Techno-Economic Viability of Solar Powered Electric Vehicle Charging Station in Rwanda

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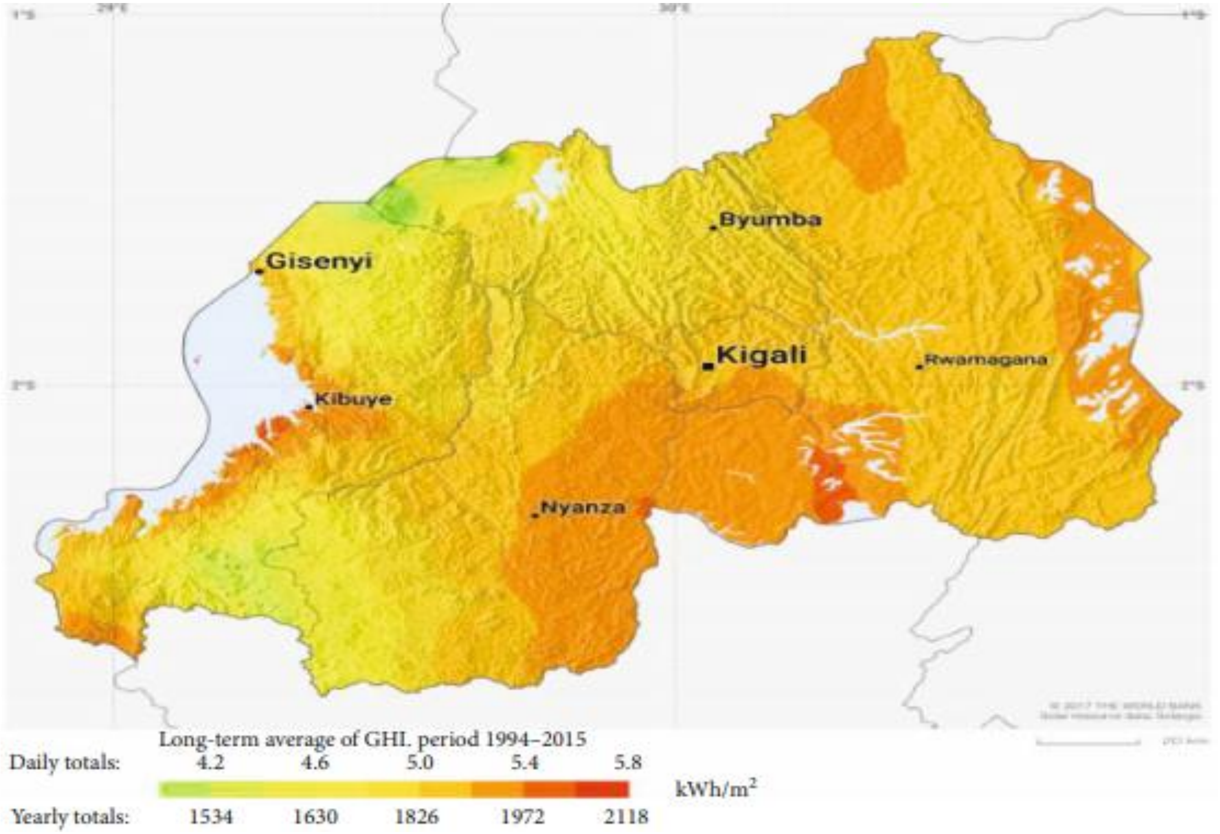
Introduction

