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Electric Vehicles-to-Minigrids Integration (V2MG): A Way Out of the Energy and Financial Poverty Trap

Ingrid Rousseau ✉ & Rob Kleinbaum ✉

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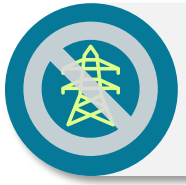
Executive Summary

This report shows the potential of vehicle-to-minigrid (V2MG) integration.

- The world is on the verge of an unprecedented surge in clean energy technologies with a widespread deployment of renewable energy and electric transportation.
- To date, the environmental and economic rewards have mostly gone to the privileged, resulting in worsening income inequality, social polarization, slower reduction of greenhouse (GHG) emissions, and growing disengagement.
- Historically, economic growth and rising emissions have gone hand in hand, presenting a dilemma to everyone concerned about both. By disrupting the system, e-mobility can help solve the dilemma.
- MDE was founded on the premise that integrating EVs with the current energy system could revolutionize the accessibility and affordability of electricity while providing transportation conducive to economic development.
- In developing markets with energy access deficits, our analysis shows that integrating electric two-wheelers with minigrids is enormous:
  - ~40% reduction of energy cost over best-in-class minigrid, bringing it on par with national grid costs, thereby creating access to affordable electricity,
  - Enabling transportation-facilitated economic growth by providing affordable and green transportation where there is none today, potentially supporting a fleet of 30 million EVs,
  - Mutually-reinforcing adoption of electric vehicles and minigrids,
  - 10% reduction ($25 billion) in global investments required to reach full electrification by 2030 for 58 countries with energy access deficit,
  - Supporting green growth,
  - Speeding the energy transition on a global scale.

The inability to access electricity and transportation is a major barrier to economic growth

$2.15/day is the average poverty line. About 700,000,000 people (~10% of global population) lived below it in 2019[1]



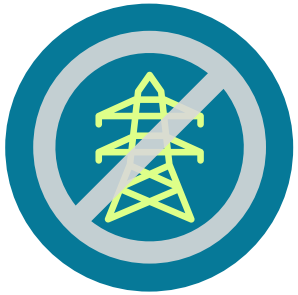
700 million people have no access to energy[1]

70% of rural Africans unable to reach jobs, education, and health care due to inadequate transport[2]

700 million more people are in the "undergrid," poorly served in peri-urban area[3]

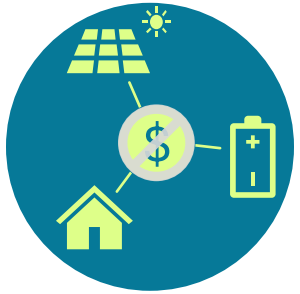
[1,2]World Bank, [3]Rocky Mountain Institute

Strong imperatives compel V2MG adoption



- **700M people have no access to energy, and 700M more live in the 'undergrid'**[1,4]
- Current means (grid expansion, small solar home systems, minigrids) to improve energy access are not viable
- **V2MG enables viable and wide-spread access to electrification**

- **The two-wheeler market is projected to grow at an annual rate of ~ 9% through 2029**
- Its **electrification rate is forecasted to grow to 30% globally by 2030**[5]
- **V2MG introduces mutually reinforcing opportunities for adoption of both minigrids and EVs**



- **Minigrids are rarely profitable and contingent on subsidies to exist**
- However, **minigrids remain the least-cost solution to electrify many** with electricity access deficit[1]
- **V2MG reduces the levelized cost of energy (LCOE) to national grids' prices enabling minigrid profitability**

- **Early pilots showing EVs being supported by minigrids are promising**[6]
- **V2MG builds on the promise of earlier pilots to support economic growth without compromising emissions**

[1]World Bank, [4,6]Rocky Mountain Institute, [5]McKinsey & Company

“Policymakers and countries shouldn't ever have to choose between reducing poverty and protecting the planet”

French President Emmanuel Macron
Summit for a New Global Financial Pact, Paris, June 2023

