DRAWDOWN GA

ELECTRICITY

COGENERATION

DEMAND RESPONSE

ROOFTOP SOLAR

FARM + COMMUNITY SOLAR

LANDFILL METHANE

COGENERATION

OVERVIEW OF A HIGH-IMPACT DRAWDOWN SOLUTION

Cogeneration involves the co-production of beneficial heat and electricity. It can involve capturing waste heat that is a byproduct of coal- and gas-fired power production, where the captured heat can be used to heat water or buildings, manufacture products, or create more electricity. It can also involve the capture of waste heat from an industrial or commercial process that is then used to generate electricity, as in the pulp and paper industry. Cogeneration reduces emissions by displacing the consumption of fossil fuels that would otherwise have been used.

TECHNOLOGY AND MARKET READINESS

Cogeneration technologies and markets are mature and market ready. Cogeneration systems – also called combined heat and power (CHP) – are able to be used in individual buildings, in a district heating network or in manufacturing and electricity generation systems. They have long been viewed as beneficial along a variety of dimensions including grid reliability, energy efficiency, water conservation, and pollution reduction. As a result, countries around the world have increased subsidies for CHP and are expecting rapid growth (from 33 GW in 2015 to 74 GW by 2024 worldwide) (Navigant Research, 2015). With the 2012 U.S. Executive Order establishing national goals for CHP by 2020, CHP has been growing in the United States, as well (Brown, 2017).

Numerous different types of cogeneration systems are possible, including combinations of (1) prime mover (e.g., microturbine, fuel cell), (2) renewable energy source (e.g., solar PV, wind turbine) and (3) energy storage (e.g., lithium-ion battery, compressed air energy storage). Most experience to date has been with natural gas-driven microturbines (EIA, 2020), but cogeneration with solar systems would appear to hold promise.

LOCAL EXPERIENCE AND DATA AVAILABILITY

In 2017, Georgia had 43 cogeneration facilities totaling 1.4 GW of capacity. Most of the largest facilities are industrial (e.g., pulp and paper), but some are commercial (such as the 3,000 KW system in the Bank of America Plaza in Atlanta). One cogeneration system run by Albany Green Energy is located at P&G's paper manufacturing facility; it provides 100% of the steam energy utilized in the manufacturing of Bounty paper towels and Charmin toilet paper. It also generates electricity for the local utility, Georgia Power, and powers an 8.5 MW electricity generator using steam at the Marine Corps Logistics Base in Albany (Holbrook, 2017). The plant can co-generate 394,000 MWh per year using wood waste from local forestry operations as fuel supply (CEO, 2017).

TECHNICALLY ACHIEVABLE CO2 POTENTIAL

Using NEMS, Brown, Cox and Baer (2013) estimated that industrial cogeneration had the technical potential to reduce CO2 emissions in the United States by 1.9% by 2035, meeting 18% of U.S. electricity requirements, up from 8.9% in 2012. Given the sizable and compatible industrial base in Georgia, a comparable level of penetration would seem achievable. Because of Georgia's amount of heavy industry, the opportunities for cogeneration should be greater in our state than elsewhere.

COST COMPETITIVENESS

Research has documented the cost competitiveness of district, industrial, and power generation CHP systems. The cost-effectiveness of commercial CHP depends on rate design and system ownership (Brown, 2017). Albany CHP LCOE is estimated to be $127-132 (in $2017)/MWh without including a value for the steam that is produced. A 35-year plant life brings the LCOE down to $123/MWh.

The cost competitiveness of CHP systems depends on whether they are customer or utility owned, and on the type of rate tariff that they operate under. Two possibilities that have been evaluated include a CHP system that is owned and operated by a customer, subject to a flat tariff, versus a CHP system that is owned and operated by a utility subject to time varying locational marginal prices. The latter was found to be more financially favorable (Brown, 2017).

BEYOND CARBON ATTRIBUTES

Environmental benefits mainly relate to air quality improvements from efficient and clean electricity and thermal energy generation [2]. However, cogeneration may lead to greater local pollution, depending on the system design and the primary energy source (Bo Yang, et al., 2019).

From an economic development perspective, research on The Job Generation Impacts of Expanding Industrial Cogeneration (Baer, et al., 2015) estimates: (for new CHP generation investments driven by a federal investment tax credit) first-order jobs of 0.08 full time equivalent (FTE)/GWh from construction and installation, and 0.09 FTE/GWh from operations and maintenance; second-order jobs of 0.33 job-years/GWh from household and commercial re-spending. These gains are partially offset by a loss of 0.45 job-years/GWh from centralized plant generation. In addition to overall net jobs benefits, as a decentralized energy resource, cogeneration can also lead to lower infrastructure requirements/costs (T&D) and improve grid resilience as a source of reliable, base load generation.

