Computing Our Way to Electric Commuting

(e-Taxis for Africa!)

I'd like to start by asking you to raise your hand on Teams if you've ever ridden in an electric vehicle. Post on the chat what vehicle it was.

While you do that, I'd like to tell you a story.

So when I was studying in undergrad, I used to take part in a competition called the SEM. Have any of you heard of it? (thumbs up)

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ckstar.co.za

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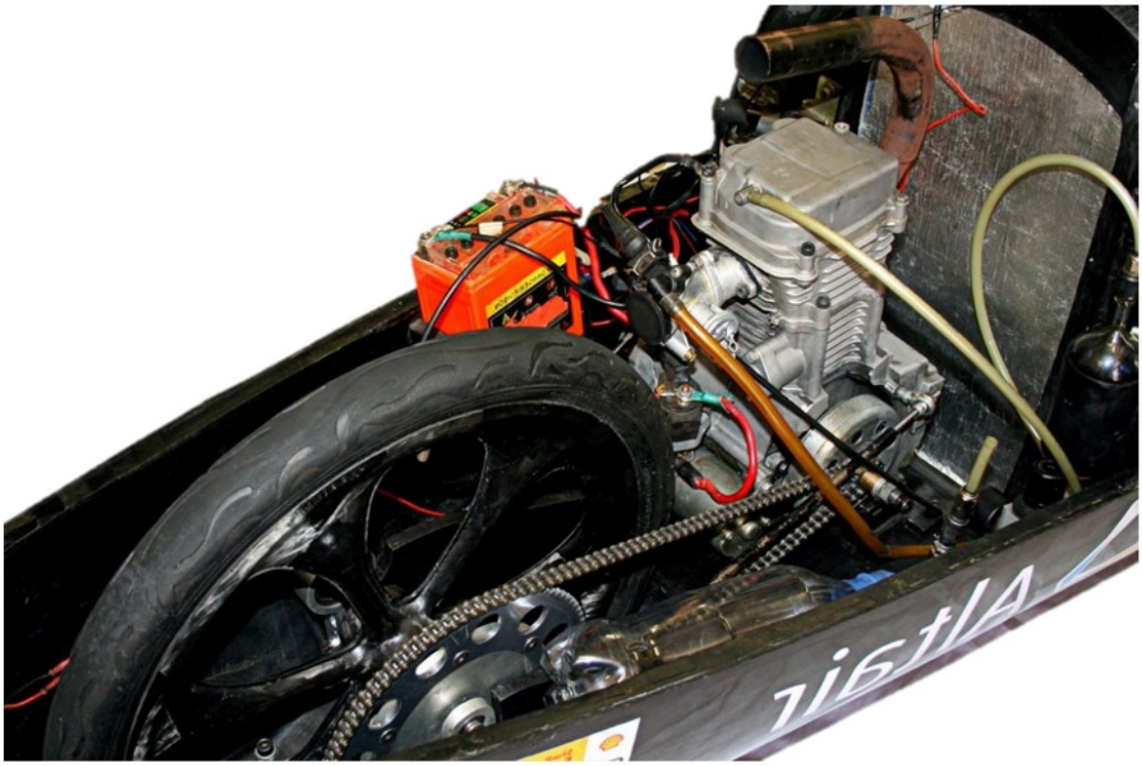
WINNING DESIGN: NMU's eco-car aces, from left, Prince Sekere, Chris Abraham, Matt Henry, Kahl Kritzinger, Nureen Hoosein and team leade
Brett Steyn after their win at Zwartkops Raceway

The goal of the competition is to make a car that can go as far as possible, using as little energy as possible. In 2018, we opted to use petrol, and we obtained a mileage of 180 km/l. We came first in the petrol category, and it was one of the highlights of my university career.

But in 2019, we took a big risk. To switch the car from petrol power to electricity! That was a huge risk. Would we come first in the battery-electric category? That was the task of my final year project.



So here is the original petrol transmission. It was a rear-wheel drive.

Hot-swappable electric transmission.

Our plan was to participate in the petrol category, then swap out the petrol transmission with the electric one. Then we would participate in the electric category. And hopefully… WIN BOTH!!!

Unfortunately, the event got cancelled that year, due to the Xenophobic pandemic in Johannesburg. We decided to test the electric drive at a nearby race-track, and we obtained a mileage of 240 km/kWh! So much better than the 180 km/l we were getting before. We were very chuffed.

From that day onwards, I had decided that I would dedicate my career to improving the way that we think about vehicles and transport.

