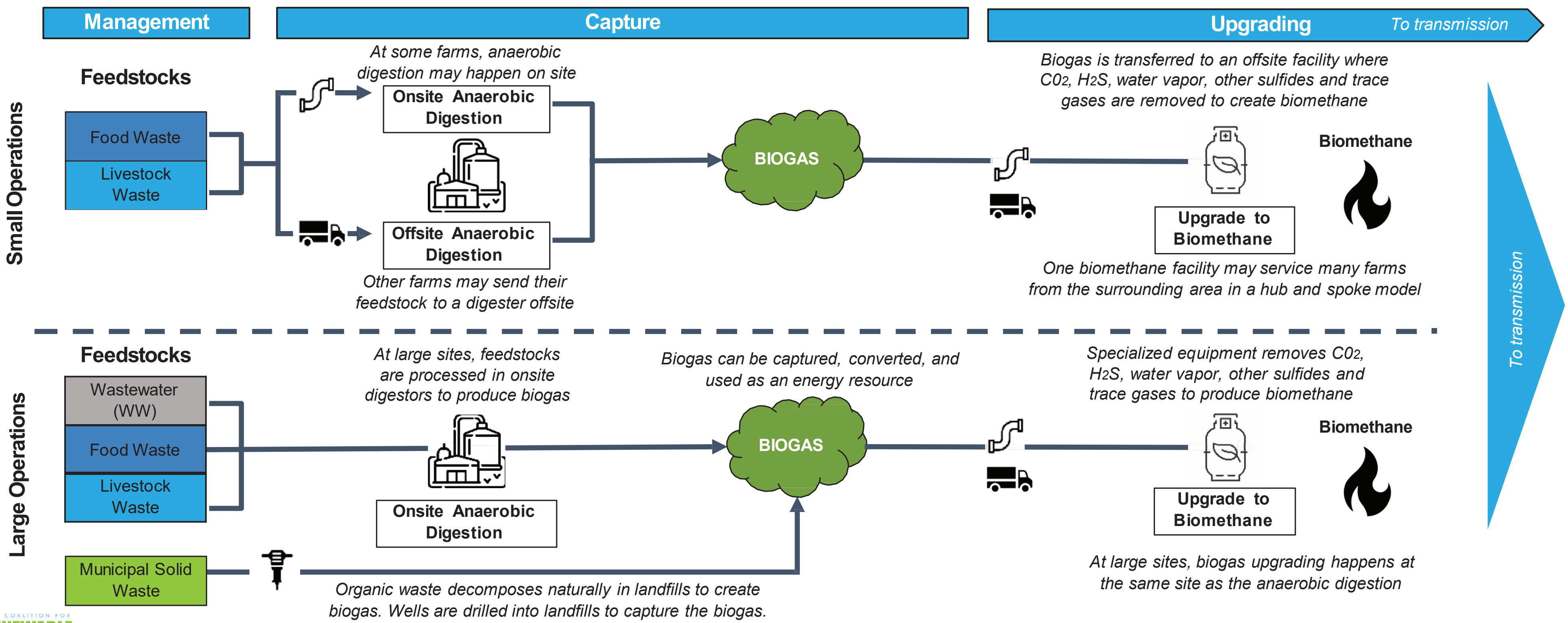


[9] Distribution types for vehicle fuel

[10] RNG Coalition data only included MMBtu volumes of Biomethane

2 RNG Value Chain: Diagram Illustrates Management, Capture and Refinement Phases of Anaerobic Digestion Value Chain

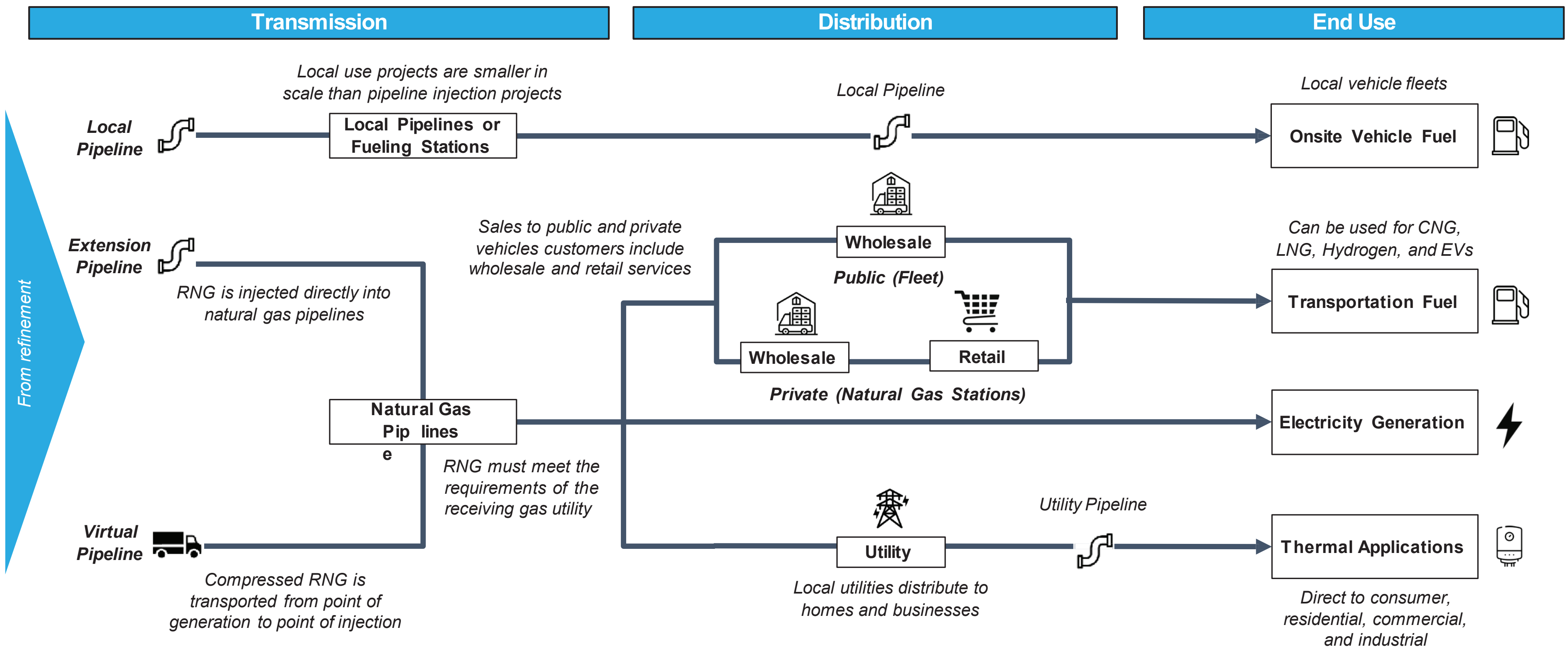
There are generally two streams for the management, capture, and refinement phases of the value chain. Many small operations must capture and refine their biogas offsite, resulting in a hub and spoke model for upgrading, while many large operations can capture and refine biogas onsite.



THE COALITION FOR RENEWABLE NATURAL GAS

2 RNG Value Chain: Diagram Illustrates Transmission, Distribution and End Use Phases of Anaerobic Digestion Value Chain

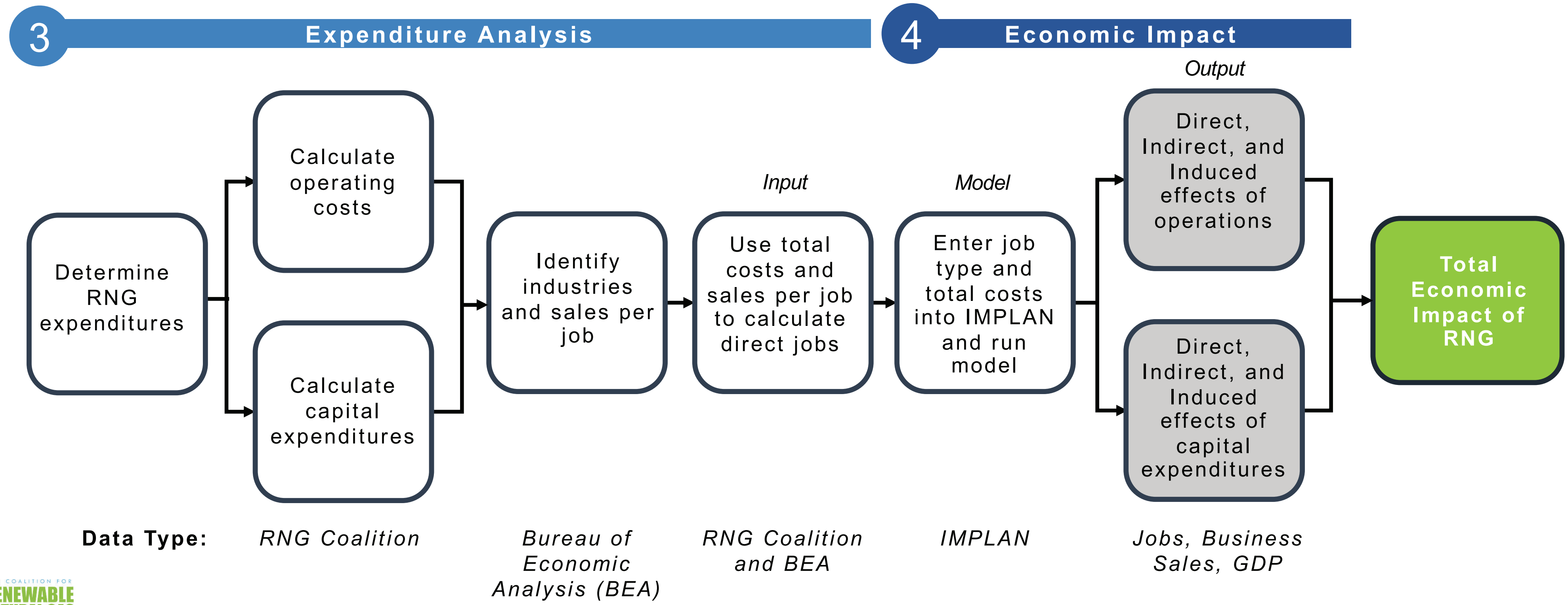
All biomethane, whether produces onsite or at a centralized upgrading location, is transmitted through one of three ways:



THE COALITION FOR RENEWABLE NATURAL GAS

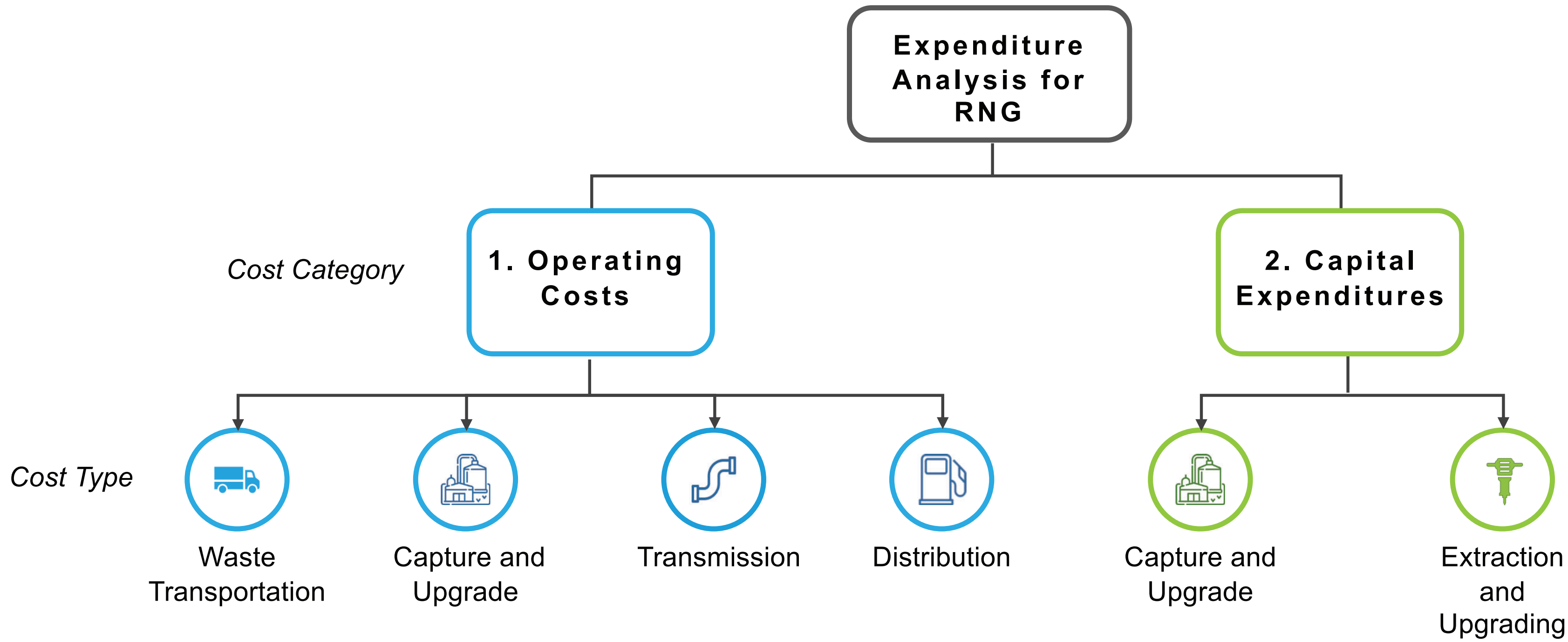
This Study Uses Input-Output Analysis Models to Analyze the Economic Impacts of RNG to the U.S. Economy in 2020

The study's primary focus is the economic impact of existing operating RNG plants and the building of new RNG plants on the U.S. economy. This analysis method is the most appropriate for this task. The diagram below illustrates the steps, outputs, and data types used to calculate the total current economic impact of RNG.