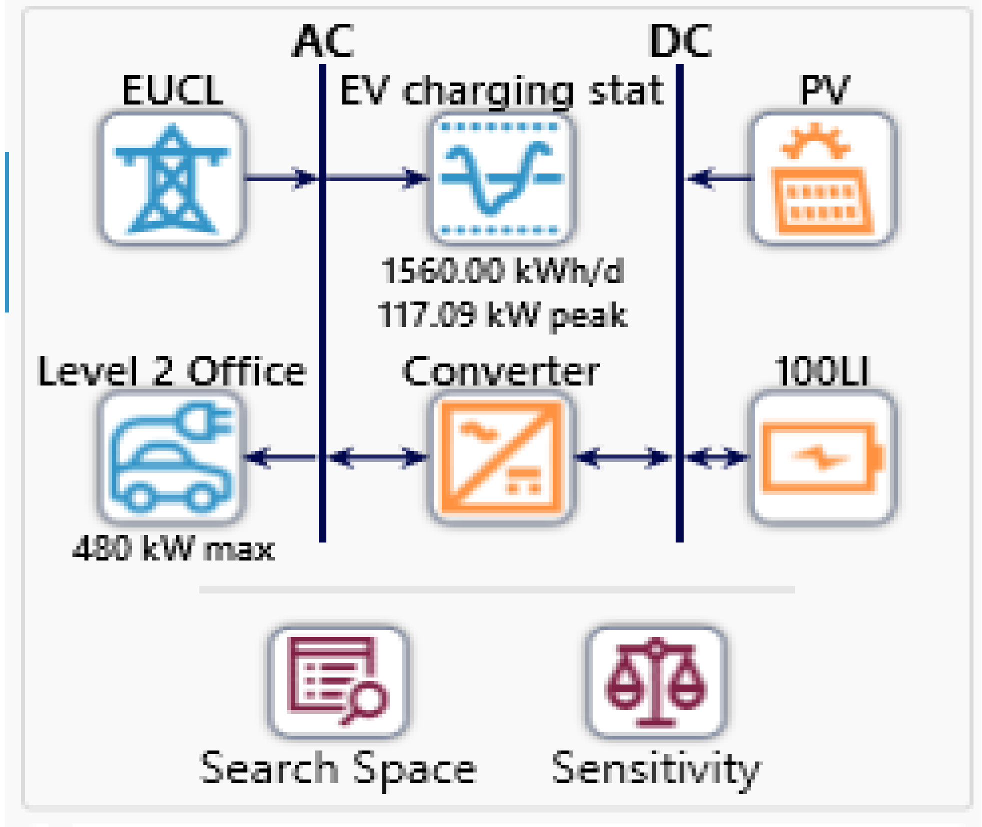
- Rwanda intends to focus on the transport sector as a key initiative to achieve the country’s climate change goals.
- Within Rwanda’s Vision 2020 framework, it was estimated that petroleum products will increase by more than 10% per annum, which will also increase emissions.
- Rwanda began a collaboration with Volkswagen, and now the Rwandan Volkswagen plant currently assembles three models in Kigali.
- Electric vehicle (EV) charging stations will impose pressure on the national grid, leading to grid instability along with the load profile.
- There will be an increase in greenhouse gases resulting from electricity systems in order to meet rising demand.

Solar EV charging



- The global horizontal irradiation (GHI) map of Rwanda (1534 – 2018) classifies the country is suitable for solar energy (Figure 1, Solargis, 2015).
- Currently, the GHI in Rwanda is 5.3.
- The utilization of solar EV charging stations will resolve the pressure on the grid and also uses clean renewable energy sources to power the station.

Methodology



1. Technical modeling: Through HOMER Grid software, the research identified the solar PV system sizing to estimate the output energy required to meet EV demand.
2. Economic modeling: Through HOMER Grid software, the research identified the economic parameters, such as payback period, net present cost (NPC), cost of energy (COE) and internal rate of return (IRR) to evaluate the economic viability of the project.

Three levels of EV charging system

There are three main types of electric vehicles, including hybrid electric vehicles (HEVs), plug-in electric vehicles (PHEVs and full electric vehicles (FEVs). (Shahindra Md Nordin, 2018)

There are three power levels of EV charging system:

1. Level 1: chargers are typically located in homes and have power levels up to 1.4kW.
2. Level 2: chargers have power levels up to 19.2kW but typically offer charging at 3.3kW or 6.6kW, depending on battery capacity.
3. Level 3: direct current (DC) fast chargers have powers levels up to 90kW, though stations typically only provide power at a rate up to 50kW.