As a social benefit, cogeneration generally offers a competitive energy costing structure for its users (mainly commercial and industrial players) and reduces the wholesale electricity prices for the grid consumers [3].

References:

Baer, Paul, Marilyn A Brown, and Gyungwon Kim. "The Job Generation Impacts of Expanding Industrial Cogeneration." Ecological Economics 110 (2015): 141-53.

Bo Yang, Jiajun Gu, Tong Zhang, K. Max Zhang, 2019. Near-source air quality impact of a distributed natural gas combined heat and power facility, Environmental Pollution, Volume 246, https://doi.org/10.1016/j.envpol.2018.12.067.

Brown, M. A. (2017). Commercial cogeneration benefits depend on market rules, rates, and policies. Environmental Research Letters, 12(3), 031003.

Brown, M. A., Cox, M., & Baer, P. (2013). Reviving manufacturing with a federal cogeneration policy. Energy Policy, 52, 264-276. Engineering; (109) Part A, Pages 423-431.

CEO, A. (2017) Albany Green Energy Biomass Plant Showcased in ADEDC's. Retrieved from http://albanyceo.com/features/2017/11/albany-green-energy-biomass-plant-showcased-adedcs-madeinalbanyga/

DOE. (2019). Combined Heat and Power Basics. Retrieved from https://www.energy.gov/eere/amo/combined-heat-and-power-basics

Energy Information Administration (EIA). 2020. "Annual Energy Outlook 2020 with Projections to 2050," www.eia.govv/aeo.

Holbrook, E. (2017). From Scrap Wood to Steam: How Procter & Gamble is Using Renewable Energy to Make Toilet Paper. Retrieved from https://www.environmentalleader.com/2017/09/scrap-wood-steam-proctor-gamble-using-renewable-energy-make-toilet-paper/

Navigant 2015 Combined Heat and Power for Commercial Buildings (Boulder, CO: Navigant) https://doi.org/10.1016/j.ecolecon.2014.12.007.

Endnotes:

1. https://www.drawdown.org/solutions/electricity-generation/cogeneration
2. https://www.energy.gov/sites/prod/files/2013/11/f4/chp_clean_energy_solution.pdf
3. https://www.energy.gov/sites/prod/files/2017/11/f39/StateOfCHP-Georgia.pdf

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DEMAND RESPONSE

OVERVIEW OF A HIGH-IMPACT DRAWDOWN SOLUTION

Demand response programs serve to "adjust the timing and amount of electricity use" and can help utility companies reduce peak load, shift load, or reduce overall usage. This can include changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

TECHNOLOGY AND MARKET READINESS

Demand response (DR) is in a technology demonstration phase. DR has been used extensively in industrial and commercial sectors since the 1970s, but today's DR is being transformed by technology and market innovations. Wholesale markets are incentivizing DR to participate in markets, smart grid technologies and dynamic pricing are enabling faster and better control of DR resources, and increasingly system aggregators are enabling smaller entities to participate. Many agree that DR can, on the one hand, reduce daily peak loads and contribute to system reliability, and on the other hand, reduce the cost of electricity supply. DR's impact on carbon emissions, by contrast, is less well understood (Smith and Brown, 2015).

LOCAL EXPERIENCE AND DATA AVAILABILITY

Georgia Power operates DR programs with industrial customers, and it has used direct load control of water heaters in the residential and commercial sectors. Georgia Power's Integrated Resource Plan proposes two new residential programs (demand response and low-income qualified energy efficiency) and one new "behavioral" commercial program. By 2022 its energy efficiency programs "are designed to help reduce peak demand approximately 1,600 MW, which is 10% of the company's current peak demand." DR is also an aspect of its microgrid smart community in Atlanta called "Altus at the Quarter" by load shifting demand for electricity from heat pump water heaters. This is a first-of-a-kind demonstration project for Georgia.

We assume that DR can shift one hour of electricity from an on-peak hour that is served by natural gas to 30 minutes that is served by solar (perhaps via home storage) and 30 minutes of curtailment through appliance cycling (i.e., reduction in consumption). That reflects the goals of some DR programs such as the Microgrid Pulte Homes community in Atlanta. We also assume that the peak load for each family is 4.39 kW (Georgia Power, 2019) [1].

TECHNICALLY ACHIEVABLE CO_2 REDUCTION POTENTIAL

We used GT-NEMS to model DR as an increase from 3% to 20% maximum peak load shift in 2030. This produced a total reduction of 3.6 MtCO_2 in the SERC SE region, which equates to 1.63 Mt CO_2 in Georgia. This peak load shift produced a reduction of summer peak demand of 365 MW. This would result in an estimated reduction of 164 MW summer peak load in Georgia. Based on shifting 20% of the 4.4 KW peak load of an average household in Georgia, this reduction in summer peak is equivalent to 187,000 households in Georgia participating in a demand response program.