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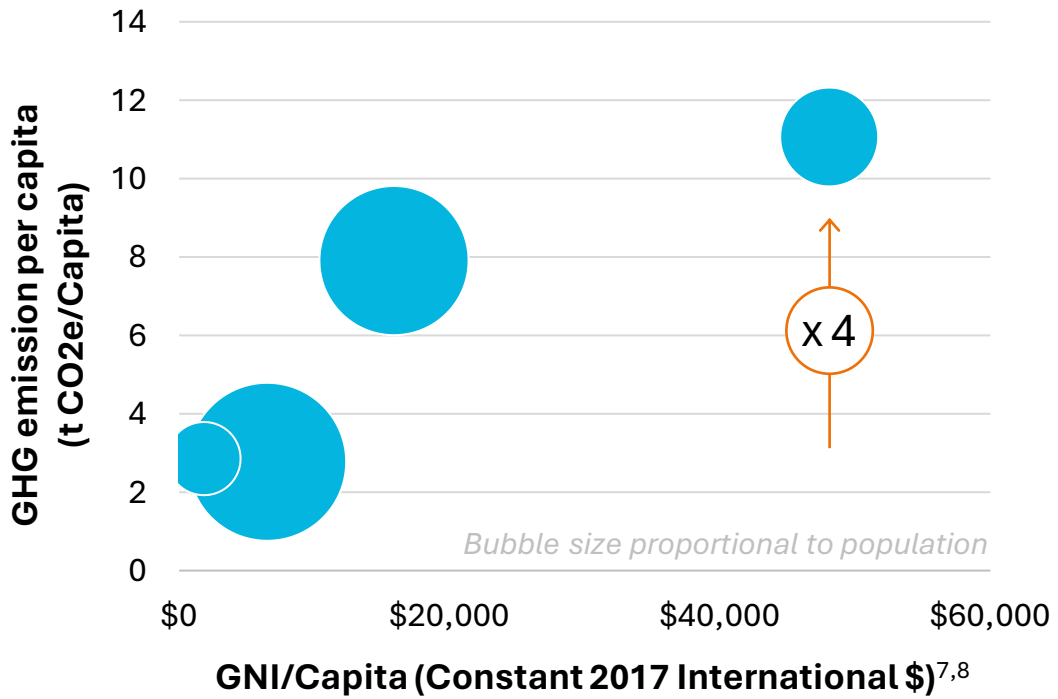
The conviction that decarbonization and economic growth cannot be solved simultaneously has misled many to believe that the growth, *specifically that of low income*, would irreparably increase global emissions

Historically, per capita CO2 emissions and income go hand in hand; with emissions quadrupling from low- to high-income countries



Adapted from [7]Climate Watch and [8]The World Bank

"Developing countries […] even excluding China from the calculation, are likely to emit more than half the annual global total of greenhouse gas (GHG) emissions as early as 2030."

[9]*Brookings*

"[…] two dozen emerging economies […] could cause the same massive wave of emissions that China produced during the first two decades of this century […]. This would render impossible the efforts to reach global "net zero" by midcentury."

[10]*Foreign Affairs*

"African governments rightly resent being told to cut emissions rather than help people in desperate need — especially given that Westerners continue to belch carbon."