(9kWh in a liter of petrol)

(Tesla: Maybe 10 km/kWh)

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So let me see what EVs you have driven…

Interesting! Well in my case, I've also driven an EV, and it was one that I built!

BTW, the Eco-Car has an efficiency of 240 km/kWh, while a Tesla only has an efficiency of less than 10 km/kWh!!

It would be nice, but I guess it's not feasible for everyone to drive our eco-car. After all, the whole thing is made of carbon fiber, has zero suspension, and only seats one person.

Obviously, the type of vehicle that you drive: its size, weight, etc. have a huge impact on its efficiency and your carbon footprint.

So the real question is: what is the best type of EV for our future? (Tesla, eco-car, electric bus, go-kart, motorbike, etc…?)

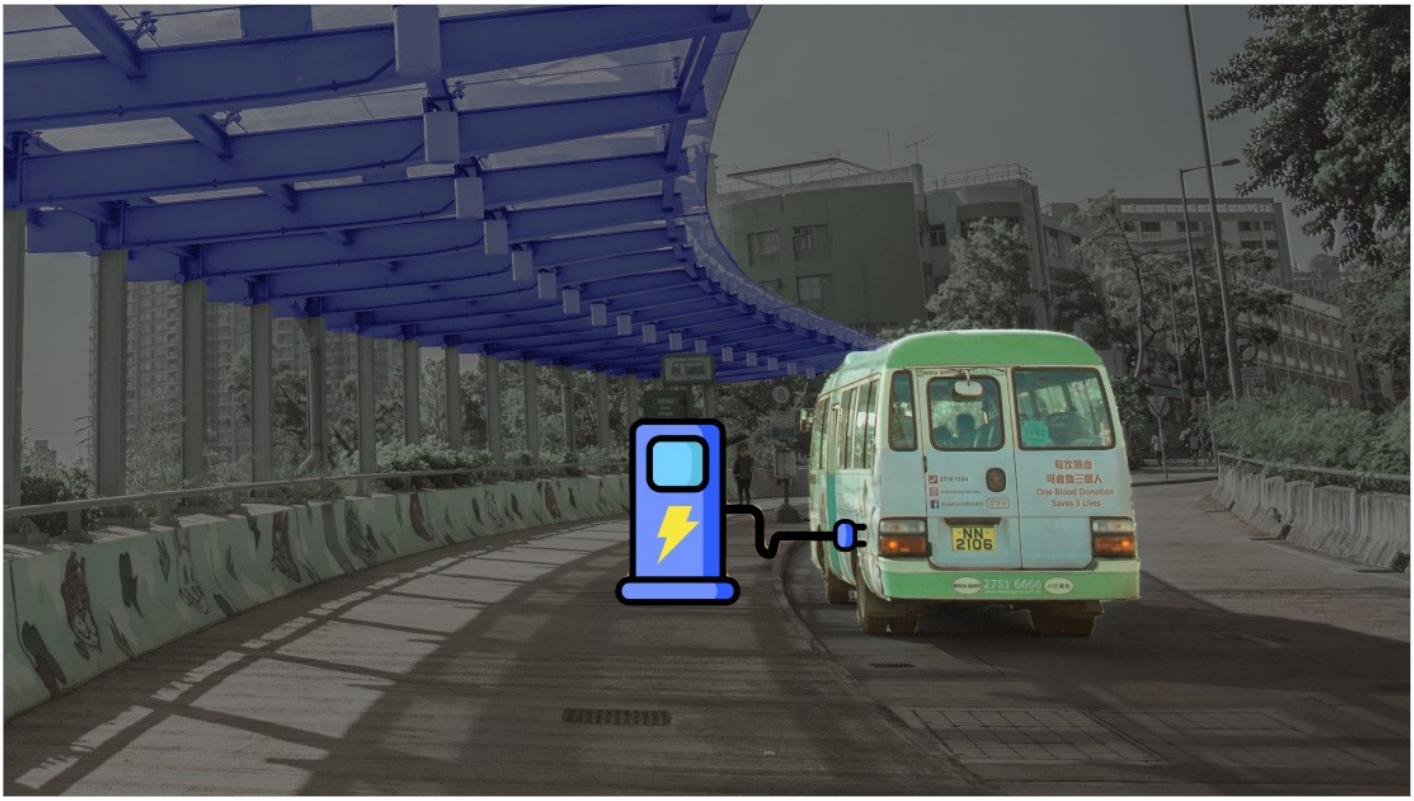
How many of you have been in a situation like this? Give moment to read…

Now substitute the word "bus" with "taxi", because that's what we use here in Africa.