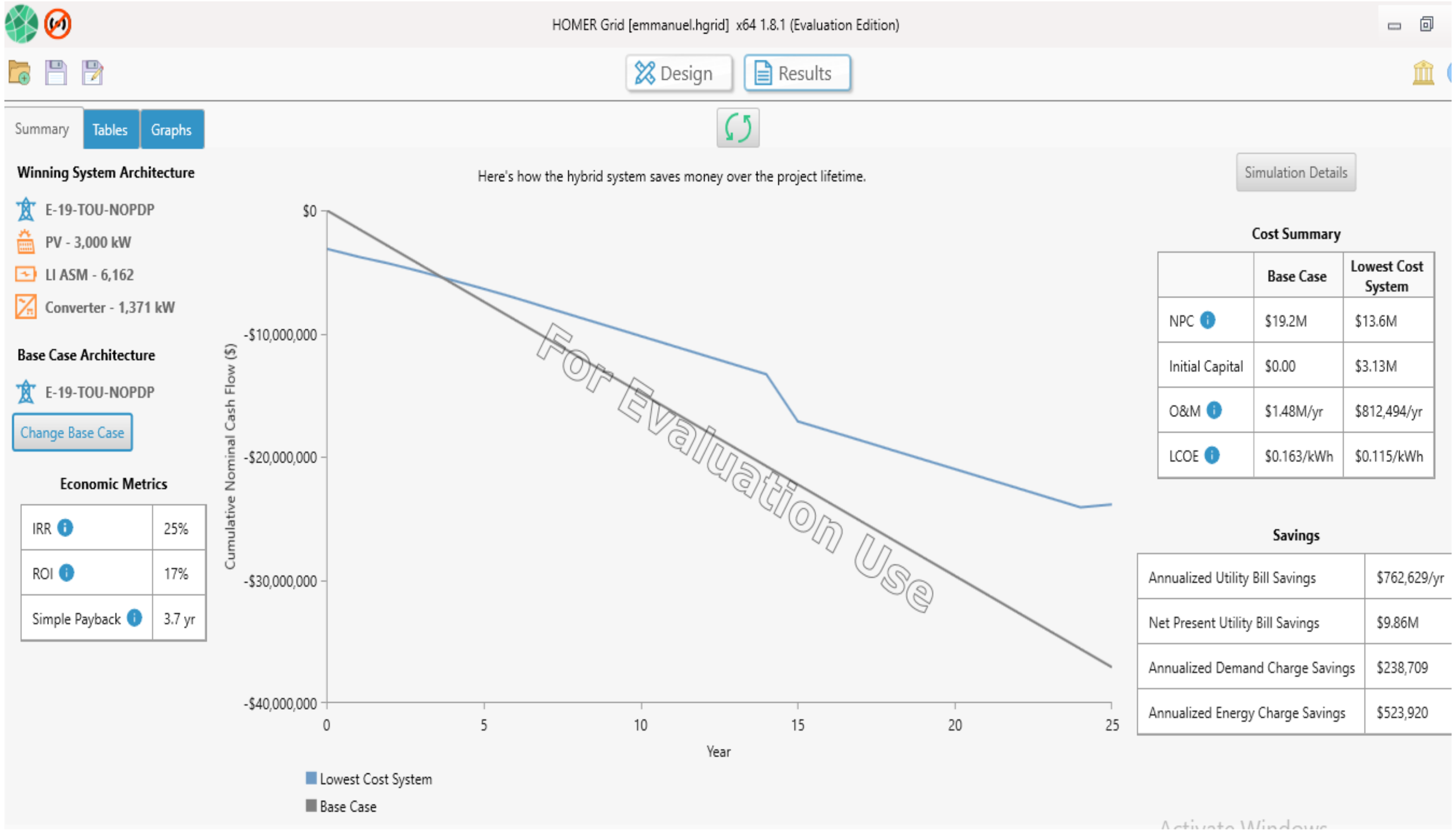
Results and discussion

- By assuming EV use is 29Kwh within 100 miles, that equates to 3.48 miles per kWh. The daily operating hours for EVs is approximately 12 hours, and the estimated distance travelled by EVs is between 40-80 kilomters per day. This means EVs will consume 0.2kWh per kilometer (C. Thomas, 2019).
- From real world testing, we can deduce these EVs are capable of providing approximately 85% of the 122.4 mile-range an consume 39.40kWh of energy per 196.9 kilometers for a single EV compared to the manufacturer’s claim. The energy demand of the charging station can provide charging for 100 EVs, which this study assumes have a load value of 3940kWh. For one EV, the load is approximated to 10kWh — for 100 EVs, this daily load is approximated to 1000kWh (1MWh).

Results and discussion

- These technical modeling estimations show the daily load consumption of the system will be 1560kWh/day. 56 modules will make up the solar powered EV charging station; the storage for backup will have 192 batteries and an inverter capacity of 20,940.233W.

Economic results



- ✓ The total NPC of $13.6M from this PV system is cheaper than that of $19.2M from a grid connected system, which was considered as the base case for this study.

Economic results

Architecture				Cost				System		Compare Economics						
				NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Present Worth ($)	Annual Worth ($/yr)	ROI (%)	IRR (%)	Simple Payback (yr)	Discounted Payback (yr)	Utility Bill ($/yr)
				$13.6M	$0.115	$812,494	$3.13M	49.9	0	$5.55M	$429,289	17	25	3.7	4.3	$762,629
				$14.8M	$0.112	$865,425	$3.60M	45.7	0	$4.40M	$340,258	13	18	5.2	6.6	$612,451
				$19.2M	$0.163	$1.48M	$0.00	0	0	$0	$0	0				$0
				$19.2M	$0.163	$1.49M	$28,167	0.00127	0	-$45,421	-$3,513	-9				$1,773

- ✓ The COE of $0.115/kWh from this PV system is cheaper than that of $0.163/kWh from a grid connected system, which was considered as the base case for this study. The IRR of 25% is also greater than that of 18% from the grid connected alternative, but without the storage.

Conclusion

- The annual average solar global irradiance in Rwanda is 4.91kWh/m^2 per day, which makes a solar powered EV charging station technically feasible due to the high energy potential of the region.
- The IRR of 25% is also greater than that of 18% from grid connected stations, but without the storage.
- The COE of a solar EV charging station is lower compared to the COE of the national grid, which makes the project economically feasible and sustainable.

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Thank you

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