3 Expenditure Analysis: To Understand the Economic Impact of RNG, this Study First Identified its Two Major Cost Categories: 1) Operating Costs and 2) Capital Expenditures

Operating costs refer to the ongoing expenses incurred from the normal day-to-day of running of the waste transportation, capture and upgrade, transmission, and distribution phases of the value chain. Capital expenditures refers to the construction costs for the extraction, capture, or upgrade of biogas into RNG. Each cost category can be further broken into cost types as depicted below:



3 Expenditure Analysis: The First Step of the Expenditure Analysis is Understanding the Operating Costs of RNG

The first cost category for RNG is operating costs. Within operating costs, there are four types of costs that can be mapped onto the six phases of the value chain as depicted below. This diagram also provides information on the sources that were used to calculate costs for each cost type.

Operating Costs

Cost Type:	Waste Transportation	Capture and Upgrade	Transmission	Distribution
Value Chain Phase:	Management	Capture Refinement	Transmission	Distribution
Costs Source:	Tons of waste collected	1) MMBTU's of biomethane produced & 2) number of administrative jobs	Value of MMBTU's sold (market prices)	Value of MMBTU's sold (market prices)

3 Expenditure Analysis: Total Waste Transportation Costs are $13.5M

Waste collection is the first cost type within the operating costs category. Using data from the Argonne National Lab and the RNG Coalition's own data sources, transportation costs were estimated by multiplying the MMBTU's by tons of waste per MMBTU for the food waste and livestock feedstocks. Wastewater and municipal solid waste were not included in this calculation because waste collection would have occurred even without the biogas capture and upgrade process. The final transportation cost for the two feedstocks multiplies tons of waste by the cost per ton.

Waste Transportation Costs

(Transportation) = MMBTU (Trillion) × Tons of Waste per MMBTU[11] = Tons of Waste × Cost per Ton[12] = Transp. Costs

		MMBTU (Trillion)	Tons of Waste per MMBTU[11]	Tons of Waste	Cost per Ton[12]	Transp. Costs
Feedstock	**Food Waste**	5.6	0.48	2.7M	$1.65/ton	$4.5M
	Livestock	8.1	0.66	5.3M	$1.65/ton	$8.9M
	Total	13.7		8M		$13.5M

[11] Based on feedstock weighted average from Argonne National Labs database.
[12] Bioenergy Supply in Ireland 2015 – 2035. Sustainable Energy Authority of Ireland.

3 Expenditure Analysis: Capture and Upgrade Costs for RNG Have Two Components: 1) Costs Associated with Upgrading Biogas to RNG and 2) Associated Administrative Costs

RNG upgrading is the second cost type within the operating costs category. This slide outlines the steps taken to calculate both types of costs associated with RNG capture and upgrade.

RNG Capture & Upgrade

1. RNG Upgrading

- Identify ranges of average cost of RNG capture & upgrade per $/MMBTU
- Assign range of RNG costs to specific levels of Biomethane volume of MMBTU's
- Multiply the cost per MMBTU's times the volume for each facility

2. Administrative Costs

- Determine the number of RNG Facilities
- Add one administrative job per facility
- Sum the number of administrative jobs for all RNG facilities

3 Expenditure Analysis: The Average $/MMBTU Cost of Upgrading Biogas to RNG Ranges from $7 Per MMBTU up to $23 Per MMBTU

The first step of calculating RNG upgrading costs is determining the average $/MMBTU cost of upgrading biogas to RNG. Guidehouse identified ranges of the average cost of RNG capture & upgrade ($/MMBTU) using a variety of sources. Across all sources, costs ranged from $7 per MMBTU up to $23 per MMBTU. Guidehouse then assigned these costs ($/MMBTU) to the various volumes of biomethane detailed in the EPA report. The EPA Report provided the biogas flow output in SCFM associated with each $/MMBTU output amount. With the volume and average cost per MMBTU, Guidehouse estimated the overall RNG capture and upgrade costs for each facility, resulting in the RNG Cost/Volume Matrix.

Averaging the ranges of $/MMBTU from the reports resulted in an average cost range of $7.24 to $22.97

Sources

- World Resources Institute — Working Paper — The Production and Use of Renewable Natural Gas as a Climate Strategy in the United States
- EPA — United States Environmental Protection Agency
- A Report to the Washington State Legislature — December 2018 — Energy Program — Department of Commerce
- ICF — Study on the Use of Biofuels (Renewable Natural Gas) in the Greater Washington, D.C. Metropolitan Area — March 2020
- Guidehouse Proprietary Research

RNG Cost/Volume Matrix

Biogas Output Volume Range		Costs ($/MMBTU)	Operating Costs
SCF/Min	MMBTU/Year (Biomethane)[11]	Average	Average
50	13,600	$22.97	$312.4K
100	27,200	$17.30	$470.4K
200	54,400	$12.22	$664.8K
300	81,599	$12.22	$997.1K
475	129,199	$10.63	$1,373.4K
650	176,799	$9.04	$1,598.3K
1,125	305,998	$7.45	$2,279.7K
1,600	435,197	$7.24	$3,152.1K
2,300	625,595	$7.24	$4,531.1K

[11] Guidehouse used the Argonne National Lab Methodology to convert SCFM to MMBTU/Year: SCFD *.001 * 365 *.9 = MMBTU (Assumes 1000 BTU/SCFD, 90% run time, 365 days)

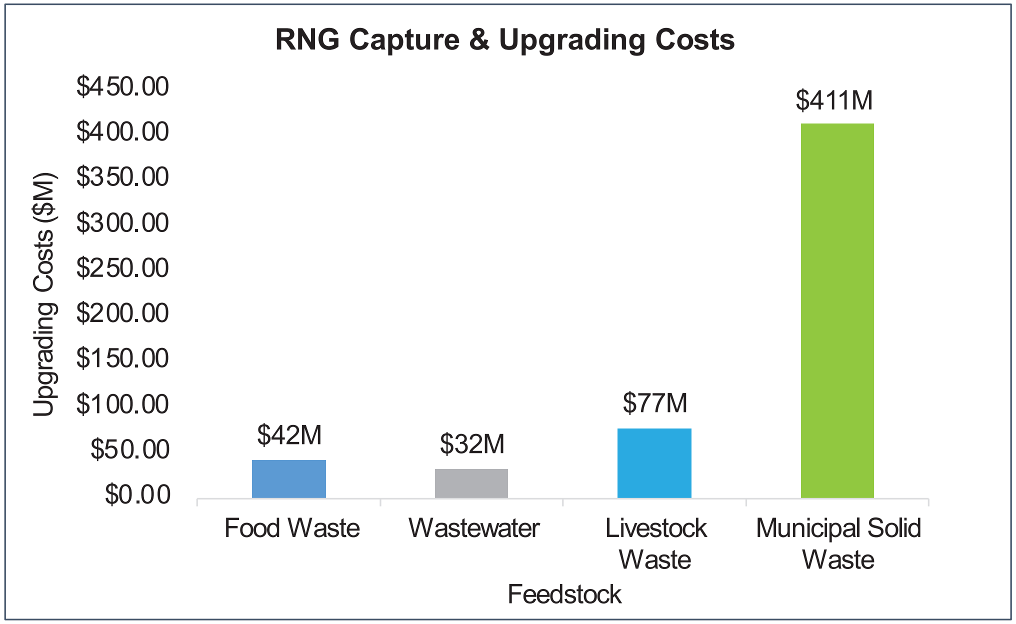
The Coalition for Renewable Natural Gas

3 Expenditure Analysis: Total Cost of RNG Upgrading is $561.8M

Guidehouse used the RNG Cost/Volume Matrix to estimate capture and upgrading costs by multiplying the MMBTU's produced times the $ per MMBTU for each facility and then aggregated across all feedstock types.[13] These values represent the costs of capturing the biogas and upgrading it into biomethane.

Total Cost of RNG Upgrading			
Feedstock(s)	**Volume (MMBTU/Year)**	**$ per MMBTU**	**Upgrading Costs**
Food Waste	5,692,689	$7.24 to $22.97	$42.2M
Wastewater	3,885,970		$32.3M
Livestock Waste	8,080,104		$76.5M
Municipal Solid Waste	56,474,133		$410.9M
Total	74,132,896		$561.8M

Municipal solid waste has the largest volume of RNG and therefore has the highest associated costs of $410.9 million. The total cost for upgrading RNG across all four feedstocks is $561.8 million.



[13] RNG costs were calculated using the sources outlined on slide 23. Volume amounts were provided by the RNG Coalition.

3 Expenditure Analysis: The Total Administrative Costs for RNG Capture and Upgrade are $12.6M

The second cost component for capture and upgrade is administrative jobs. These jobs include overseeing financial transactions, bookkeeping, transactions, and other needed support. To account for these activities, Guidehouse estimated 1 administrative job per facility based on guidance from the RNG Coalition. Assuming an average income of $72k per admin job (U.S. Bureau of Economic Analysis) Guidehouse then estimated the total administrative costs for each feedstock.

Total Administrative Costs					
Feedstock(s)	**Number of Facilities**	**Admin Jobs per Facility**	**Number of Admin Jobs**	**Sales Per Job[14]**	**Total Admin Costs**
Food waste	13	1	13	$71,642	$0.9M
Wastewater	23	1	23	$71,642	$1.6M
Livestock	68	1	68	$71,642	$4.9M
Municipal Solid Waste	72	1	72	$71,642	$5.2M
Total	176		176		$12.6M

[14] Average wage for office and administrative support (BEA)

3 Expenditure Analysis: Adding Upgrading Costs and Administrative Costs Together, the Total Cost for RNG Capture and Upgrade for All Four Feedstocks is $574.4M

This diagram shows RNG capture and upgrade costs combined. RNG upgrading costs are added to total administrative cost for reach feedstock to determine the total cost.

RNG Capture and Upgrade Costs

Input		Capture and Upgrade Costs		Total Cost
Feedstock(s)	**Volume (MMBTU/Year)**	**1 RNG Upgrading Costs**	**2 Total Admin Costs**	**Total Cost of Capture and Upgrade**
Food Waste	5,692,689	$42.2M	$0.9M	$43.1M
Wastewater	3,885,970	$32.3M	$1.6M	$33.9M
Livestock	8,080,104	$76.5M	$4.9M	$81.4M
Municipal Solid Waste	56,474,133	$410.9M	$5.2M	$416.1M
Total	74,132,896	$561.8M	$12.6M	$574.4M

3 Expenditure Analysis: The Total Cost of Transmission for RNG is $284M

Transmission is the third cost type within the operating costs category. Of the 74 trillion BTU's of RNG produced in 2021, 66 trillion (89%) are injected into the natural gas pipeline transmission system. Guidehouse used the U.S. Energy Information Administration (EIA) to find the natural gas pricing information for each of the final uses. Guidehouse then estimated the revenues for transmission of RNG using natural gas prices by category of final use and the volume (1,000 SCF) of RNG.

Transmission

Final Use	MMBTU's[15]	% of Total	Volume (1,000 SCF)	Natural Gas Price	Sales
Vehicle (Public)	32,841,043	50%	34,056,162	$4.01	$136M
Vehicle (Private)	26,503,298	40%	27,483,920	$4.01	$110M
Electricity	5,275,053	8%	5,470,230	$3.10	$17M
Thermal	1,318,763	2%	1,367,557	$8.90	$12M
Total	65,938,157	100%	68,377,869		$276M

Definitions

Vehicles (Public) Government Agency Fleets

Vehicles (Private) Retail Natural Gas Stations

[15] Adjusted for only pipeline volume

3 Expenditure Analysis: The Total Cost of Distribution (Wholesale and Retail) for RNG is $34.1M

Distribution is the fourth cost type within the operating costs category. Of the four final uses, sales to public and private vehicles customers include wholesale and retail services. In addition to the transmission sales, wholesale (4%) and retail (22%) markup percentages were applied to account for distribution services provided. Wholesale services cost an additional $9.9M and retail services cost an additional $24.2M to get RNG to it final users (e.g., public fleets and private natural gas retail stations).

Distribution

Final Use	Sales	Wholesale margin	Wholesale Sales	Retail Margin	Retail Sales	Total Sales
Vehicles (Public)	$136M	4%	$5.5M			$5.5M
Vehicles (Private)	$110M	4%	$4.4M	22%	$24.2M	$28.6M
Total	$246M		$9.9M		$24.2M	$34.1M

Definitions

Retail Margin The margin (e.g., mark-up) added to T&D (Transmission & Distribution) sales to reflect associated retail costs

Wholesale Margin The margin (e.g., mark-up) added to T&D sales to reflect associated wholesale costs

3 Expenditure Analysis: Total Direct Jobs from Operating RNG Projects

The total costs from the four major cost categories of the value chain can be used to estimate the direct number of jobs for RNG. Total costs are divided by the industry productivity ratios (e.g., sales per job) provided by the BEA. The graphic below illustrates this calculation as well as the industries associated with the direct job counts.