[11]*The Economist*

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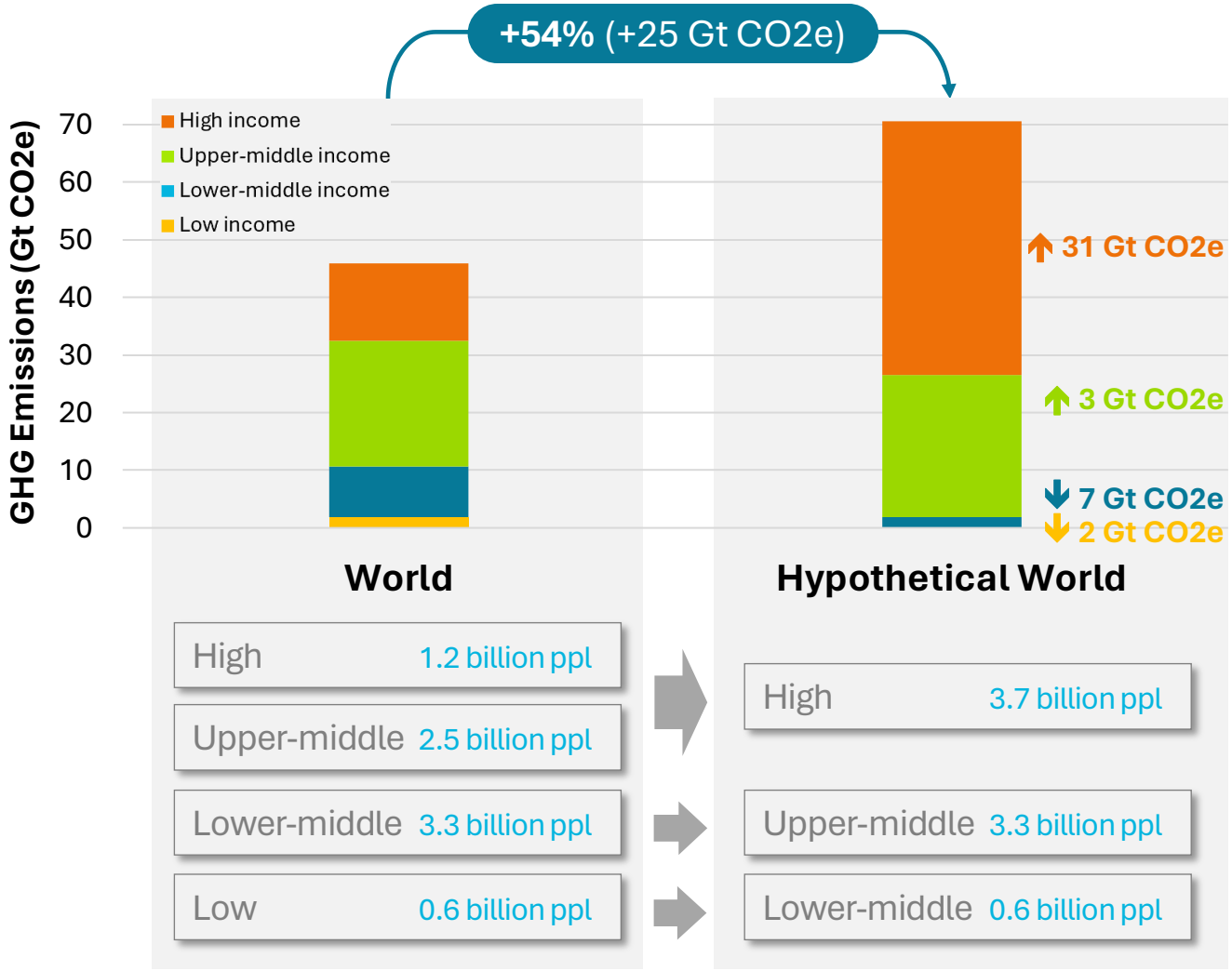
However, if each income group grew one level, it is the upper-middle income that would drive the global increase in emissions



Using today's per capita emissions, if each income group grew one level:

- Global emissions would increase by 54%
- The 2.5 billions **upper-middle income** joining the existing 1.2 billion high income **add 31 Gt CO2e/yr**
- Lifting the **low- and lower-middle-income** to lower- and upper-middle income, respectively, would **reduce emissions** by a net 6 Gt CO2/yr and significantly improve the life of billions

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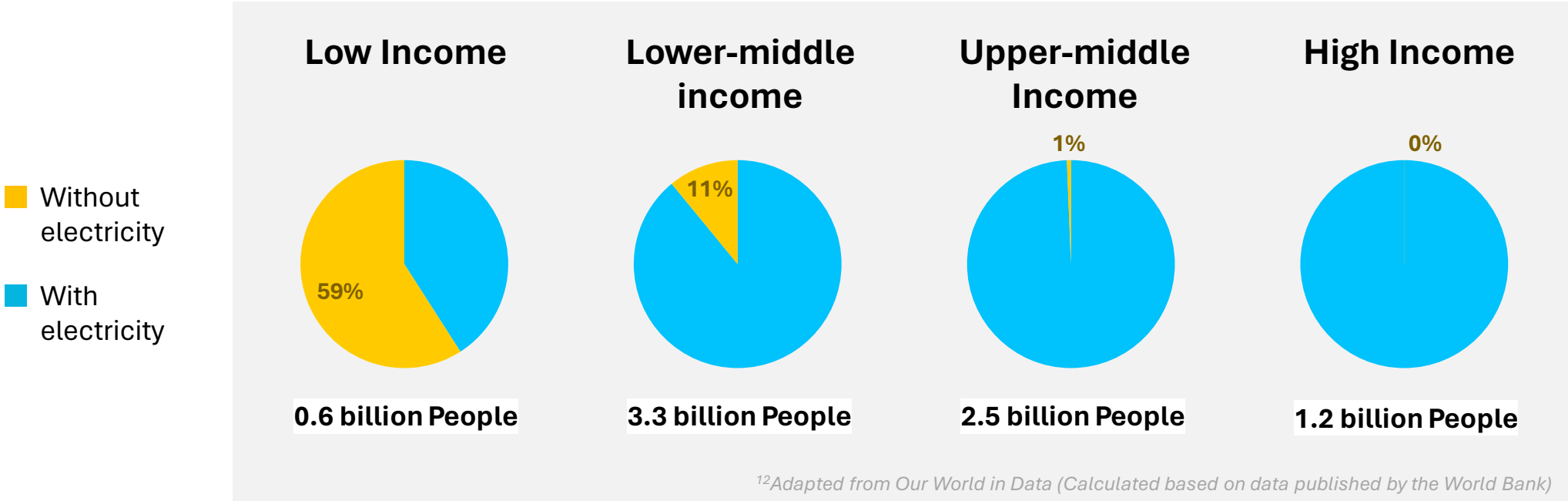
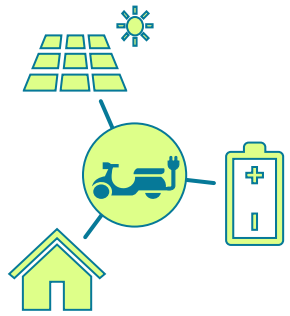
In addition to sheer financial poverty, the low-income population also lives in absolute energy poverty[12]



