Modeling Renewable Microgrids in South Africa

Duke UNIVERSITY | BASS CONNECTIONS

Kerim Algul (Pratt '17), Nitish Garg (Pratt MEMP '17), Ryan Hussey (Trinity '17), Cassidee Kido (Pratt '17), Ashley Meuser (Pratt '19), Savini Prematilleke (Pratt '19), Tyler Wakefield (Trinity '18)

Bass Connections in Energy

Introduction

1.1 billion people around the world have little to no access to reliable electricity. Electricity access is essential to economic growth and development, but cost and physical barriers make it such that connection to the central grid is years away for many rural communities. As shown in Figure 1, many areas in South Africa are still unelectrified. Microgrids can bring power to these communities at a smaller scale, giving them the economic benefits of electricity access without the costs of connecting to the larger grid. Powering the microgrid with energy sources already found in these communities, including wind, solar, and biogas from cattle waste, makes this system self-sustaining with a low environmental impact. This project evaluates the potential for improving electricity access in the KwaZulu-Natal and Eastern Cape regions of South Africa (circled in Figure 1) through the implementation of a microgrid. HOMER, a program developed by the NREL that models microgrids' physical behaviors and costs, was the main tool used in evaluating different microgrid configurations. This analysis proposes three different microgrid configurations and assesses their technical and economic feasibilities.

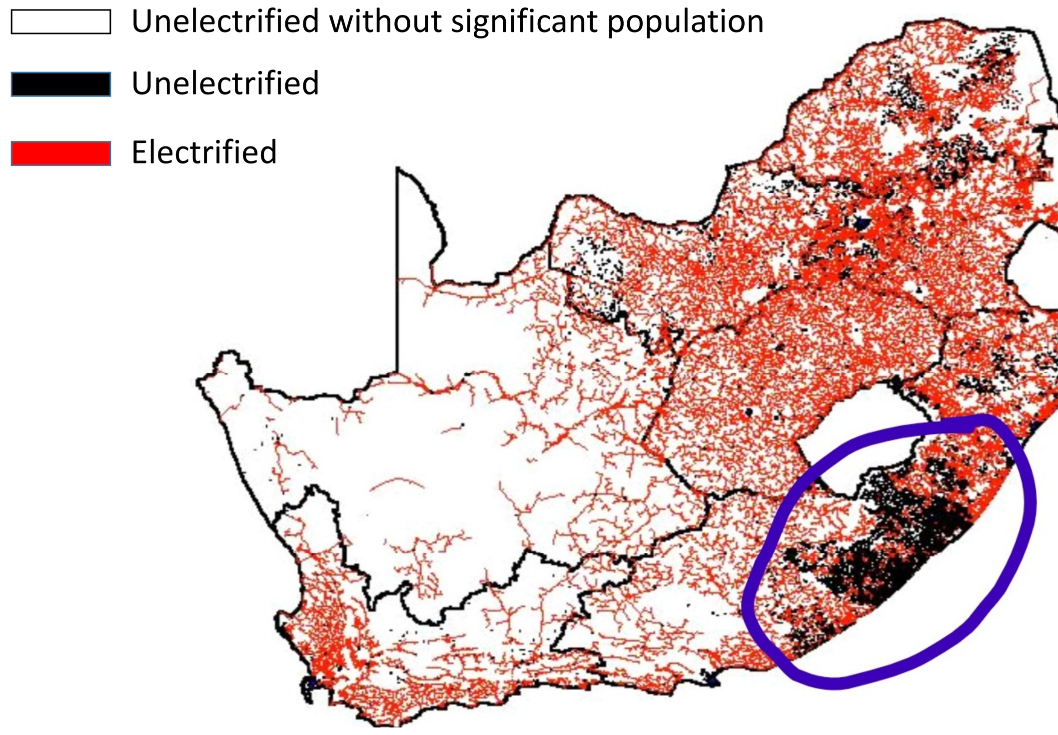
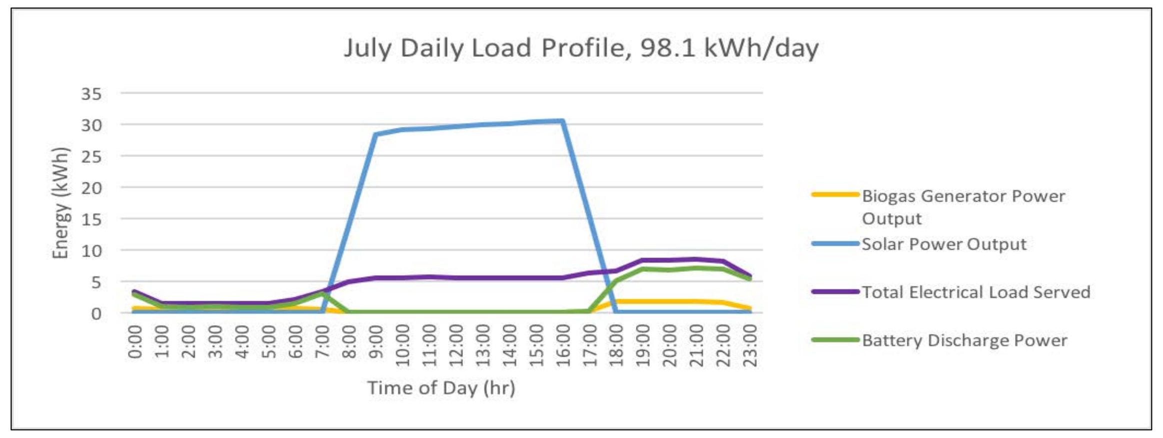