COST COMPETITIVENESS

Smith and Brown (2015) found that DR is likely to defer significant amounts of expensive, aging peak capacity such as single-cycle natural gas. Georgia Power conducts EE education initiatives as a pillar demand side management (DSM) and DR program and as a way of achieving flexibility and clean energy goals. One form of digitally connected 'smart' energy technology such as NEST thermostats and home energy management systems (HEMS), can enable consumers to visualize, monitor and manage electricity consumption within their household. Smith and Brown (2015) provide evidence that "suggests that demand response can serve as a long-term, low-cost alternative for peak-hour load balancing without increasing carbon emissions."

BEYOND CARBON ATTRIBUTES

Together with microgrids, grid flexibility solutions, and distributed energy resources, DR can improve resiliency and flexibility to mitigate climate change impacts on the grid (resulting from extreme weather temperatures, intense storms, etc.) [2,3].

From an environmental and public health standpoint, adoption of demand response solutions can lead to air quality improvements over existing alternatives. For example, simple cycle gas turbines or coal power plants that run during peak hours, tend to be inefficient and higher emitting. Offsetting these peaking plants with demand response can significantly reduce environmentally-harmful emissions. The degree of air quality benefit should, however, be assessed on a case-by-case basis because results vary significantly depending on the energy source utilized.

The social and economic benefits of demand response include affordability and potentially greater accessibility by low-income households (versus for example rooftop solar). Besides moderate upfront costs, some studies found that residential demand response technologies generate overall energy savings in addition to shifting demand to low rate off-peak hours [4].

DR solutions requiring high adoption rates of lithium-ion batteries may impose environmental risks regarding their end-of life disposability (EPA, 2013).

References:

Balijepalli, Murthy; Pradhan, Khaparde (2011). "Review of Demand Response under Smart Grid Paradigm". IEEE PES Innovative Smart Grid Technologies.

EPA. (2013). Application of Life- Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles

Georgia Power. (2019). Integrated Resource Plan. PDF File. Atlanta, January 31, 2019. https://eteconline.org/news/doe-celebrates-georgia-powers-first-smart-neighborhood/ https://www.epa.gov/sites/production/files/2014-01/documents/lithium_batteries_lca.pdf

Smith, A. M., & M.A. Brown. (2015). Demand response: A carbon-neutral resource? Energy, 85, 10-22.

Endnotes:

1. National Renewable Energy Laboratory (NREL) System Advisor Model
2. https://www.eesi.org/articles/view/protecting-the-grid-from-the-impacts-of-climate-change
3. https://www.betterenergy.org/wp-content/uploads/2018/03/DR-Fact-Sheet-2-Environmental-Benefits-of-DR.pdf
4. https://dotearth.blogs.nytimes.com/2012/11/05/how-natural-gas-kept-some-spots-bright-and-warm-as-sandy-blasted-new-york/

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LANDFILL METHANE

OVERVIEW OF A HIGH-IMPACT DRAWDOWN SOLUTION

Landfills are a major source of methane emissions. This GHG is created from anaerobic digestion of municipal solid waste in landfills. The gas can be captured and then used to generate electricity. This process can prevent methane emissions and replace conventional electricity-generating technologies such as coal and natural gas.

TECHNOLOGY AND MARKET READINESS

The technology is mature and market ready. Landfill gas can be extracted from landfills using wells and a blower/flare system. The system transports the gas to a central point where it can be processed and treated according to the ultimate use for the gas. Landfill gas can be used to generate electricity through different process like reciprocating internal combustion engines, fuel cells, turbines, microturbines and cogeneration. The electricity generated can be used on site or sold to the grid. Nearly 72% of operating landfills in the U.S. generate electricity. Currently in the United States, landfill methane is collected from 352 landfills, producing 11 billion kWh of electricity, or 0.3% of electricity production [1]. Landfill gas can also be directly used to replace another fuel like natural gas or coal in a boiler, dryer or other thermal applications. About 18% of operating landfills use landfill gas to offset the use of other fuels. Lastly, landfill gas can be upgraded to renewable natural gas by increasing its methane content through treatment processes. Renewable natural gas can be used as compressed natural gas, pipeline-quality gas or liquified natural gas. Around 10% of operating landfills upgrade landfill gas [1].

Landfill Methane has been in use for decades and there are ample sites that are candidates in the United States and in Georgia for potential implementation of this technology. Given the high global warming potential of methane (34 CO2-e), opportunities to capture methane can produce significant CO2-e reductions.