[12]*Adapted from Our World in Data (Calculated based on data published by the World Bank)*

The electrification of transportation will unlock unprecedented opportunities by transforming the energy system and its economics.



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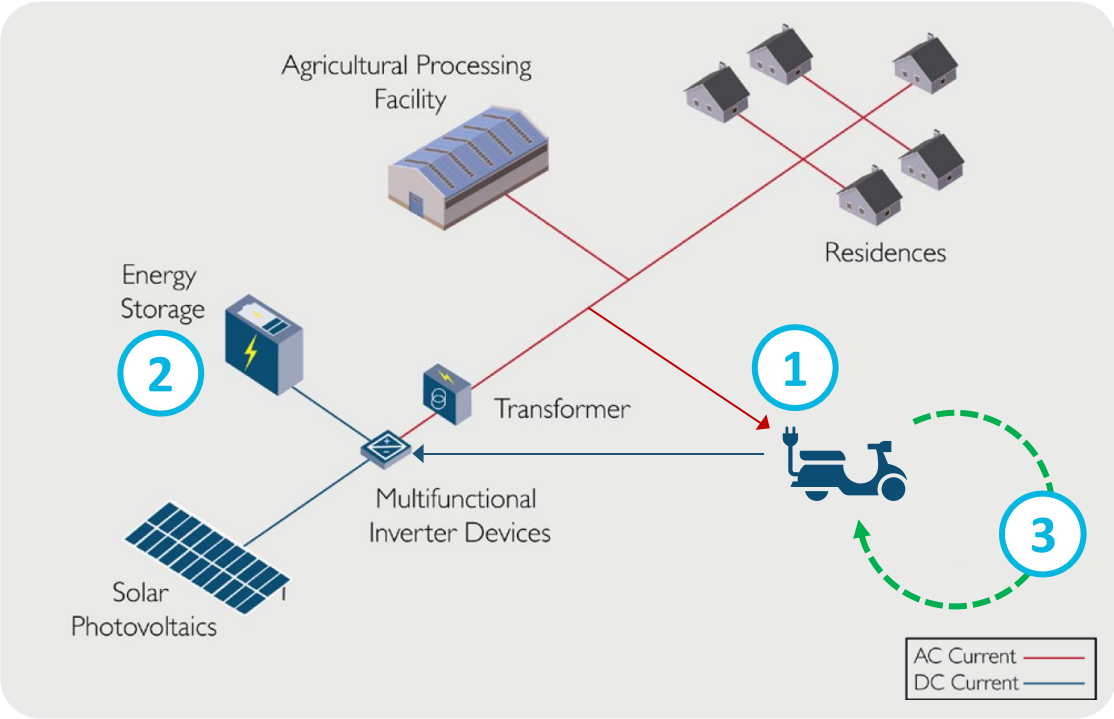
Bidirectional EVs will become key enablers to ending the trade-off between emissions reduction and economic development by…



Sub-Saharan Africa (SSA) Mini grid[13]