Value Chain	Direct Effects		Sales Per Job*		Direct Jobs	Industry
Waste Transportation	$13.5M (Transportation)	÷	$235,000 / job	=	57	*Waste management*
Capture and Upgrade	$561.8M (Upgrading)	÷	$722,000 / job	=	778	*Misc. Chemical Product Mfg*
	$12.6M (Admin)	÷	$71,642/ job	=	176	*Office Administrative Services*
Transmission	$275.7M (Transmission)	÷	$974,000 / job	=	283	*Natural Gas Distribution*
	$9.9M (Wholesale)	÷	$1,558,000 / job	=	6	*Wholesale – Petroleum*
Distribution	$24.2M (Retail)	÷	$115,000 / job	=	210	*Retail – Gasoline Stores*
	Total: $897.6M		**Total Direct Jobs**		**1,511**	

*Provided by Bureau of Economic Analysis

3 Expenditure Analysis: Understanding RNG Capital Expenditures

The second cost category for RNG is capital expenditures. There are two capital expenditures types: 1) Capture and Upgrade and 2) Extraction and Upgrade. These type of costs vary depending on the type of feedstock.

Capital Expenditures

Cost Type:

Capture & Upgrade

Extraction and Upgrade

Feedstock:

Food Waste
Livestock Waste
Wastewater

Food Waste, Livestock Waste, and Wastewater require an anaerobic digestor to capture biogas. The biogas is then conditioned and upgraded into biomethane.

MSW

MSW at landfills requires pumps and wells to capture (extract) the biogas created by decomposing organic waste. The biogas is then conditioned and upgraded into biomethane.

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3 Expenditure Analysis: Total Capital Expenditures is 1.03B

For food waste, livestock waste, and wastewater, capturing and converting biogas into biomethane requires a digester and upgrading facilities. For municipal solid waste, the landfill acts as the digester and collection pipes are installed in the landfill cap to extract the biogas that naturally is generated. Construction costs for each expenditure type were multiplied by the volume of gas for each feedstock.

Capture and Upgrade

Extraction and Upgrading

Feedstock	Expenditure Type	Expenditure ($)
Food Waste	Capture (Digester) and Upgrade	$129.2M
Livestock Waste	Capture (Digester) and Upgrade	$385.5M
Wastewater	Capture (Digester) and Upgrade	$101.6M
Municipal Solid Waste	Extraction and Upgrade	$413.6M
Total		$1.03B

Definitions

Capture and Upgrade — The cost of capture via anaerobic digester and biomethane upgrading

Extraction and Upgrade — The cost of capture via wells and biomethane upgrading

3 Expenditure Analysis: Using RNG Capital Expenditure Costs, We Can Estimate an Additional 5,576 of Direct Jobs

Total capital expenditures across all feedstocks amount to over $1.03B. To estimate the direct number of construction jobs, the costs are divided by the industry productivity ratios (e.g., sales per job) provided by the BEA (within IMPLAN). The graphic below illustrates this calculation as well as the industries associated with the direct job counts. Total direction construction jobs amount to 5,576 assuming one year of construction.

	Direct Effects		Sales Per Job*		Direct Jobs	Industry
Capture and Upgrade	$616M (Capture & Upgrading)	÷	$158,608 / job	=	5,090	*Construction (non-residential)*
Extraction and Upgrade	$206.8M (Extraction) $206.8M (Upgrading)	÷	$271,703 / job	=	486	*Drilling Oil & Gas well*
			Total Direct Jobs		**5,576**	
	Total: $1.03B					

*Provided by Bureau of Economic Analysis

3

Expenditure Analysis: Most Jobs Associated with RNG are High Paying [16]

Below are the average mean salaries for the industries associated with each cost category.[17]

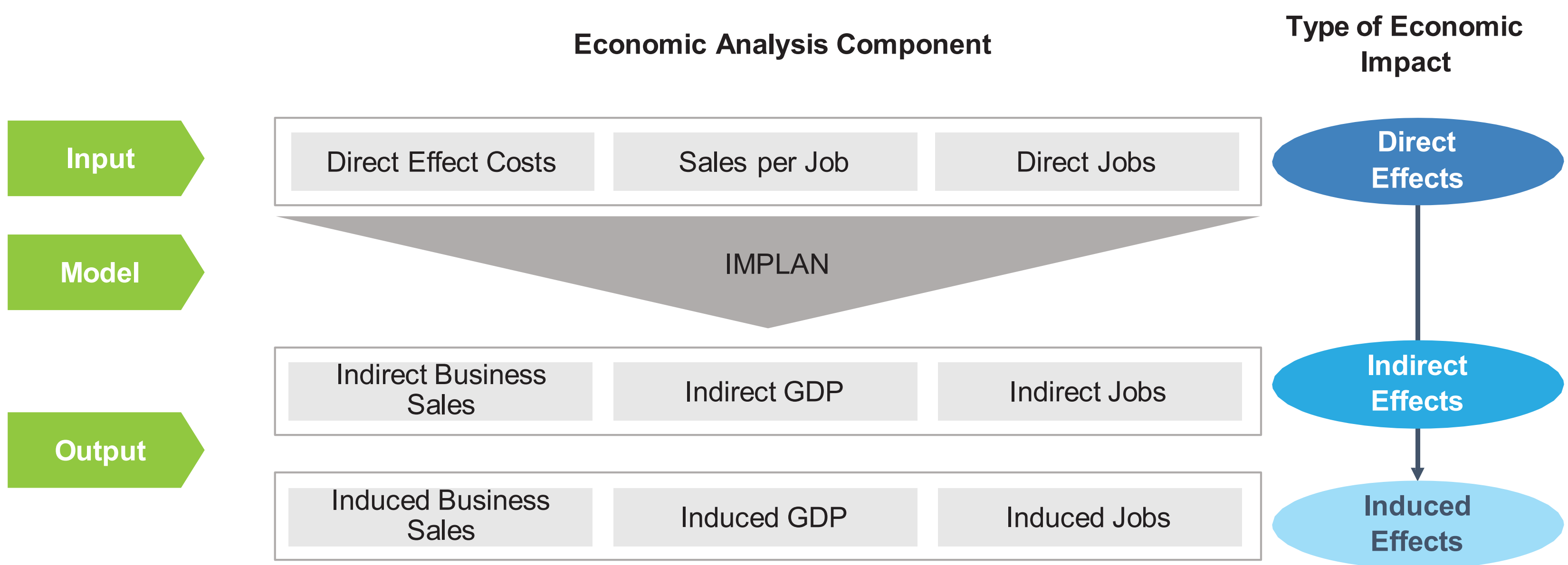
Average Wages by Cost Category

Waste Transportation	Capture and Upgrade *Operations*	Transmission	Distribution	Capture and Upgrade *Capital Expenditures*	Extraction and Upgrade
$43,290	$101,900 (Upgrading) $69,000 (Administrative)	$87,470	$63,410 (Wholesale) $67,160 (Retail)	$51,200	$58,460

[16] Based on Average Income of $36,000/yr reported by Federal Reserve of St. Louis
[17] Wages come from the Quarterly Census of Employment and Wages published by the U.S. Bureau of Labor Statistics

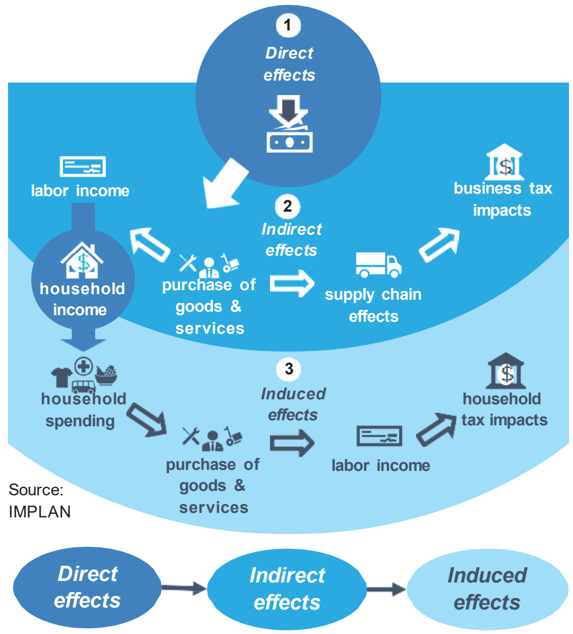
4 Economic Impact: The Modeling Tool IMPLAN Calculates Direct, Indirect, and Induced Effects of RNG

The expenditures analysis produced three values for the operating costs and the capital expenditures of RNG – RNG Business Costs, Average Sales per Job, and the Number of Direct Jobs. This information is used as inputs in the economic modeling tool IMPLAN to calculate indirect and induced effects. This modeling indicates how much additional economic activity is supported by supplier purchases (indirect) and employee spending (induced) beyond the initial RNG capture and upgrade.



4 Economic Impact: Understanding Direct, Indirect, and Induced Effects of RNG

Input-output models estimate how money moves through the economy based on supply chain relationships; the effects are categorized into direct, indirect, and induced.



Source: IMPLAN

Type of impact	RNG Example
Direct Effects resulting from direct spending	Spending within the RNG value chain
Indirect Effects resulting from industries purchasing from each other	Spending on materials, components, and services
Induced Effects resulting from household spending of labor income	Spending on housing, healthcare, transportation, food, retail and entertainment by workers

Metrics used in this report

Business Sales	Sales of goods and services across the supply chain.
Gross Domestic Product (GDP)	The sum of the value added or 'premium' created from each stage of the supply chain
Jobs	The number of jobs created from the supply chain activity stimulated through expenditure

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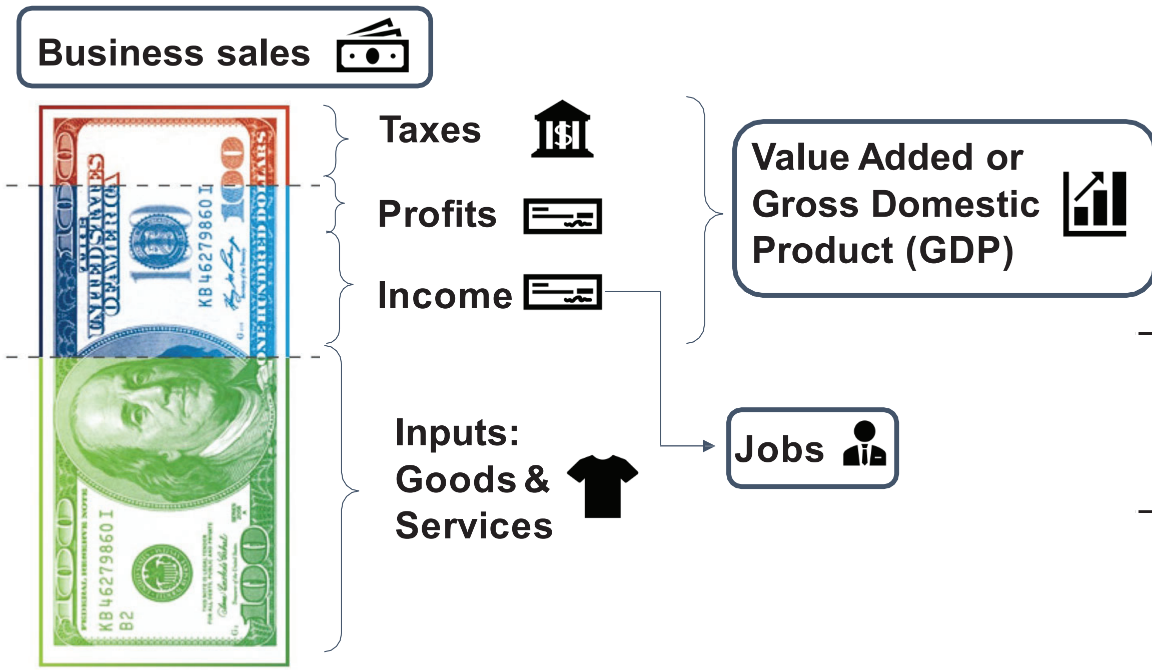
4 Economic Impact: Economic Impact Measures Reflect Changes in the Economy but are Subsets of One Another, Meaning They Should Not be Added Together



Taxes

Profits

\+ Income

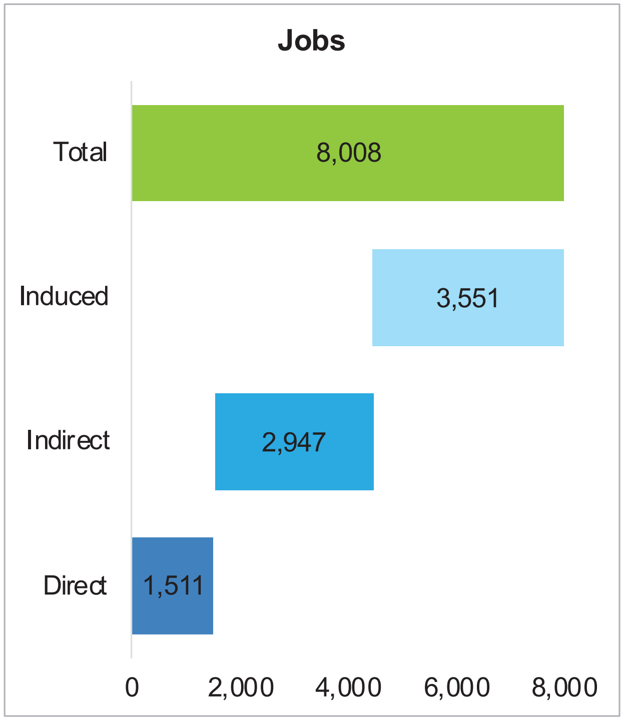
= Value Added (GDP)