LOCAL EXPERIENCE AND DATA AVAILABILITY

In 2019, Georgia had 92 landfills totaling more than 495 Mt of waste. The landfills are categorized as: operational (25), candidate (20), future potential (5), low potential (23), construction (1), planned (1) and shutdown or unknown (17). The operational landfills in Georgia have in total 239 Mt of waste. The one with the most waste has 21 Mt while the one with the least has 1 Mt in place. Out of the 25 operational landfills, 18 generate electricity, 4 use landfill gas directly and the other 3 upgrade landfill gas to renewable natural gas. The total installed capacity of the operational landfills that generate electricity is 66 MW [2].

There are several active landfill-to-gas retrofit projects in Georgia (e.g., Seminole Road MSW Landfill in DeKalb County, and Macon Bibb Walker Road MSW Landfill in Bibb County). There are EPA data available for landfills in Georgia, including potential for future landfill gas-to-energy retrofits. The EPA defines a candidate landfill as “one that is accepting waste or has been closed for five years or less, has at least one million tons of waste, and does not have an operational, under-construction, or planned project; candidate landfills can also be designated based on actual interest by the site [2]

TECHNICALLY ACHIEVABLE GHG REDUCTION POTENTIAL

The GHG reduction potential is high. Based on data from EPA's Landfill Methane Outreach Program [2], there are 25 landfills categorized as "Future Potential" or "Candidate" for landfill gas-to-energy retrofitting in Georgia. Preliminary analysis based on this data indicates that a typical 5 MW retrofit at each facility could abate approximately 0.25 Mt CO2-e annually per facility. Retrofitting just 4 of the 25 landfills could abate 1 Mt CO2-e annually.

COST COMPETITIVENESS

This is a potentially cost-effective solution, based on global Project Drawdown® estimates and EPA data (EPA, 2013; Harmsen et al. 2019). Review of other literature indicates mixed results on cost-effectiveness, especially in the absence of a carbon tax [5]. Preliminary analysis suggests that the 6.3 MW Georgia Landfill Gas Oak Grove Plant produces electricity at a LCOE of 9.6 cents per kWh. We will explore Georgia-specific cost effectiveness during the next phase of research.

BEYOND CARBON ATTRIBUTES

Social benefits of this solution include improvement of air quality by reducing GHG (mainly methane) and toxic gas emissions. Additionally, the utilization of landfill gases (LFG) for electricity generation can offer an offset to the use of non-renewable sources [4,5,6]. Moreover, the capture and use of LFG to generate electricity mitigates the possible health risks associated with the release of non-methane organic compounds (including hazardous air pollutants and volatile organic compounds (VOCs)) that are present at low concentrations in uncontrolled LFG. An added economic benefit, LFG energy projects provide a source of revenue from the sale of captured gas and can create local jobs associated with the design, construction, and operation of energy recovery systems [7]. The Landcaster Landfill in Pennsylvania, for example, created over 100 temporary construction jobs, while an LFG project in Virginia resulted in 22,000 hotel stays for project workers [8]. Additionally, waste management and landfill businesses stand to benefit from the expansion of this solution by reducing their environmental compliance costs that is mandated by the Clean Air Act [9].

Potential concerns center around high upfront costs for installation of the landfill gas-to-electricity system. Also, decreasing landfill waste can be considered a challenge for the adoption rates of this solution.

References:
EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010-2030. Report Number EPA-430-R-13-011.
Harmsen et al. (2019). Long-term marginal abatement cost curves of non-CO2 greenhouse gases. Environmental Science and Policy, 99, p. 136-149.

Endnotes:
1. EPA Landfill Methane Outreach Program (LMOP). Available online: https://www.epa.gov/lmop/landfill-technical-data
2. Biomass Explained. Energy Information Administration. https://www.eia.gov/energyexplained/biomass/landfill-gas-and-biogas.php
3. https://www.drawdown.org/solutions/buildings-and-cities/landfill-methane
4. EPA Basic Information About Landfill Gas: https://www.epa.gov/lmop/basic-information-about-landfill-gas
5. Environmental and Energy Study Institute Landfill Methane Fact Sheet: https://www.eesi.org/papers/view/fact-sheet-landfill-methane
6. Agency for Toxic Substances & Disease Registry Landfill Gas Control Measures https://www.atsdr.cdc.gov/HAC/landfill/html/ch5.html
7. Global Methane Initiative Internatinal Best Practices Guide for Landfill Gas Energy Projects https://www.globalmethane.org/documents/toolsres_lfg_IBPGAppendixA.pdf
8. Landfill Methane Outreach Program LFG Energy Project Development Handbook https://www.epa.gov/sites/production/files/2016-11/documents/pdh_full.pdf
9. EPA Benefits of Landfill Gas energy Projects: https://www.epa.gov/lmop/benefits-landfill-gas-energy-projects

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LARGE SCALE SOLAR

OVERVIEW OF A HIGH-IMPACT DRAWDOWN SOLUTION

Solar photovoltaic systems can convert solar energy into electricity. Utility-scale solar is defined as any ground mounted solar panel facility that has a capacity rating larger than 5 MW. Community-scale solar generally has a capacity of 0.5-5 MW. This solution also considers the possible advantage of coupled on-site storage to enhance reliability.