[13] *Meister Consultants Group*

① **Adding load** to eliminate wasted energy and lowers the cost of energy

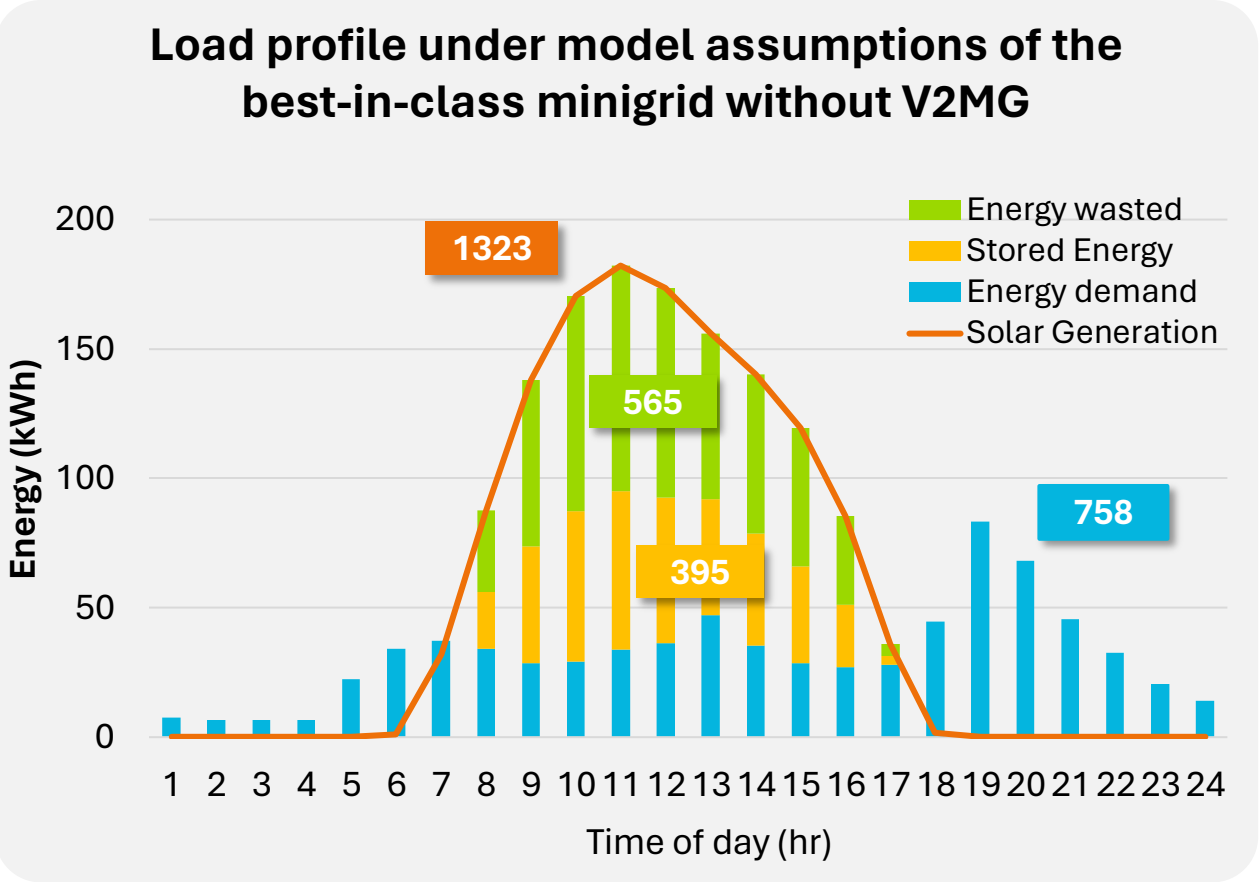
② **Storing energy** thereby reducing capital costs by substituting the mini grid battery with e-bikes

③ **Providing "fit for purpose" transportation** tailored to local conditions to facilitate **economic growth**

Our modeling assumptions

Model Assumptions		
e-motorcycle	**Battery capacity** Nameplate, Dual Battery (kWh)	6.5
	Battery capacity Nominal (% of Nameplate capacity)	88%
	Energy efficiency (Wh/km)	47
	Battery charger (kW)	0.6
Best-in-class minigrid[1]	**kWp**	286
	Stationary battery capacity (kWh)	690
	Average daily load, Total (kWh)	758
	Load factor, Year period	22%
	Number of connections	793
	Stationary battery CapEx as % of system	15%
	LCOE ($/kWh)	0.38
V2MG	**People per EV**	30
	Productive use mileage (km)	50
	% stationary battery capacity replaced by EVs	80%
Solar profile	**Yearly average for Wamba, Kenya**[14]	