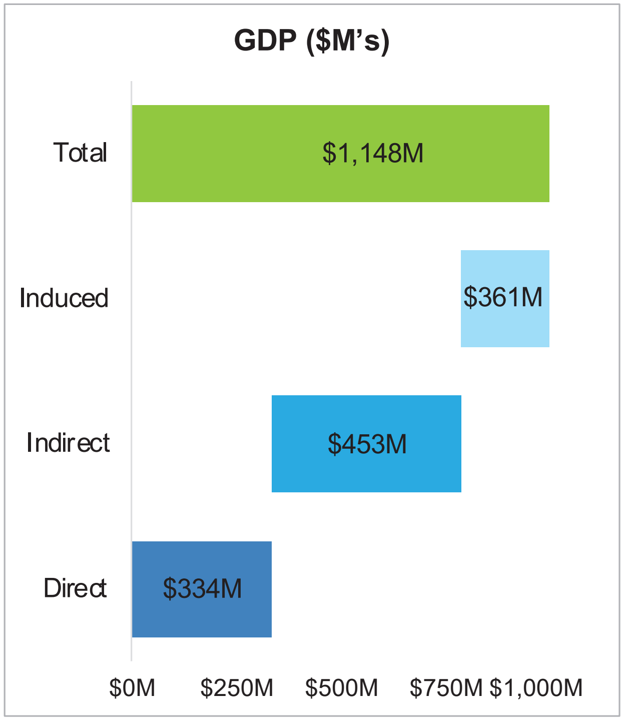
\+ Inputs

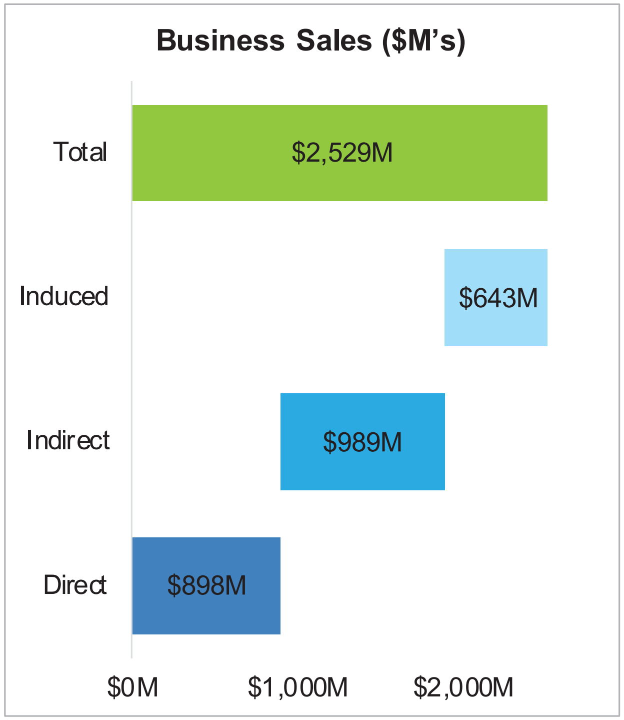
= Business Sales

4 Economic Impact (Existing Plants): RNG Operations Create 8,008 Jobs, Support $1.1B in GDP and Over $2.5B in Sales in 2021

Based on the spending for RNG operations, the direct, indirect, and induced economic impacts are presented below. Over 1,500 direct jobs are attributed to activities within the RNG value chain with a total of 8,008 jobs. In 2021, RNG supports a total of $1.1B in GDP and over $2.5B in business sales.

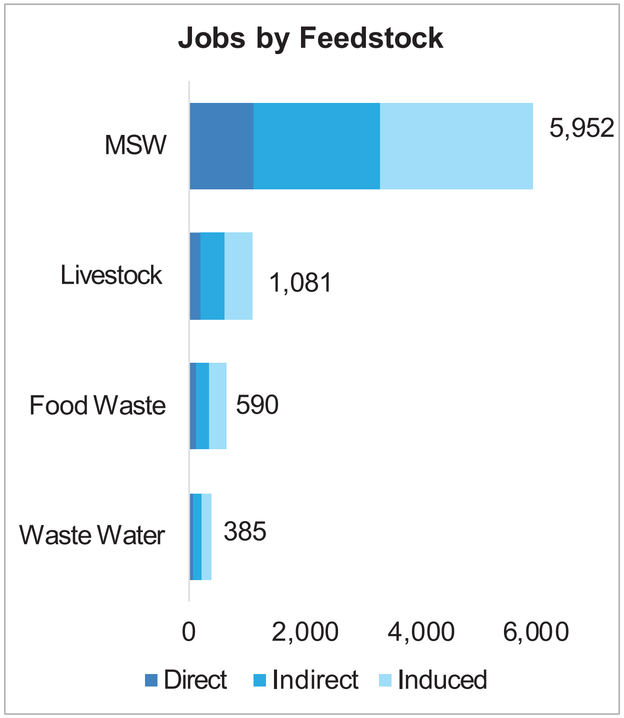


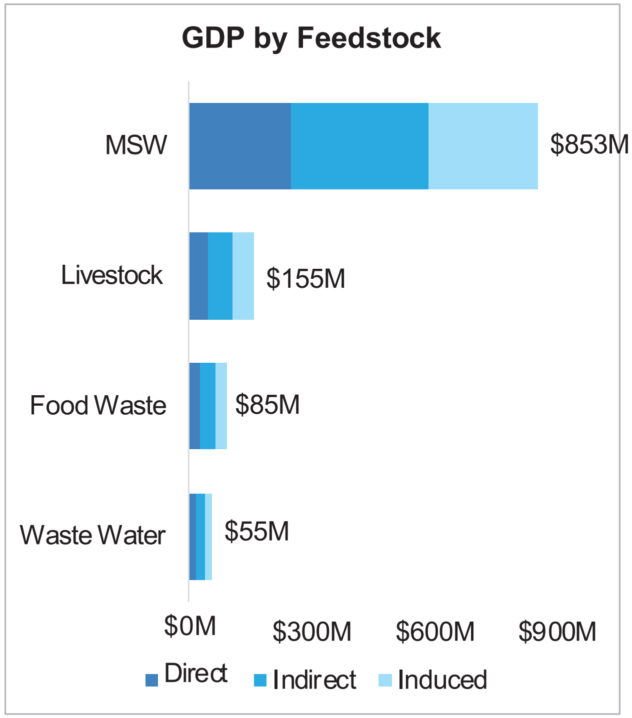


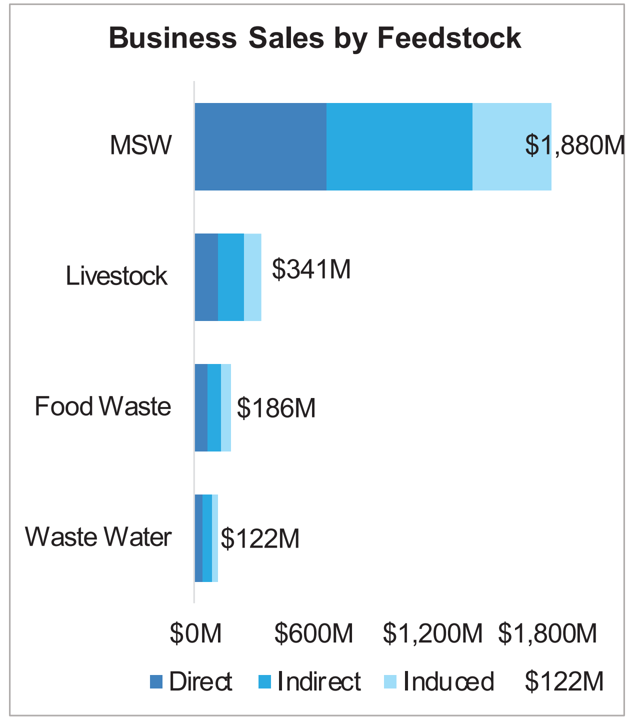


4 Economic Impact (Existing Plants): Municipal Solid Waste Has the Greatest Economic Impact from Operations of the Four Feedstocks, Accounting for 5,952 Jobs, Supporting $853M in GDP and $1,880M in Sales

The economic impacts by feedstock type are presented below with most impacts supported by RNG produced from municipal solid waste (MSW) with nearly 6,000 jobs. The remaining 27% of all jobs are spread across the other three feedstocks.

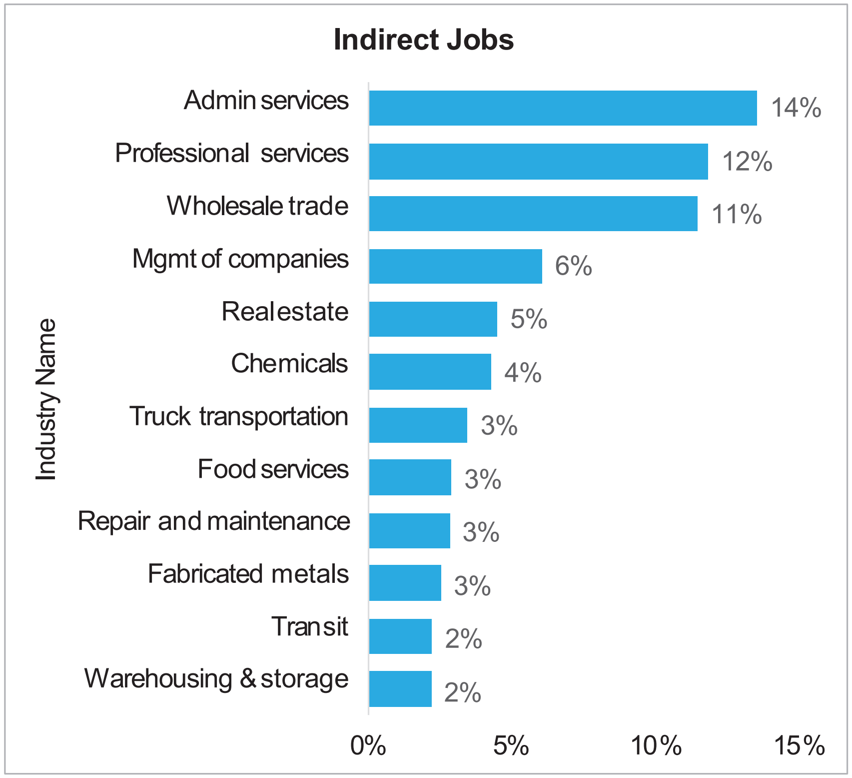


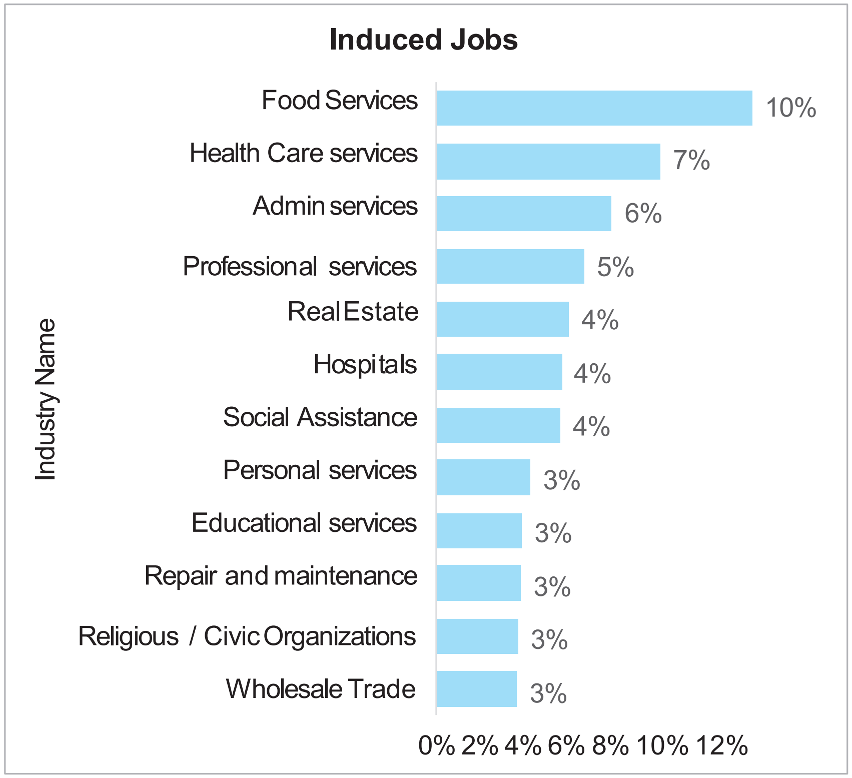




4 Economic Impact (Existing Plants): RNG Supports Jobs Across a Spectrum of Industries

The industries with the most indirect jobs are administrative services, professional services, and wholesale trade. The industries with the most induced jobs are food services, health care services, and administrative services.