TECHNOLOGY AND MARKET READINESS

The technology is mature and market ready. In Georgia, the United States and globally, utility-scale solar is growing rapidly and costs have been declining. By mid-2019, total solar PV capacity in Georgia had risen to more than 1,570 MW, with more than 1,000 MW of that at utility-scale facilities. There is less experience with solar and storage projects in Georgia. Across the United States, at least 85 co-located solar and storage projects are in the planning stages, according to S&P Global Market Intelligence data, [1] pairing 4,175 MW of storage with 8,921 MW of solar. Roughly 40 such systems were in operation in the United States as of late September 2019, combining about 533 MW of storage with 1,242 MW of solar capacity. None of these hybrid facilities are proposed or currently located in Georgia (Hering, 2019).

LOCAL EXPERIENCE AND DATA AVAILABILITY

In 2014 Silicon Ranch Corporation and Green Power EMC constructed a solar farm located in Jeff Davis county in southeast Georgia near Hazlehurst, one of the first and largest solar farms in the Southeast. (Silicon Ranch is one of the nation's largest independent solar power producers and the U.S. solar platform for Shell.) This solar farm sits on 135 acres of land with a capacity of 55.2 MW. Georgia now has 8 solar farms with an operating capacity above 50 MW totaling 559.4 MW. Three of the largest solar facilities in the state have capacities of 100 MW or greater. In 2018, utility-scale facilities produced almost 90% of the state's solar PV generation (EIA 2019). Thus, there is ample documentation of the performance of solar farms in the United States and the Southeast.

Georgia Solar Farms with an Operating Capacity above 50 MW

Jeff Davis, 100 MW	Butler Solar Project, 100 MW
Decatur Parkway Solar Project, 80 MW	White Oak, 76.5 MW
Hazlehurst Solar II, 52.5 MW	White Pine, 101.2 MW
Sand Hills, 143 MW	Live Oak, 51 MW

Source: S&P Global Market Intelligence [1]

Community solar projects range from a few hundred kW to a few MW on the distribution grid (i.e., non-customer-sited) and are administered by the utility or a third-party entity in which multiple customers can participate. In 2015, approximately 60 MW of community solar was operating in the United States (Funkhouser, et al., 2015). Several community solar projects are currently operating in Georgia.

TECHNICALLY ACHIEVABLE CO2 REDUCTION POTENTIAL

Lopez, et al. (2012, Table 3) estimates that the total technical potential for rural utility-scale solar farms in Georgia is 3,088 GW and 5,492,000 GWh, covering 64,343 km [2]. It estimates an additional technical potential for urban utility-scale solar that might be suitable for community projects, totaling 24 GW and 43,167 GWh, covering 506 km [2] (Lopez, et al., 2012, Table 2). These estimates exclude sites with slopes over 3%, <0.4 square miles of contiguous area, and wetlands, federal parks, wilderness areas, wildlife areas, and many other incompatible land uses. Based on these estimates, only 16 states are estimated to have higher technical potential than Georgia. According to the Solar Energy Industries Association (SEIA), Georgia is 11th in potential for future growth. Georgia's solar resource of 4.5-5.0 kWh/m2/day is slightly less than that of Florida (NREL, 2012).

The Georgia Power IRP 2019 calls for 2,000 MW of new utility-scale solar by 2022. This would displace 1.36 Mt CO2 in 2030 [1]. GT-NEMS forecasts a growth of solar farms in Georgia from 11,600 GWh or 7.9% in 2020, to 12,800 GWh or 8.9% in 2030 (Source: GT-NEMS modelling). This growth would displace 0.47 Mt CO2 in the year 2030.

To displace an additional 1 Mt CO2 will require 2,580 GWh of additional solar generation. At a capacity factor of 25%, this would require 1,178 MW of new capacity, or 10 additional 100 MW solar farms and 36 additional 5 MW community solar projects. The total of these two estimates is a technical potential of 5,535,000 GWh from utility-scale solar. This could displace 2,145 Mt CO2, which is more than 10 times the current GHG footprint of Georgia

COST COMPETITIVENESS

EIA cost estimates for new generation in the SERC-SE Region is $37.6/MWh x 0.94 (regional multiplier) = $33.5/MWh. Utilizing data from S&P Global Market Intelligence and the Georgia Tech LCOE calculator, the estimated LCOE for utility-scale solar today is $85.6/MWh. Levelized energy prices for solar farms with lithium-ion batteries have dipped into the range of $30-$40/MWh for many projects scheduled to come online in the next few years in California, Arizona, and Nevada (Bolinger and Seel, 2018).