[1]The World Bank, [14]Global Solar Atlas



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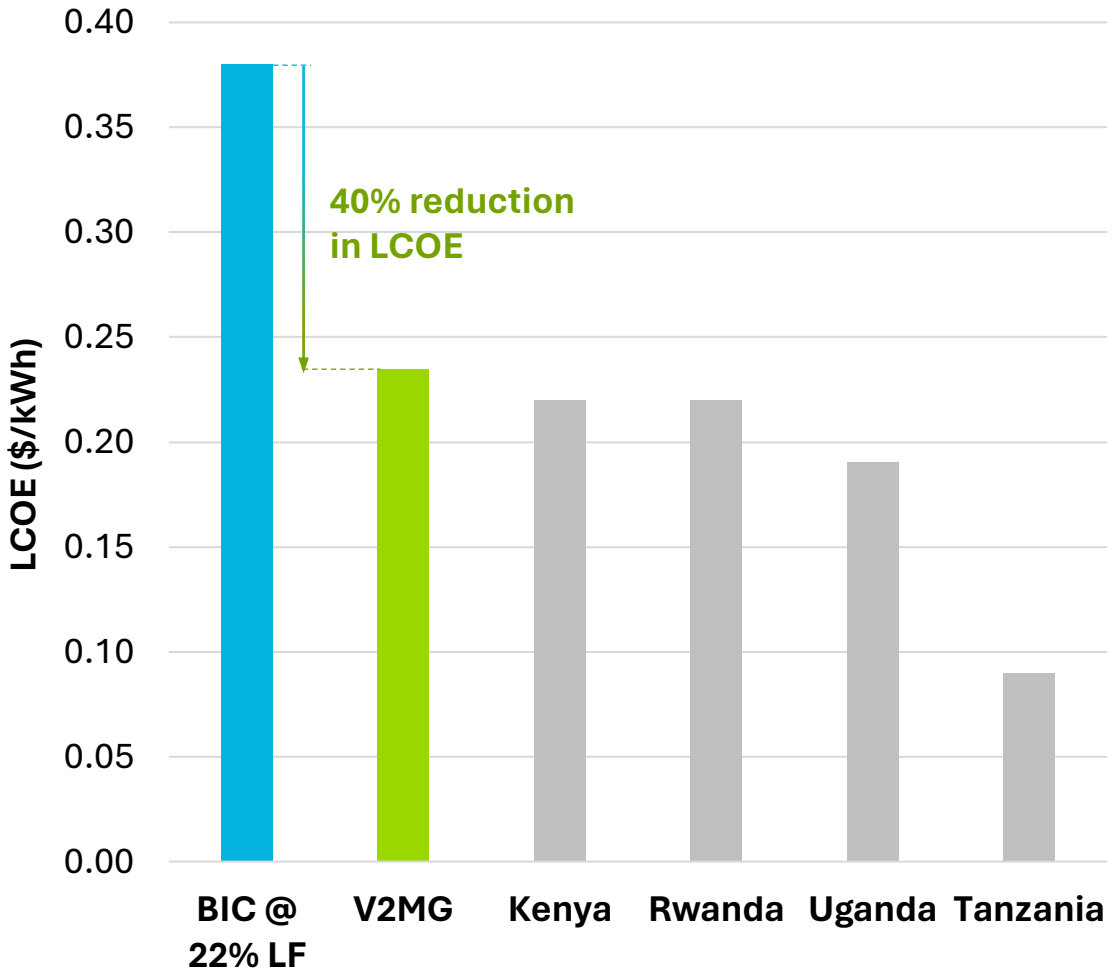
Modelling suggests that V2MG lowers the cost of energy sufficiently to drive widespread access to electricity



V2MG enables minigrids that are viable by:

- **Reducing LCOE by 40%** over the best-in-class (BIC) minigrid ($0.23/kWh vs. $0.38/kWh)
- **Reaching grid parity** with Kenya, Rwanda and Uganda's national grids. Grids like that of Tanzania, with heavily subsidized electricity, will challenge unsubsidized ways to bring electricity and opportunities to those who have neither
- And, inherently, **enabling transportation-facilitated economic development**

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V2MG could support a fleet of 30 millions e-bikes in countries with an energy deficit