Figure 1: Electricity Access Map of South Africa

Community Size (households)	Electric Load (kWh/day)	Peak Load (kW)	PV (kW)	Wind (kW)	Biogas Generator (kW)	Storage (kW)	Converter (kW)	Cost of Energy	Net Present Cost (25 years)	Operating Cost	Initial Cost
75	98.1	13.81	83.1	0	2	79.47	14.5	$0.273	$204,628	$3,364	$134,145
400	523.3	73.68	349	96	10	298.01	68.1	$0.25	$999,365	$13,815	$709,949
1250	1635.0	230.2	874	207	30	1,142.38	228	$0.243	$3,030,000	$38,622	$2,230,000

Community A: 75 Households

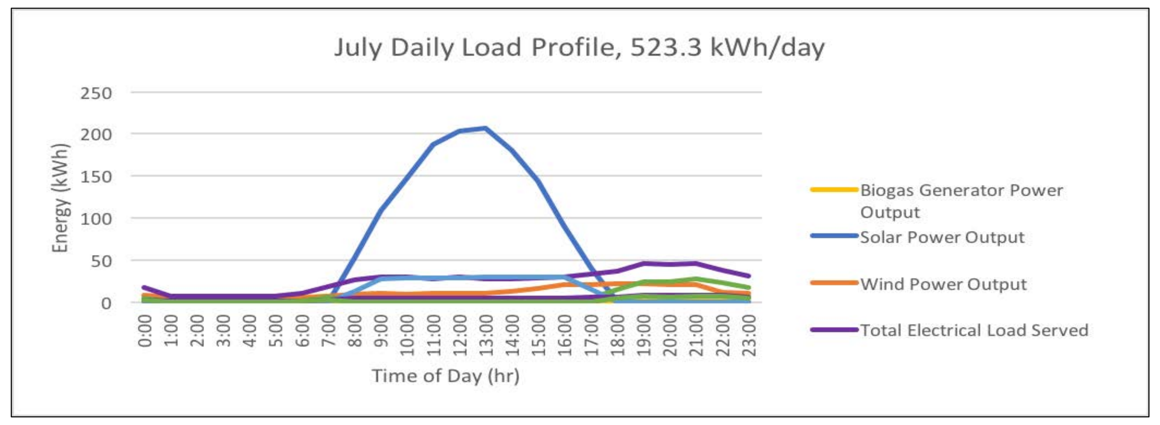


Multi-Year Model

- PV increases to 130 kW
- No change in biogas
- Storage increases to 119.16kW
- COE increases to $0.317
- Converter increases to 21 kW
- NPC increases to $285,797
- OC increases to $4,054
- IC increases to $200,866

Payment Methodology	COE ($/kWh)	Annual Revenue	Present Value (25 Years)	NPC ($204,628) minus PV
HH's pay avg. COE in SA	$.100	$3,581	$75,014	$166,405
HH's pay avg. of 8% of income	$.181	$6,482	$135,806	$135,430
HH pay enough to meet NPC	$.273	$9,775	$204,628	-