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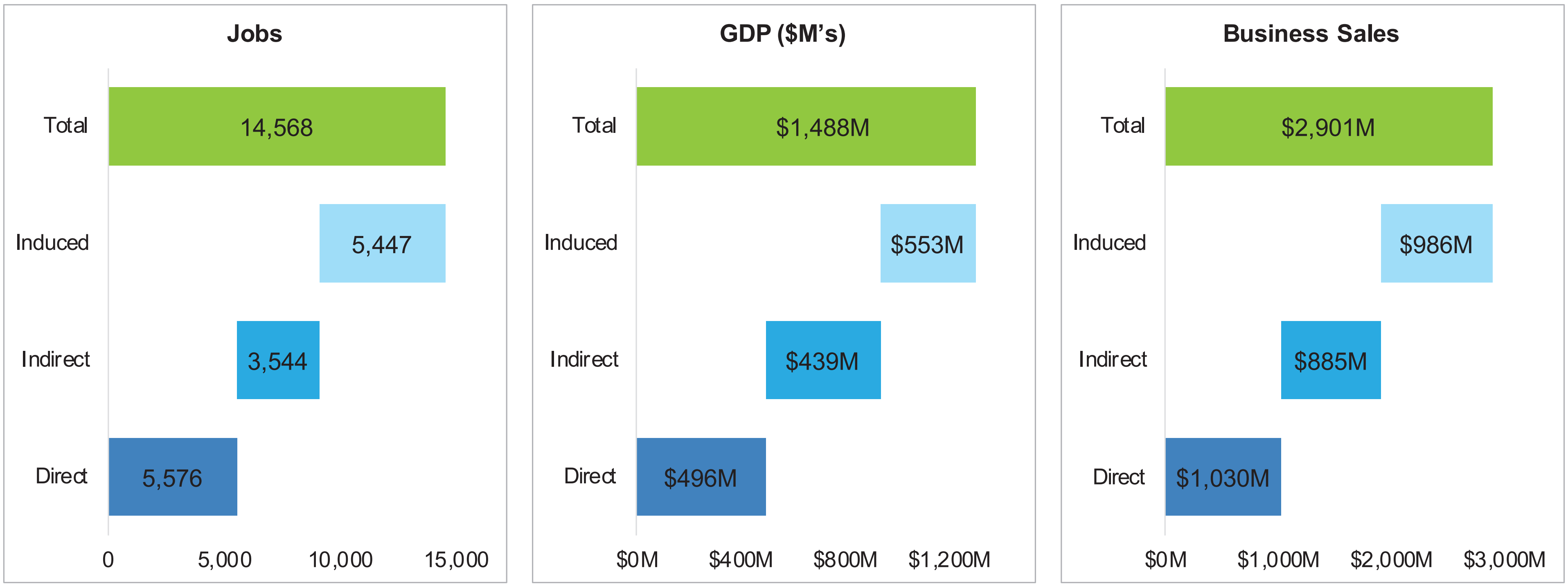
4 Economic Impact (Under Construction): RNG Capital Expenditures Create a Total of 14,568 Jobs and Support a Total of $1.5B in GDP and Over $2.9B in Sales

Based on the spending for RNG Capital expenditures, the direct, indirect, and induced economic impacts are presented below in terms of jobs, GDP, and Business Sales.



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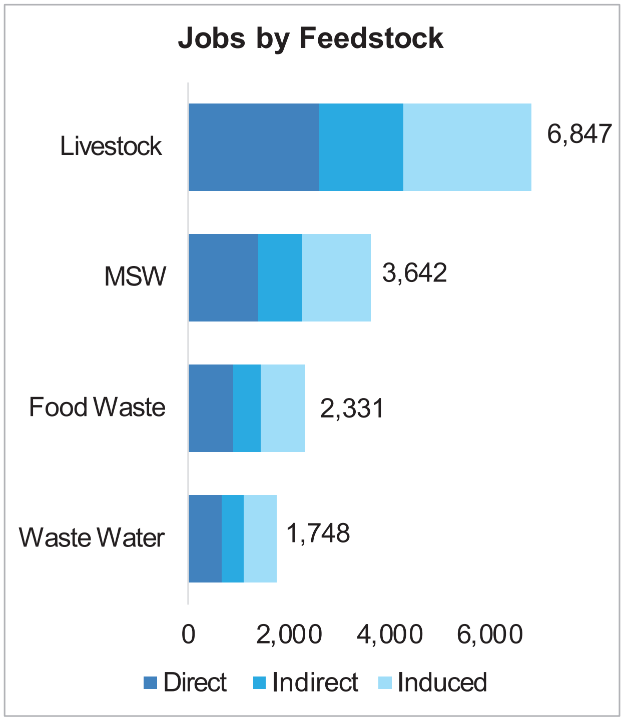
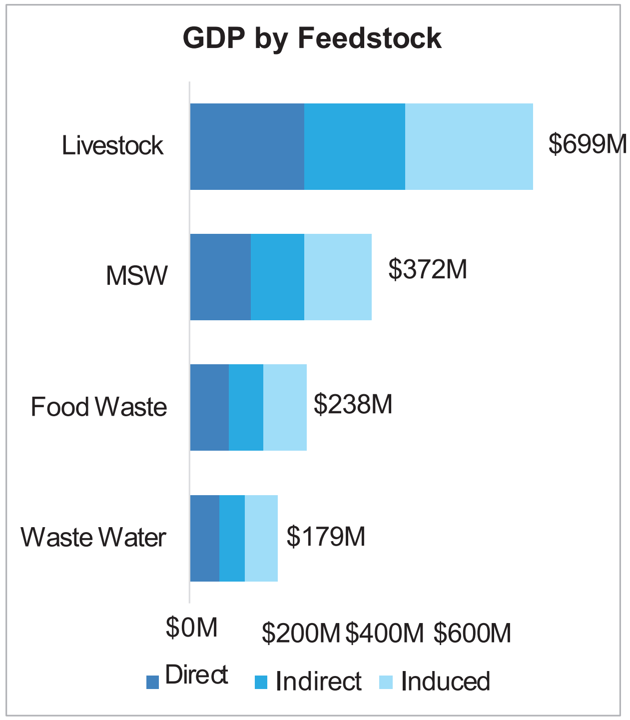
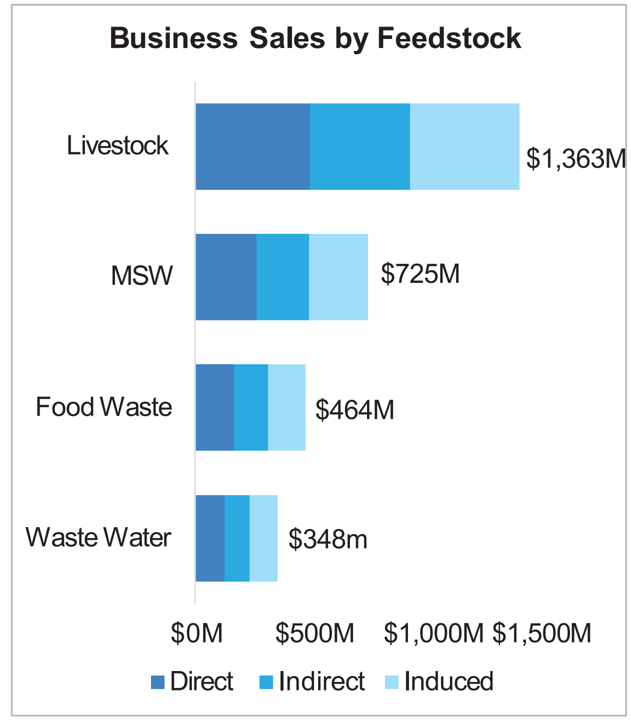
4 Economic Impact (Under Construction): Livestock Waste Has the Greatest Economic Impact from Capital Expenditures of the Four Feedstocks, Accounting for 6,847 Jobs and Supporting $699M in GDP and $1,363M in Sales

The economic impacts by feedstock type are presented below with most impacts supported by RNG produced from Livestock Waste with 6,847 jobs. The remaining 28% of all jobs are spread across the other three feedstocks.



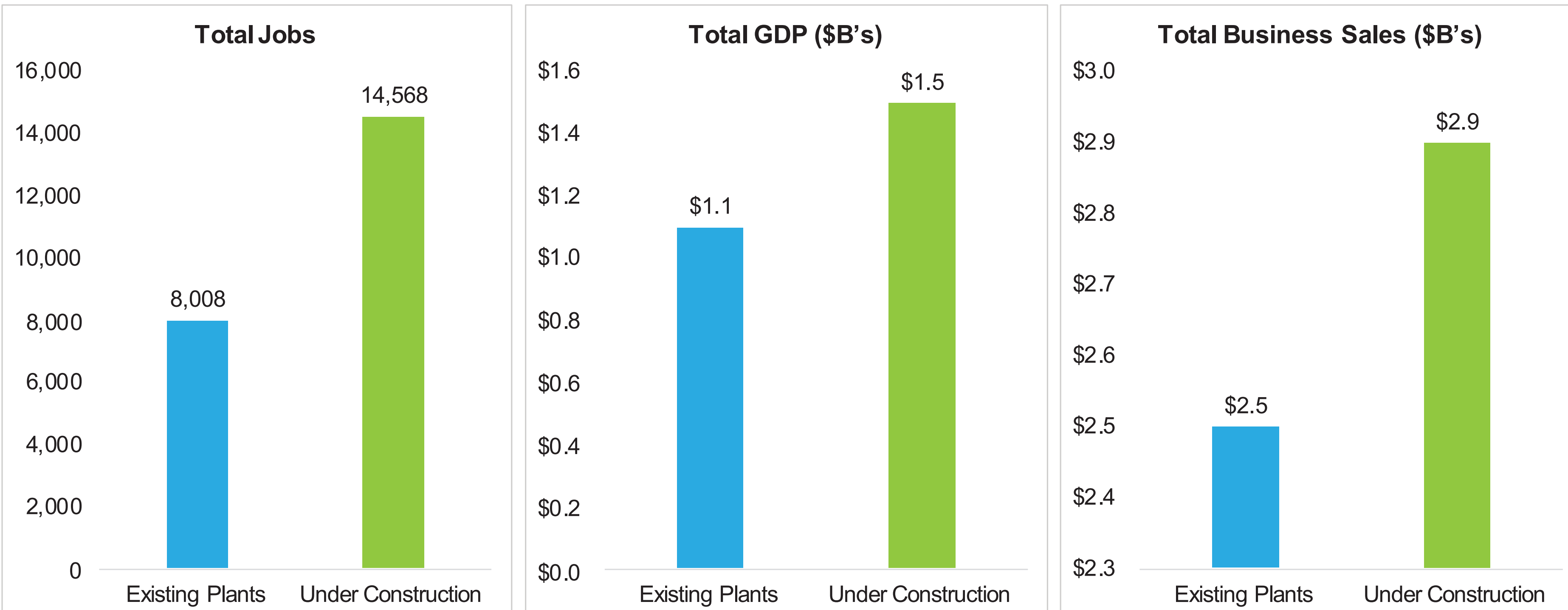




4

Economic Impact: RNG Contribution in Jobs, GDP and Total Sales

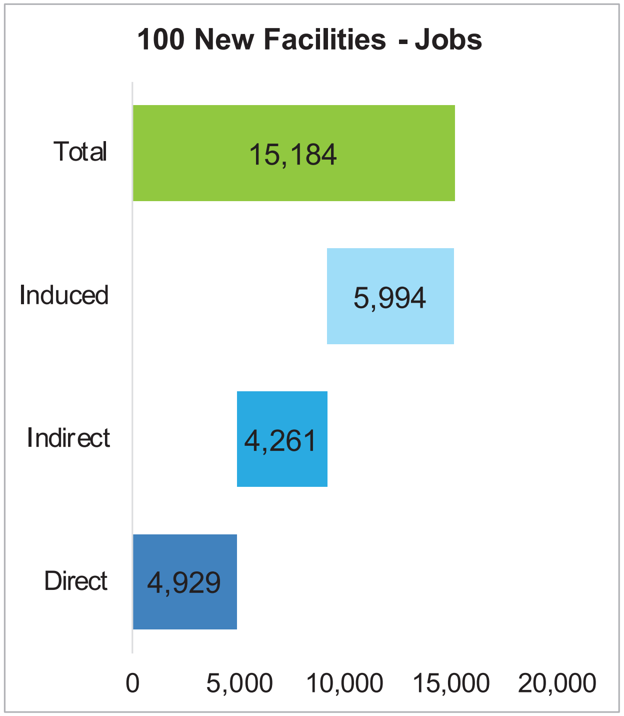
These numbers include the direct, indirect, and induced effects of RNG. Operations jobs are ongoing at completed RNG facilities; capital expenditure or construction jobs last approximately one year and are renewed as additional projects are developed in this growing industry.