BEYOND CARBON ATTRIBUTES

The environmental and public health benefits of solar farms relate to air quality improvements from the reduction of fossil fuel pollution, particularly SO2 (a major contributor to acid rain), PM2.5 (a respiratory health concern), and NOX, besides CO2 (Millstein et al., 2017).

From an economic development standpoint, construction and operation of solar farms offer local and statewide employment. According to Georgia Solar Job Census 2018, there are 304 solar companies operating in Georgia. In 2019, Georgia was second to Florida in the number of new solar jobs, with 30% growth, bringing the total solar employment in Georgia to 4,798 [4]. For many of the solutions noted in this document, displacement of jobs from coal or other sources will need to be considered/addressed against these positive economic benefits.

Despite its jobs potential, the solar workforce is currently not yet representative of America's ethnic, racial, and gender diversity. Solar Jobs Census 2019 [4] found that only 26% of the solar workforce was made up of women, and the racial breakdown is dominated by the workers who are White, comprising 73.2% of the overall solar workforce.

Potential environmental costs may include the depletion of water resources due to solar panel cleaning (approximately 20 gal/MWh [5]), and land use concerns about displacement of native flora and fauna. While monitoring water use and seeking efficiencies are worthwhile endeavors, solar farms use of water is less intensive than traditional fossil fuel alternatives (Klise, et al., 2013)[6]. On land use, solar farms in Georgia can produce 18.5 MW per square mile (Lopez, et al., 2012). Thus, 1 Mt CO2 reduction via solar farms requires about 64 square miles of land.

Potential impacts (both positive and genitive) of intermittent solar generation on retail electricity prices are supported by mixed research findings.[7,8] Similarly the property-value impacts near utility-scale solar farms needs to be explored further [9].

Given the scale of current and potential solar panel installations, end-of-life disposability of PV panels is a pertinent environmental issue (Chowdhury et al., 2020) due to toxic materials contained within the cell, for example, cadmium, arsenic, and silica dust. 13,000 tons of PV panel waste is expected to be produced by the United States in 2020 [10].

References:

Bolinger, Mark, and Joachim Seel. (2018) "Utility-Scale Solar: Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States – 2018 Edition.

Chowdhury, S., K.S. Rahman, T. Chowdhury, N. Nuthammachot, K. Techato, Md. Akhtaruzzaman, S. Kiong Tiong, K. Sopian, N. Amin, An overview of solar photovoltaic panels' end-of-life material recycling, Energy Strategy Reviews, Volume 27, 2020, 100431, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2019.100431

Energy Information Administration (EIA). (2019). Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019.

Funkhouser, E., Griselda Blackburn, and Varun Rai. (2015). "Business model innovations for deploying distributed generation: The emerging landscape of community solar in the U.S." Energy Research & Social Science 10: 90-101. https://doi.org/10.1016/j.erss.2015.07.004

Hering, Garrett (2019) "Solar-plus-storage power plant development accelerates in the U.S., October 16, 2019 https://platform.marketintelligence.spglobal.com/web/client?auth=inherit#news/article?id=54590775&KeyProductLinkType=http://www.thesolarfoundation.org/wp-content/uploads/2019/03/TSF_Georgia_State-Fact-Sheet-2018.pdf

Klise, Geoffrey T., Vincent C. Tidwell, Marissa D. Reno, Barbara D. Moreland, Katie M. Zemlick, Jordan Macknick. 2013. Water Use and Supply Concerns for Utility-Scale Solar Projects in the Southwestern United States, SAND2013-5238.

Lazard. (2018). "Lazard's Levelized Cost of Energy Analysis." Version 12.0. (November), https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf

Lopez, Anthony, Billy Roberts, Donna Heimiller, Nate Blair, and Gian Porro. (2012) U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis National Renewable Energy Laboratory, NREL/TP-6A20-51946, https://www.nrel.gov/docs/fy12osti/51946.pdf

Millstein, D., R. Wiser, M. Bolinger, G. Barbose, 2017. The climate and air-quality benefits of wind and solar in the United States. Nature Energy, 2, doi:10.1038/nenergy.2017.134.

The Solar Foundation, Georgia Solar Jobs Census 2018.