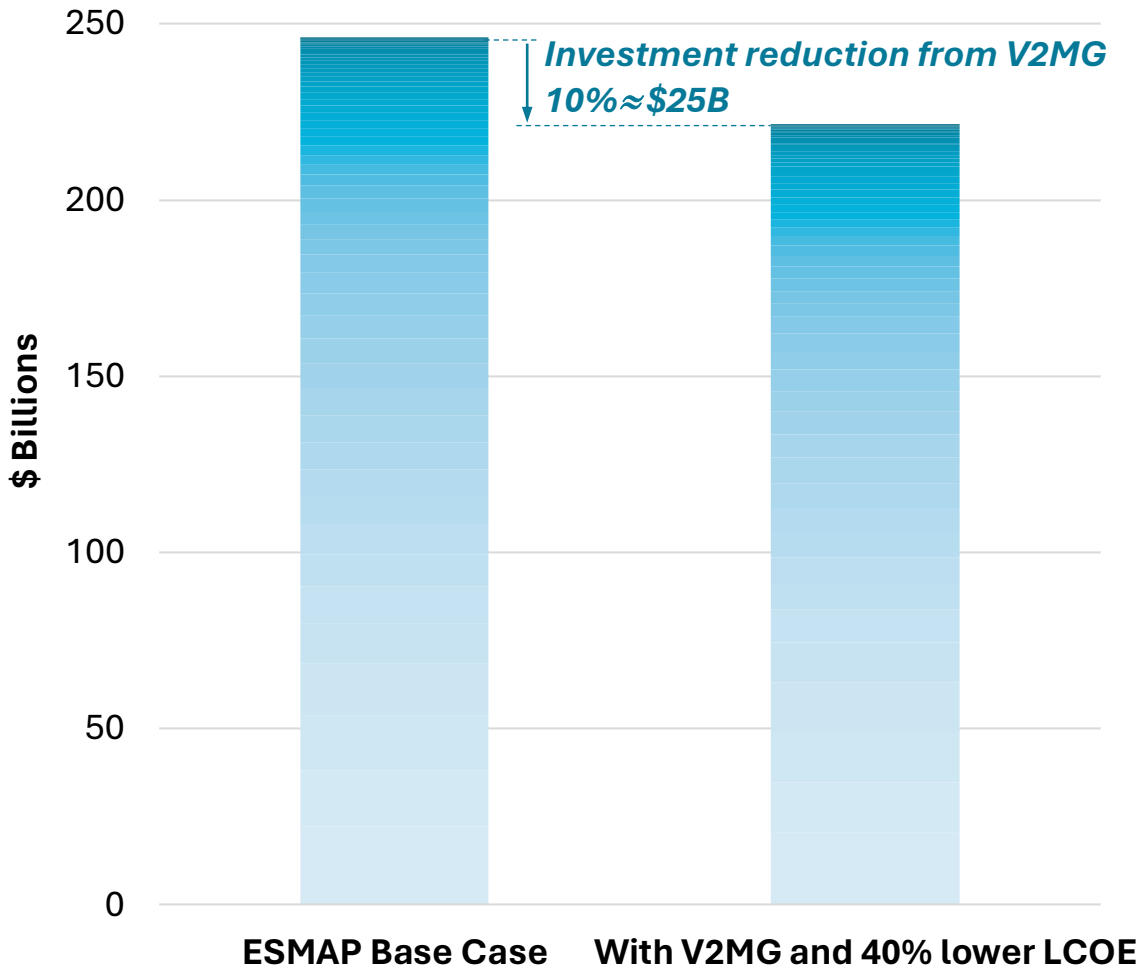
- Extrapolating our base case model to the almost 430 million people identified by the World Bank (see Table below[1]) that could be served at least-cost by minigrids (~90% in Sub Saharan Africa) projects that the size of the e-bike fleet from V2MG could reach 30 million vehicles
- This could be a conservative estimate once V2MG is proven to lead self-reinforcing systems that drive organic demand of both EVs and minigrids

	Optimal minigrid system size (kW)						
	<20	**20-80**	**80-200**	**200-500**	**500-1000**	**>1000**	**Total**
Population per Settlement	72	294	944	2,264	5,043	13,793	-
# of settlements (thousands)	622	421	104	33	7	4	-
kWp	9	40	121	298	679	4420	-
# of EV per settlement	4	18	56	137	314	2,043	-
# of people per EV*	17	16	17	16	16	7	-
# of EV (Millions)	3	8	6	5	2	7	30

**Although realistic, the number of people per EV tabulated differs from our best case (16 vs. 30, respectively). The difference is due to the distribution by minigrid system size provided by the World Bank and sourced from the ESMAP analysis of Global Electrification Platform results. It infers population per settlement numbers that are about half what the World Bank best in class minigrid settlement population to be (2,264 vs. 3,965, respectively).*

V2MG could decrease by 10% the required investment to reach full electrification by 2030 for most countries with an energy deficit