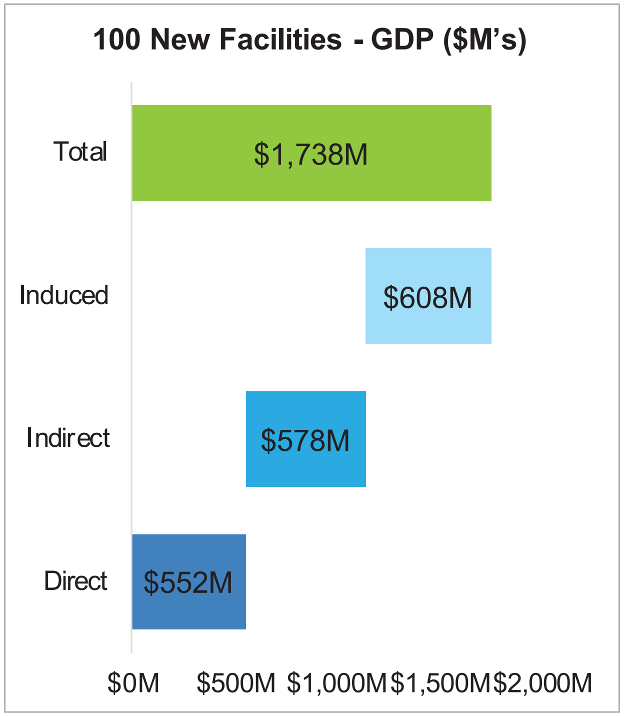


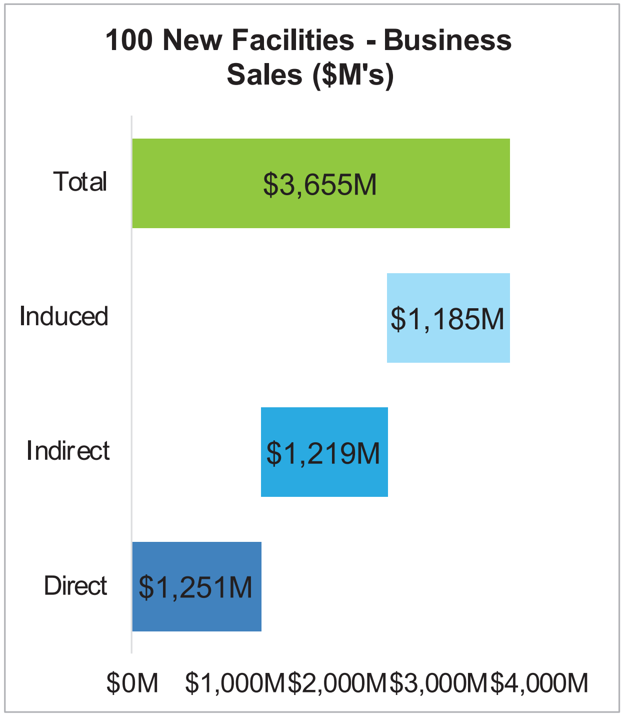
4

Economic Impact of 100 New RNG Facilities

Over 4,929 direct jobs could be attributed the construction and operations and maintenance of 100 new RNG facilities with a total of 15,184 jobs. 100 new facilities could also support a total of $1.1B in GDP and over $2.5B in business sales.[18]





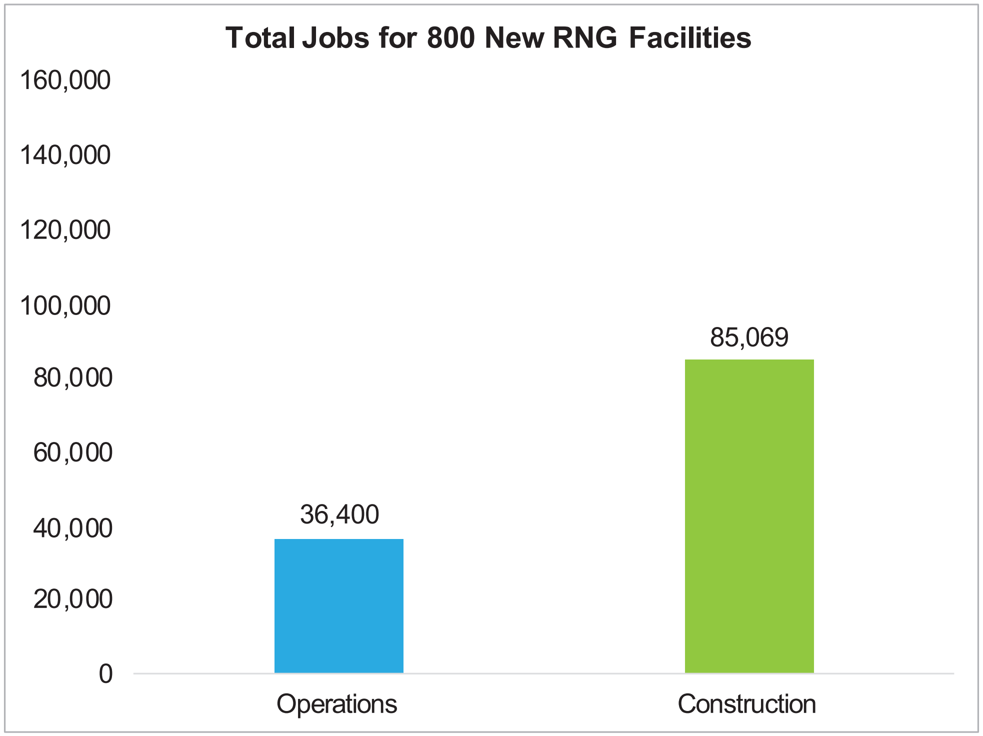


[18] Calculations are based on the average jobs per facility for each feedstock in 2021. Operations jobs ratios were calculated using current operational facilities in 2021 while construction job ratios were calculated using the number of facilities currently under construction in 2021. These numbers were provided by the RNG Coalition.

4

Economic Impact: Projected Jobs from RNG Industry Growth by 2030

An additional 800 new facilities, the growth target for 2030 under RNG Coalition's SMART initiative, would create an estimated 121,469 total jobs.[19]

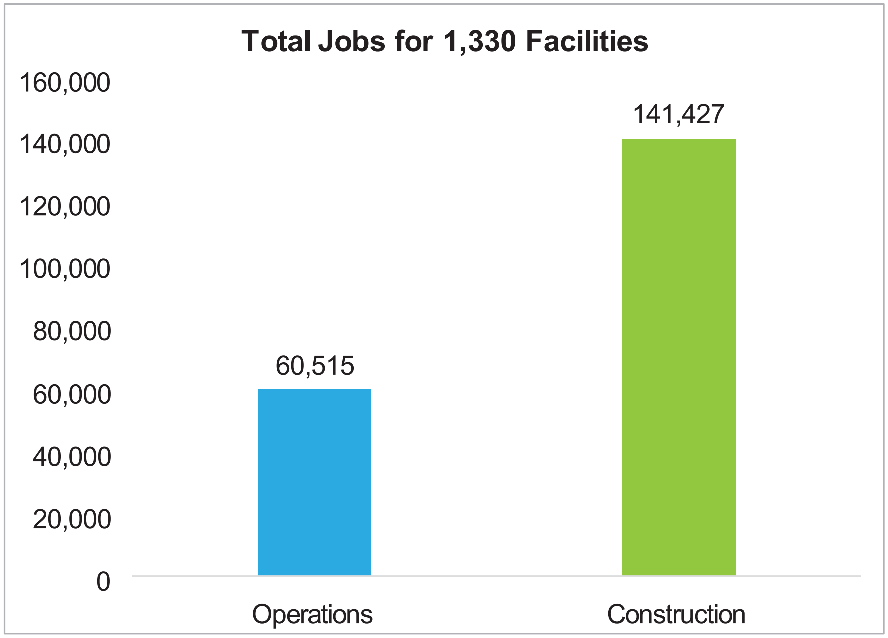


[19] Calculations are based on the average jobs per facility for each feedstock in 2021. Operations jobs ratios were calculated using current operation facilities in 2021 while construction job ratios were calculated using the number of facilities currently under construction in 2021. These numbers were provided by RNG Coalition and are based on the Sustainable Methane Abatement and Recycling Timeline (SMART Initiative) Goals. These calculations do not take into consideration yearly economic changes that might affect RNG job numbers.

4

Economic Impact: RNG Jobs Growth if U.S. Follows a Net Zero Pathway

According to the International Energy Agency's (IEA) Net Zero by 2050 scenario*, if the world follows a pathway to prevent the worst impacts of climate change, global RNG volume could increase sevenfold in the next decade. In the US, this could result in 1,330 RNG facilities. An additional 1,330 facilities would create an estimated 201,578 jobs.[20]

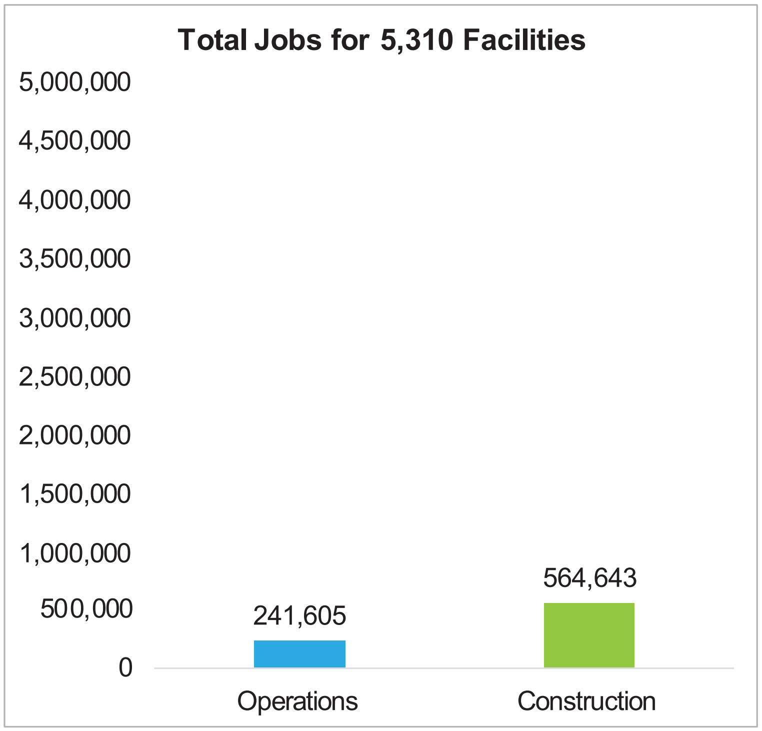


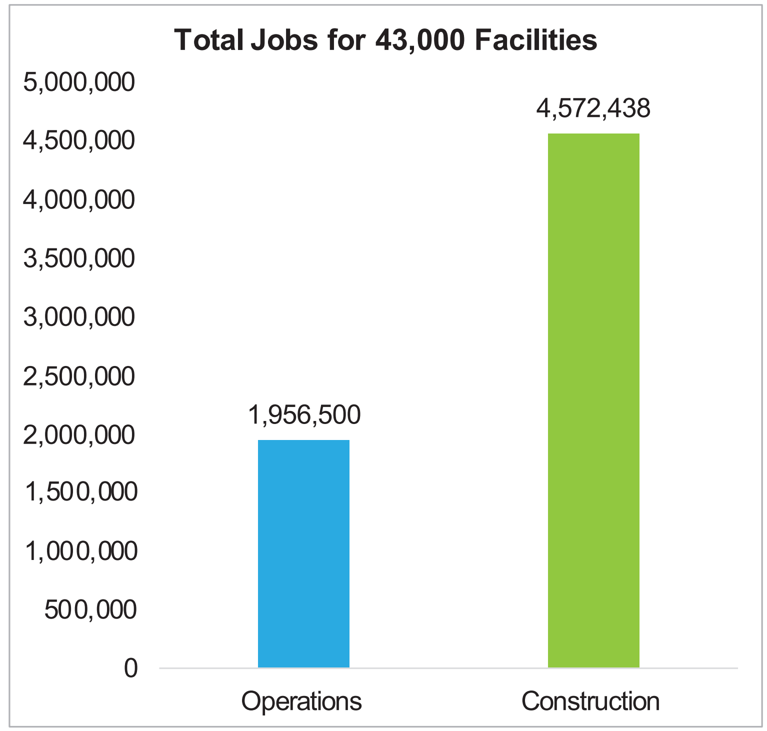
[20] Calculations are based on the average jobs per facility for each feedstock in 2021. Operations jobs ratios were calculated using current operation facilities in 2021 while construction job ratios were calculated using the number of facilities currently under construction in 2021. These numbers were provided by RNG Coalition. These calculations do not take into consideration yearly economic changes that might affect RNG job numbers.

* Source: International Energy Agency, Net Zero by 2050 A Roadmap for the Global Energy Sector (2021)

4 Economic Impact: RNG Industry Jobs Growth by 2050

The IEA Net Zero by 2050 scenario estimates 5,310 new facilities by 2050, which could create an estimated 806,248 jobs. If, however, RNG reaches total buildout under the SMART Initiative, this could result in 43,000 facilities by 2050, which would create an estimate 6,528,938 jobs.[21]





[21] Calculations are based on the average jobs per facility for each feedstock in 2021. Operations jobs ratios were calculated using current operation facilities in 2021 while construction job ratios were calculated using the number of facilities currently under construction in 2021. These numbers were provided by the RNG Coalition. This calculations do not take into consideration yearly economic changes that might affect RNG job numbers.

Presson Exhibit No. 6
Docket No. E-7, Sub 1264

THE COALITION FOR RENEWABLE NATURAL GAS

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EXHIBIT NO. 7

DOCKET NO. E-7, SUB 1264

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Presson Exhibit No. 8
Docket No. E-7, Sub 1264

DC Meters – Field Testing @ McAlpine Microgrid

Tom Fenimore, PE
March 31, 2021

ANSI C12.32 – DC Metering Standard – Congrats David and Team!