Endnotes:

1. S&P Energy Market Intelligence. (2020). S&P Global Intelligence Energy Data. https://www.spglobal.com/marketintelligence/en/about/
2. EIA.gov. (2019). Georgia - State Energy Profile Analysis - U.S. Energy Information Administration (EIA). [online] Available at: https://www.eia.gov/state/analysis.php?sid=GA
3. NREL: Energy Efficiency and Renewable Energy Clearinghouse (EREC) DOE/GO-10096-050 FS 119 March 1996
4. The Solar Foundation, National Solar Jobs Report 2019. (2020). https://www.thesolarfoundation.org/national/
5. https://www.seia.org/initiatives/water-use-management
6. NREL: Water Impacts of High Solar PV Electricity Penetration, NREL/TP-6A20-63011, 2015
7. https://economics.mit.edu/files/16650
8. https://www.forbes.com/sites/brianmurray1/2019/06/17/the-paradox-of-declining-renewable-costs-and-rising-electricity-prices/#26d2229961d5
9. https://emp.lbl.gov/sites/default/files/property-value_impacts_near_utility-scale_solar_installations.pdf https://www.greenmatch.co.uk/blog/2017/10/the-opportunities-of-solar-panel-recycling

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ROOFTOP SOLAR

OVERVIEW OF A HIGH-IMPACT DRAWDOWN SOLUTION

Solar photovoltaic systems convert solar energy into electricity. Rooftop solar systems are small-scale installations that can produce electricity primarily for onsite use. When combined with storage, additional benefits can accrue.

TECHNOLOGY AND MARKET READINESS

The technology is mature and market ready. In Georgia, the United States and globally, rooftop solar is "market ready" and is growing rapidly. With technology breakthroughs and cost reductions from "learning by doing," costs have been declining rapidly. Solar panels have become economically feasible, with the average price for a 6 KW solar system dropping from $51,000 to $17,880 in the past decade (Matasci 2019).

LOCAL EXPERIENCE AND DATA AVAILABILITY

Ample data are available for rooftop solar. NREL publishes maps of solar radiation, and there are rigorous and numerous assessments of the performance of rooftop solar in the United States and the Southeast.

At the end of Quarter 3, 2019, Georgia had 1,202 MW of installed solar on rooftops (residential and commercial) [7]. Solarize programs have been successful in Decatur-Dekalb (850 program participants), Atlanta (1,103 program participants), Athens (701 program participants), Carrollton-Carroll (239 program participants), Newton-Morgan (230 program participants), Roswell (148 program participants), Middle Georgia (291 program participants), and Dunwoody (inactive, 282 program participants) [8]. There are 304 solar companies in Georgia and 3,696 jobs are supported by the solar industry in Georgia (The Solar Foundation, 2019) [6].

TECHNICALLY ACHIEVABLE CO2 REDUCTION POTENTIAL

In 2030, it is assumed that 388 tCO2 will be emitted per GWh of electricity generated in Georgia. At this projected carbon intensity, 1 MtCO2 could be avoided in 2030 by adding 2,580 GWh of zero-carbon electricity (source: GT-NEMS modelling).

The median single family home floor area in Georgia is 2,200 square feet [1]. A 5-kW solar installation can use as little as 400 square feet and is therefore viable on the average home, assuming sufficient sunlight exposure and a sturdy roof. Assuming a capacity factor of 20% (or nearly 5 hours/day), a 5-kW rooftop system would generate 8.76 MWh/year. To generate 2,580 GWh of zero-carbon electricity in 2030 and displace 1 Mt CO2 would require 295,000 5-kW solar rooftops. Fewer new systems would be needed if the industry continues to experience improvements to the efficiency of rooftop solar systems over the next decade.

The Solar Energy Industries Association (SEIA) ranked Georgia 11th in potential for future growth. Lopez, et al. (2012, Table 4) estimates that the total technical potential for rooftop photovoltaics in Georgia is 25 GW and 31,116 GWh. Therefore, the goal of a 1 Mt CO2e reduction in 2030 appears challenging, but achievable.

COST COMPETITIVENESS

Using the price estimate of $2.50 to $3.38 per watt, a 5 kW solar panel installation in Georgia would cost $12,500 to $16,900 each; and $1.95- $2.6 billion to reduce 1 Mt CO2-e by 2030 [3]. Lazard (2018) estimates U.S. average LCOE for residential solar rooftop is $160-$267/MWh and for commercial and industrial solar rooftop, costs are lower at $81-$170 /MWh. EIA (2019) estimates slightly higher costs.

BEYOND CARBON ATTRIBUTES

Environmental benefits of rooftop solar relate to air quality improvements from the reduction of fossil fuel pollution, particularly SO2 (a major contributor to acid rain), PM2.5 (a respiratory health concern), and NOX, besides CO2 (Millstein et al., 2017).