Community B: 400 Households

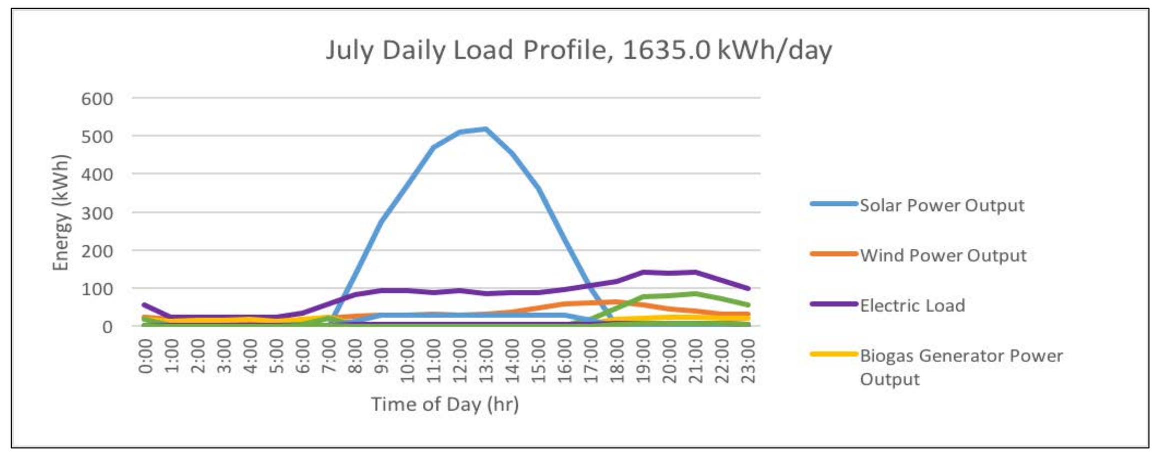


Multi-Year Model

- PV increases to 420 kW
- Wind increases to 900 kW
- No change in biogas
- No change in storage
- COE increases to $0.276
- Converter increases to 90 kW
- NPC increases to $1.10 M
- OC increases to $14,190
- IC increases to $805,204

Payment Methodology	COE ($/kWh)	Annual Revenue	Present Value (25 Years)	NPC ($999,365) minus PV
HH's pay avg. COE in SA	$.100	$19,100	$400,153	$599,212
HH's pay avg. of 8% of income	$.181	$34,573	$724,298	$275,067
HH pay enough to meet NPC	$.250	$47,751	$999,365	-

Community C: 1250 Households



Multi-Year Model

- PV increases to 1600 kW
- Wind increases to 375 kW
- No change in biogas
- Storage increases to 1,490 kW
- COE increases to $0.304
- Converter increases to 350 kW
- NPC increases to $4.56M
- OC increases to $53,726
- IC increases to $3.44M

Payment Methodology	COE ($/kWh)	Annual Revenue	Present Value (25 Years)	NPC ($3,030,000) minus PV
HH's pay avg. COE in SA	$.100	$59,678	$1,250,240	$1,779,760
HH's pay avg. of 8% of income	$.181	$108,040	$2,263,431	$ 776,569
HH pay enough to meet NPC	$.243	$145,016	$3,030,000	-

Model Assumptions

- Electric Load: linear increase with community size
- Cattle Waste: linear increase with community size, 2.5 Cattle/Household, 15kg waste/cattle/day, 25% waste reclaimed
- Annual electric load increase of 1.5% (Multi-Year Model)
- Inflation = 6.5%, Nominal Discount Rate = 8%
- Controller capital, replacement, and operation and management costs unknown; assumed zero
- Conversion rate: 1 USD: 0.07 ZAR
- Average household income: USD $1080.4
- Does not consider cost of transmission infrastructure

Environmental Impacts

- <0.01% CH_4 reduction per year
- Potential 25% N_2O reduction per year
- Minimal negative battery impacts
- Spatial impacts of the wind and solar resources could affect agriculture in the area

Conclusion

Rural microgrids using combinations of wind, solar PV, and biogas combustion for this region of South Africa are technologically feasible, but will require subsidization from government or NGO sources to be economically viable. However, all three models produce high quantities of excess electricity given their dependence on variable wind and solar coupled with storage. If communities were able to take advantage of unpredictable excess electricity through flexible manufacturing operations that generated income, the systems may become economically viable without subsidization. Likewise, the high likelihood of grid connection throughout SA within 25 years presents opportunities for communities to sell excess electricity to the grid, increasing the economic viability of the systems. **Sensitivity:** All models are highly sensitive to the availability of cattle waste. In areas that have concentrated livestock operations, the higher availability and lower cost of biomass alter the composition of energy resources to favor biogas combustion, lowering the system cost.

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