Presson Exhibit No. 8
Docket No. E-7, Sub 1264

NEMA (ASC C12) (National Electrical Manufacturers Association)
1300 North 17th Street, Suite 900, Rosslyn, VA 22209 p: (703) 477-9997 w: www.nema.org

New Standard

ANSI C12.32-2021, Electricity Meters for the Measurement of DC Energy (new standard) Final Action Date: 3/4/2021

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An open industry association
Leader in promoting the greater use of DC and hybrid AC/DC microgrids & power systems

DC Metering Technical Standards Committee

Chairman David Lawrence – Duke Energy

National Standards Institute recorded the final action of its C12 standards committee to approve the standard in its weekly pul
ry, Volume 52 Issue 11, wherein it simply states: "New Standard ANSI C12.32-2021, Electricity Meters for the Measurement o
ate: 3/4/2021." Committee Chairman Tom Nelson of NIST and Committee Secretary Paul Orr of NEMA oversaw months of tir
group led by Duke Energy's Charlie Ploeger who finalized the document and shepherded it through ANSI's formal vetting and a
cted to be published and available from ANSI within ninety (90) days of the action date.

:

ease by ANSI.

DC Metering Requirements – Some Background

- DC Coupled Solar/Storage systems continue to proliferate
- Existing PPA's are typically setup for AC metered energy and power
- Revisions to existing PPA's and new PPA's can value Solar and Storage energy differently
- The only way to separate Solar and Storage energy in a DC coupled system is with DC Meters

- Currently no U.S. Utility has a Revenue Certified DC Meter!

- The need to understand DC metering, it's installation requirements and billing system integration is here, now!

McAlpine Microgrid – DC Meter Locations

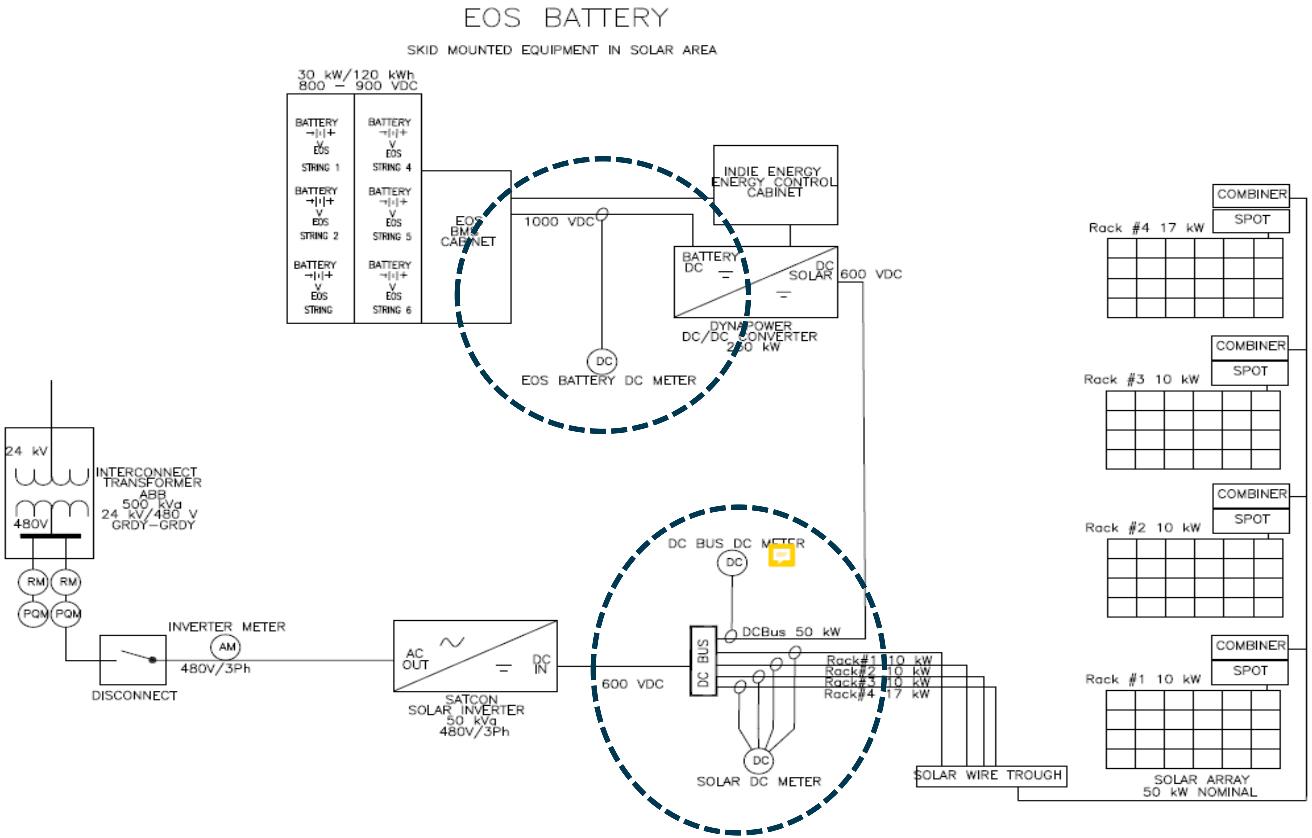
Presson Exhibit No. 8
Docket No. E-7, Sub 1264

DC Bus and Battery

- Meters @ DC/DC Converter
- 2 Meters
- 1 Acculink gateway

Solar Strings

- Meters @ Satcon Inverter
- 4 Meters
- 1 Acculink gateway



McAlpine Microgrid – DC Meter Network

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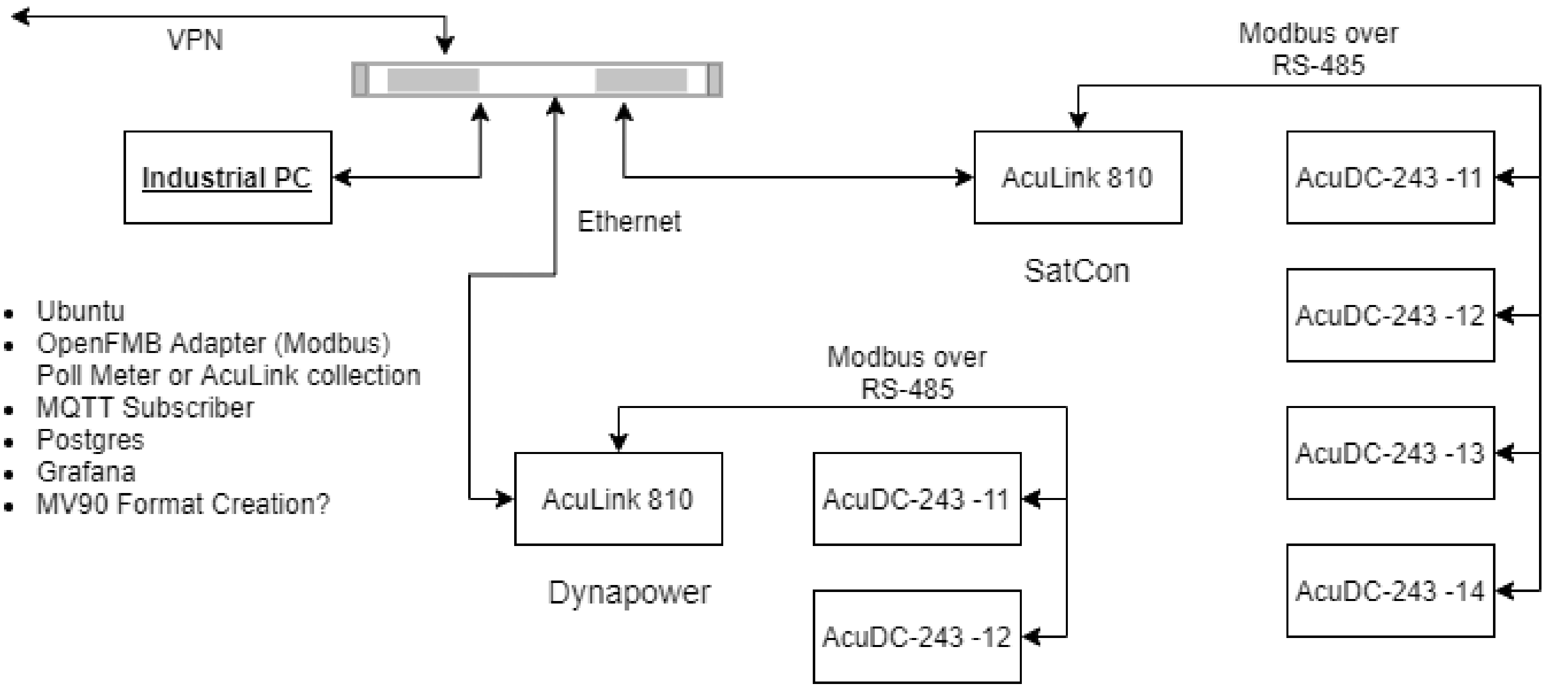

- Ubuntu
- OpenFMB Adapter (Modbus) Poll Meter or AcuLink collection
- MQTT Subscriber
- Postgres
- Grafana
- MV90 Format Creation?

McAlpine Microgrid – Solar String Meters

Accuenergy Equipment

Meters: Model 243

Acculink Gateway: Model 810

DC Shunts: 100A

McAlpine Microgrid – Battery and DC Bus Meters

Accuenergy Equipment

Meters: Model 243

Acculink Gateway: Model 810

DC Shunts: 100 A - Battery
200 A - DC Bus

100 Amp

200 Amp

McAlpine Microgrid – Grafana Screenshots of meter data

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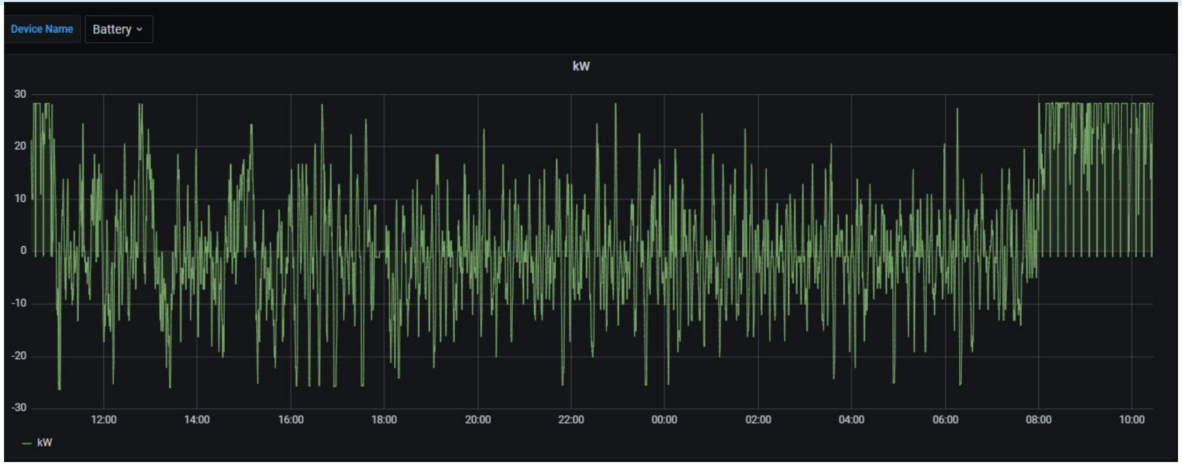

Frequency response testing of EOS battery

Battery Data

- 24 Hrs @ 1 second

DC Bus Data

- 3 Hrs @ 1 second

McAlpine Microgrid – DC Meter Testing Status As of 3/26/2021

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- DC meters installed and operational
- SEL 3355 Industrial Computer installed in control house
- Existing site network utilized for IP comms
- Palo Alto Firewall & Cell modem for access with VPN

- AccuLink Mosquitto MQTT publishes log data @ 1 second rate in JSON format
- SEL3355 subscribes to AccuLink published traffic
  - Stores JSON formatted data into the Postgres database
  - Data is available for viewing with Grafana

- Ready for Billing System Integration

McAlpine Microgrid – DC Meter Testing Observations

- DC meters are more like Transducers & SCADA devices than Utility Meters
- DC shunts for Amps measuring have distance limitations (mVolt output)
- DC Voltage cabling will be at system bus voltage 600V/1000v/1500V etc.
- Knowledge of RS485 and TCP/IP necessary to work with meters
- Manufacturers are few:
  - Accuenergy
  - Measurelogic
  - Sensus

- Manufacturers need to integrate functionality into a single device and eliminate gateway(s).
- Manufacturers need to upgrade to Utility Grade housings/terminals etc.

Questions?