From an economic development standpoint, construction and operation of solar solutions offer local and statewide employment. According to Georgia Solar Job Census 2018, there are 304 solar companies operating in Georgia. In 2019, Georgia was second to Florida in the number of new solar jobs, with 30% growth, bringing the total solar employment in Georgia to 4,798 [4]

Rooftop PV systems with battery solutions have the potential to supply electricity during grid outages resulting from emergency situations, which offers benefits for electricity system resilience. Additionally, rooftop panels have been found to have a positive impact on property values (Adomatis, et al., 2015).

Given the scale of current and potential solar panel installations, end-of-life disposability of PV panels is a pertinent environmental issue (Chowdhury et al., 2020) due to toxic materials contained within the cell, for example, cadmium, arsenic, and silica dust. 13,000 tons of PV panel waste is expected to be produced by the US in 2020 [5].

In terms of potential adverse impacts related to equity and solution accessibility, Sunter et al. (2019) found significant racial and ethnic differences in rooftop solar adoption in the US, even after accounting for income and household ownership. NREL (2015) also analyzes the impact of rate design to recover fixed utility costs arising from lower net electricity consumption after residential PV penetration, which may exacerbate the “energy burden” experienced by lower income households who, without access to solar, continue to purchase all of their electricity from the grid.

References:

Adomatis, Sandra, Jackson, Thomas, Graff-Zivin, Joshua, Thayer, Mark, Klise, Geoffrey, Wiser, Ryan, & Hoen, Ben. (2015) Selling Into the Sun: Price Premium Analysis of a Multi-State Dataset of Solar Homes. United States. doi:10.2172/1172644.

Bolinger, Mark, Joachim Seel, and Dana Robson (2019) Utility-Scale Solar: Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States – 2019 Edition, Lawrence Berkeley National Laboratory.

Chowdhury, S., K.S. Rahman, T. Chowdhury, N. Nuthammachot, K. Techato, Md. Akhtaruzzaman, S. Kiong Tiong, K. Sopian, N. Amin, An overview of solar photovoltaic panels' end-of-life material recycling, Energy Strategy Reviews, Volume 27, 2020, 100431, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2019.100431

Cook, Jeffrey J., and Lori Bird. 2018. “Unlocking Solar for Low- and Moderate-Income Residents: A Matrix of Financing Options by Resident, Provider, and Housing Type.” National Renewable Energy Laboratory. hhttps://www.osti.gov/biblio/1416133.

Energy Information Administration (EIA). (2019). Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019.http://www.thesolarfoundation.org/wp-content/uploads/2019/03/TSF_Georgia_State-Fact-Sheet-2018.pdf

Lazard. (2018). "Lazard's Levelized Cost of Energy Analysis." Version 12.0. (November), https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf

Lopez, Anthony, Billy Roberts, Donna Heimiller, Nate Blair, and Gian Porro. (2012) U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis National Renewable Energy Laboratory, NREL/TP-6A20-51946, https://www.nrel.gov/docs/fy12osti/51946.pdf

Matasci, Sara. “How Solar Panel Cost & Efficiency Change Over Time: EnergySage.” Solar News, EnergySage, 19 Sept. 2019, news.energysage.com/solar-panel-efficiency-cost-over-time/.

Millstein, D., R. Wiser, M. Bolinger, G. Barbose, 2017. The climate and air-quality benefits of wind and solar in the United States. Nature Energy, 2, doi:10.1038/nenergy.2017.134.

National Renewable Energy Laboratory (NREL). (2015). Impact of Rate Design Alternatives on Residential Solar Customer Bills: Increased Fixed Charges, Minimum Bills and Demand-Based Rates. Available at: www.nrel.gov/publications.

Sunter, D.A., Castellanos, S. & Kammen, D.M. Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity. Nat Sustain 2, 71–76 (2019). https://doi.org/10.1038/s41893-018-0204-z

The Solar Foundation, Georgia Solar Jobs Census. (2018).

Endnotes:

1. https://www.seia.org/initiatives/rooftop-solar
2. NREL: Energy Efficiency and Renewable Energy Clearinghouse (EREC) DOE/GO-10096-050 FS 119 March 1996
3. https://www.energysage.com/solar-panels/ga/
4. The Solar Foundation, National Solar Jobs Report 2019. (2020). https://www.thesolarfoundation.org/national/
5. https://www.greenmatch.co.uk/blog/2017/10/the-opportunities-of-solar-panel-recycling
6. https://www.seia.org/sites/default/files/2019-12/Georgia.pdf
7. https://www.seia.org/state-solar-policy/georgia-solar
8. https://www.solarcrowdsource.com/how-it-works-solarize/ an
9. https://www.solarcrowdsource.com/archived-campaigns/

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