- ESMAP estimates that it would take almost $250 billion to fully electrify using the least-cost method for 58 countries with an energy deficit[15]
- Under the current assumptions, by decreasing LCOE 40%, V2MG drives a 10% decline in required investment (a $25 billion difference)
- Naturally, the impact would be most important for countries that are more conducive to benefiting from minigrid installation rather than extension from the existing grid



[15] The World Bank Global Electrification Platform

While the idea looks good on paper, many “high concept” ideas crash on the rocks of commercial, technical, societal, and cultural realities

- Substantial barriers to implementation include:
  - Challenges associated with minigrids’ maintenance, battery replacement, lack of market acceptance, subpar lifecycle planning and resourcing: All affect the viability of minigrids
  - Alignment of productive use with grid load curves. Coordination between EV charging, discharging, driving, and energy generation and demand will be critical
  - Regulatory requirements, protocols, and standards: in their infancy, in flux, with great variation across geographies
  - Lack of cooperation between private, public, and NGO sectors at the global, national, and local levels
  - Costs and techno-socio-economic design: We assume that V2MG will decrease the investments required to electrify with minigrid; this is still to be proven
  - With a high market potential, scalability will hinge on the support of financial and regulatory mechanisms
- These will require work and resources, but they are not insurmountable. Success will hinge on techno-socio-economic designs, and supportive regulatory and social environments.

Conclusions

- Without economically viable, self-sustaining minigrids, too many will be left in financial & energy poverty.
- Economic growth of the already advantaged will drive the increase in GHG emissions highlighting the importance of decarbonization efforts in developed countries.
- The fear that low-income countries could generate an unprecedented increase in global emissions from economic growth appears unjustified. It must not be a reason to leave them behind.
- Our analysis shows that V2MG can provide the means to a path that lifts the poor, accelerates EV adoption and expands access to clean and affordable electricity. A path that shortens our journey to a zero-carbon world by:
  - Lowering the cost of energy by 40%, bringing it near parity with that of national grids, enabling profitable, self-sufficient systems
  - Providing affordable green transportation for productive use, enabling green growth,
  - Reducing by 10% ($25B) the investment required to reach full electrification for 58 countries with energy access deficit, if widely deployed,
  - Supporting a fleet of 30 million EVs, if widely deployed, providing mutually reinforcing opportunities for adoption

There is an opportunity to design similar solutions that integrate a variety of electric vehicles, small and large, with the energy system that would prove critical in global growth with minimal carbon cost.

Success will hinge on techno-socio-economic designs, and supportive regulatory and social environments.

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References

1. Energy Sector Management Assistance Program, Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers., Washington, DC: International Bank for Reconstruction and Development. The World Bank, 2022.
2. Sustainable Mobility for All. 2017. Global Mobility Report 2017: Tracking Sector Performance. © Washington, DC
3. World Bank (2023), Poverty and Inequality Platform (version 20230919_2017_01_02_PROD) [data set]. pip.worldbank.org. Accessed on 2023-12-06
4. J. Agenbroad, K. Carlin, K. Ernst and S. Doig, "Minigrids in the Money: Six Ways to Reduce Minigrid Costs by 60%," Rocky Mountain Institute , 2018.
5. R. Gupta, P. Hertzke, V. Lath and G. Vig, "The real global EV buzz comes on two wheels," McKinsey & Company, 2023.
6. A. Allee, J. Sherwood and S. John, "Powering Small-Format Electric Vehicles with Minigrids," Rocky Mountain Institute, 2022.
7. Climate Watch, "Global Historical Greenhouse Gas (GHG) Emissions," Climate Watch.
8. The World Bank, "World Development Indicators, GNI per capita, PPP (constant 2017 international $)," The World Bank, Washington, 2023.
9. A. Bhattacharya, H. Kharas, and J.W. McArthur, " Developing countries are key to climate action," Brookings, Commentary, March 3, 2023.
10. K. Sims Gallagher, "The Coming Carbon Tsunami," Foreign Affairs, 14 December 2021.
11. "How misfiring environmentalism risks harming the world's poor," The Economist, June 2023.
12. Our World in Data. "Access to Energy", accessed December 2023, https://ourworldindata.org/energy-access
13. Meister Consultants Group, Inc., "Practical Guide to the Regulatory Treatment of Mini-Grids," National Association of Regulatory Utility Commissioners, Washington, DC, 2017.
14. Global Solar Atlas, "Wamba North ward," The World Bank, Washington, 2023.
15. The World Bank, "The Global Electrification Platform (GEP)," The World Bank, 2021.