Tom Fenimore, PE

704-608-2389

tom.fenimore@duke-energy.com

Presson Exhibit No. 8
Docket No. E-7, Sub 1264

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EXHIBIT NOS. 9 - 14

DOCKET NO. E-7, SUB 1264

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Statement of Work

This **STATEMENT OF WORK (SOW or Statement of Work)** No. 32 is made effective as of December 1, 2021 (the "**SOW Effective Date**") and is issued pursuant to the Master Research Agreement, effective August 1, 2011, between **THE UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE ("UNCC") and DUKE ENERGY BUSINESS SERVICES LLC ("Duke Energy").** The specific terms which will apply to this request are described below:

I. SERVICES DESCRIPTION AND OBJECTIVES:

Project Title: Power Flow Analysis to Improve Integrated Volt/Var Control (IVVC) and Energy Efficiency Programs

Integrated Volt/Var Control (IVVC) and other energy efficiency and optimization programs rely on power flow results to assure that the control actions are appropriate; therefore, accurate power flow results are critical to operate a distribution system safely and efficiently. Unfortunately, power flow results are not always accurate, and existing methods of analysis provide very limited information about the cause of the inaccuracy. Moreover, with the current Distribution Management System (DMS) it has been observed that the performance of the power flow deteriorates considerably when there are Distributed Energy Resources (DER) on a distribution system. This project will address these issues by using data analytics to parse through data and identify factors that are most relevant to the quality of a power flow solution. The analysis will inform and guide modeling changes to be made to improve power flow performance. This research will directly benefit IVVC programs and enable utilities to operate IVVC more effectively on systems with high levels of DERs.

The proposed project is based on and extends upon preliminary results obtained in a comparative analysis between the DMS and other power flow tools performed in CAPER projects PU-01 and EHP-08-PU. In those projects, differences in the modeling and in the power flow performance between the software tools were identified, and important criteria for power flow performance were identified by parsing through an initial dataset of select DMS savecases. This project will have the following main aspects and objectives:

1. Preliminary observations made in the initial dataset will be tested on a larger and more varied dataset and using outputs obtained with the new version of the DMS software. Voltage mismatch will be included as a criterion for power flow performance. Based on the results of the analysis, the research team will develop recommendations of modeling changes to be made to improve power flow performance. The recommended changes will be implemented, and the obtained updated results will be analyzed.
2. A detailed analysis of the results obtained from feeders that are not consistent in their power flow performance (i.e. the 'flip-flop' cases) will be carried out. The most important characteristics that separate the converging and non-converging savecases will be

identified and will inform recommendations of modeling changes. The recommended changes will be implemented, and the updated results will be further analyzed.

3. Both parts of the project (1 and 2 above) will use results obtained with the new version of the DMS software, which includes a model for DERs. The research team will analyze and compare results to check whether the inclusion of the DER model improves power flow solutions and will look for aspects of the DER model (and the DMS model as a whole) that could be modified to improve power flow performance.

II. DELIVERABLES:

A report describing methods and findings from each of the three aspects of the project will be submitted as project deliverable. Specifically, the report will include:

- The methods developed for assessing the performance of the DMS power flow tool;
- New models and methods that will improve the performance of the DMS power flow tool;
- Observations and recommendations made specifically for feeders with high DER penetration.

The developed data analytics tool, or the requirements and configuration steps to develop it, will be provided as well.

III. MAJOR ACTIVITIES AND TIMELINE:

Start Date: 12/20/2021 **Completion date**: 6/20/2023

Project Phase 1 (1/1/2022 – 12/31/2022): Parameters identified in the analysis of the initial dataset (CAPER projects PU-01 and EHP-08-PU) will be tested on a larger and more varied dataset provided by Duke Energy, and with the use of the new version of the DMS software. Recommendations to improve DMS power flow performance will be made based on the results of the analysis. Observations and recommendations made specifically for feeders with DERs will be highlighted. The recommended changes will be implemented, and the obtained updated results will be analyzed.

Project Phase 2 (8/1/2022 – 6/30/2023): A detailed analysis of the results obtained from feeders that are not consistent in their power flow performance will be carried out. The most important characteristics that separate the converging and the non-converging savecases will be identified and will inform recommendations of modeling changes. The recommended changes will be implemented, and the updated results will be further analyzed.

IV. ACCEPTANCE PROCEDURE:

AS DEFINED IN THE MASTER RESEARCH AGREEMENT

V. INFORMATION/FACILITIES/RESPONSIBILITIES TO BE FURNSIHED BY DUKE ENERGY: Duke Energy shall provide UNCC access to information and data relevant to the activities described above and as mutually agreed by Duke Energy and UNCC. Any and all data shared belongs to Duke Energy, and shall be used by UNCC solely for the purpose of UNCC's obligations under the SOW.

VI. OTHER REQUIREMENTS/PRE-EXISTING WORKS /OR SPECIAL CONDITIONS (if applicable):

Publication of any findings from the research shall be subject to confidentiality and intellectual property restrictions and processes defined in the Masters Research Agreement.

The parties hereto explicitly agree that section 2.B of the Master Research Agreement conflicts with the following language and shall not be applicable to this Statement of Work and the compensation for the services specified herein will be made by Duke Energy in the sum of $215,000 (Two-Hundred-Fifteen-Thousand Dollars), i.e. this work shall be performed on a "fixed price" basis. Duke Energy agrees to pay the sum of $215,000 upon a fully executed agreement.

Invoices should be directly submitted to: supplierservices@duke-energy.com

Duke Energy agrees to pay said invoices within 45 days of the invoice date. University reserves the right to discontinue work if Duke Energy fails to pay invoices within the time herein specified.

VII. FEES AND EXPENSES:

The total budget for personnel and University fees is $215,000. Both parties agree to cover their own expenses for work related to this project <u>other than stated above</u>. Each party will endeavor to obtain concurrence if a project decision will require a significant expense from the other party.

VIII. IP OWNERSHIP: Intellectual property restrictions, rights and processes will be as per defined in the Master Research Agreement.

IX. PRINCIPAL REPRESENTATIVES

THE PARTIES ACKNOWLEDGE THAT THEY HAVE READ THE STATEMENT OF WORK NO. 32, UNDERSTAND IT, AND AGREE TO BE BOUND BY ITS TERMS AND CONDITIONS. FURTHER, THE PARTIES AGREE THAT THE COMPLETE AND EXCLUSIVE STATEMENT OF THE AGREEMENT BETWEEN THE PARTIES RELATING TO THIS SUBJECT SHALL CONSIST OF 1) THIS STATEMENT OF WORK NO. 32, 2) ITS SCHEDULES, AND 3) THE MASTER RESEARCH AGREEMENT (INCLUDING THE EXHIBITS THRERETO), INCLUDING THOSE AMENDMENTS MADE EFFECTIVE BY THE PARTIES IN THE FUTURE. THIS STATEMENT OF THE AGREEMENT BETWEEN THE PARTIES SUPERSEDES ALL PROPOSALS OR OTHER PRIOR AGREEMENTS, ORAL OR WRITTEN, AND ALL OTHER COMMUNICATIONS BETWEEN THE PARTIES RELATING TO THE SUBJECT DESCRIBED HEREIN.

"DUKE ENERGY" Duke Energy Business Services, LLC	**"UNCC"** University of North Carolina at Charlotte
By: Jonathan M. Jones	By: /s/ Hector Henry III
Print: Jonathan M. Jones	Print: Hector Henry III
Title: Lead Sourcing Specialist	Title: Senior Contracting Negotiator
Date: December 8, 2021	Date: 12/09/2021 | 7:46 AM EST

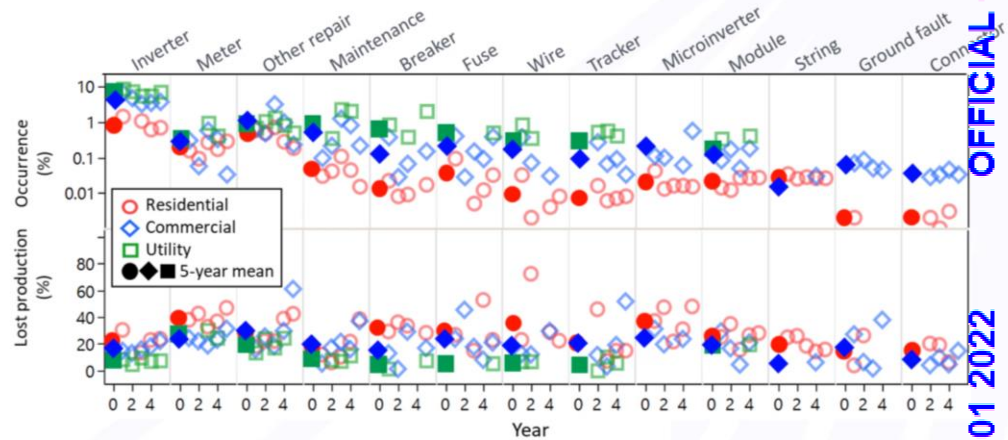
Presson Exhibit No. 16
Docket No. E-7, Sub 1264

Reliability Assessment for Utility PV Inverter System

Dr. Tiefu Zhao, University of North Carolina at Charlotte, Tiefu.Zhao@uncc.edu

Background/Trend

- Reliability is critical for PV systems to maintain safety, efficiency, and uptime.
- DOE SETO office's current focus: "improving reliability and efficiency of new and existing PV technology" – with the goal of **increasing PV useful system life to 50 years** while lowering the cost of energy.
- **PV inverters** are associated with **40% or more of the service requests** – single largest category.



PV system hardware failures (data based from100k+ systems in the U.S.)
Source: Dirk Jordan, PV System Failures – temperatures & installation effects, IEEE PVSC 2020.

Objectives

- Develop a **reliability assessment** tool to support the development of safer and more reliable PV.
- **Quantitively assess** the PV system **reliability** based on the field data provided by Duke Energy.
- **Provide recommendations** for failure mechanism identification, **predictive maintenance** and **lifetime extension strategy.**

*Near Miss Arc Flash – Twin Rivers Solar Project (source: **Duke Energy Safety Alert,** April 2021)*

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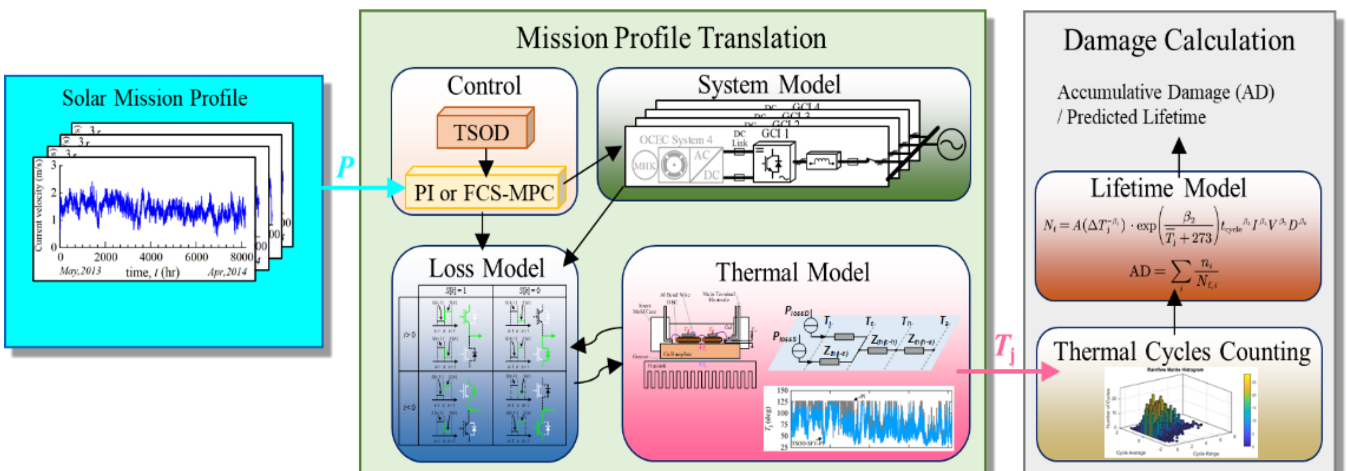
CHARLOTTE

Reliability Assessment for Utility PV Inverter System

Dr. Tiefu Zhao, University of North Carolina at Charlotte, Tiefu.Zhao@uncc.edu

Technical Approach

- Investigate integrated reliability for **critical Balance of Systems (BOS) components** in utility PV system, including PV inverters, PV protection devices, ground and arc fault detection.
- Develop PV inverter thermal stress and **remaining useful lifetime (RUL) estimation**, and reliability oriented thermal management.
- Provide **predictive maintenance recommendations** based on the analysis of field data (including irradiance, temperature, PV system layout and inverter control).
- Conduct **NFPA standard review** on PV fire and arc flash protection.
- Recommend **lifetime extension strategies** based on a case study of the PV system at Duke's choice.



Reliability assessment framework for utility PV system

UNIVERSITY OF NORTH CAROLINA
CHARLOTTE

Reliability Assessment for Utility PV Inverter System

Dr. Tiefu Zhao, University of North Carolina at Charlotte, Tiefu.Zhao@uncc.edu

PV Data Needed

The team plans to work closely with Duke Energy to collect **available data from existing PV system** for reliability assessment. Data that can be used in this project include:

- Solar mission profile (output/input power record)
- Environment data (irradiance, temperature, humidity)
- PV inverter data (manufacturer part number and control), PV system single line diagram, layout, and grounding, etc.
- O&M record and equipment fault log (if available)
- Grid disturbance (optional)

Funding Request

- $100K for 1 Year

Project Milestones and Timeline:

- Define and collect available data for PV system reliability assessment – M1
- Investigate integrated reliability for critical BOS components through data analysis, lifetime and failure mechanism characterization – M3
- Develop PV inverter thermal stress and remaining useful lifetime (RUL) estimation – M6
- Modeling and simulation of PV inverter with the reliability oriented thermal management (including thermal and lifetime model) – M9
- Model validation and performance assessment based on field data – M11
- Provide recommendations for predictive maintenance and lifetime extension strategy – M12

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