… many solutions in the past … bus and train … struggle to meet the needs of the poor … operate at a loss. We need to take a different approach – by upgrading our taxi industry, rather than … competing … 1st world solutions which, simply, don't meet our needs.

Taxis are so valuable… need to be improved…

So… Here is the big idea. Are you ready?



ELECTRIC minibus taxis.

Africa’s home grown public-transport solution. But now, with batteries.

I know, I know… I can hear you screaming your pants off already: “What about Eishkom, I mean Eskom!? Can they cope with thousands of electric taxis?”


One Blood Donation
Saves 3 Lives
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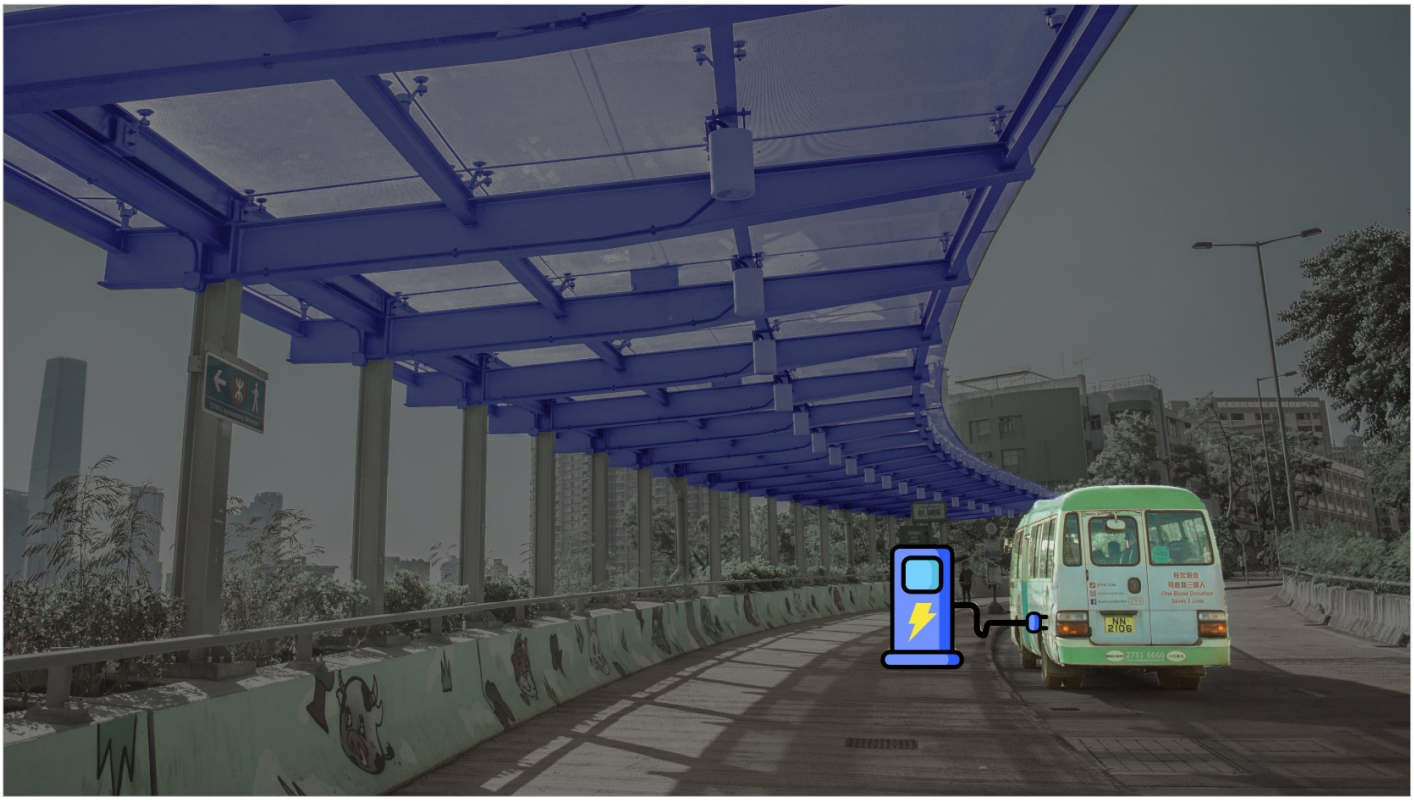
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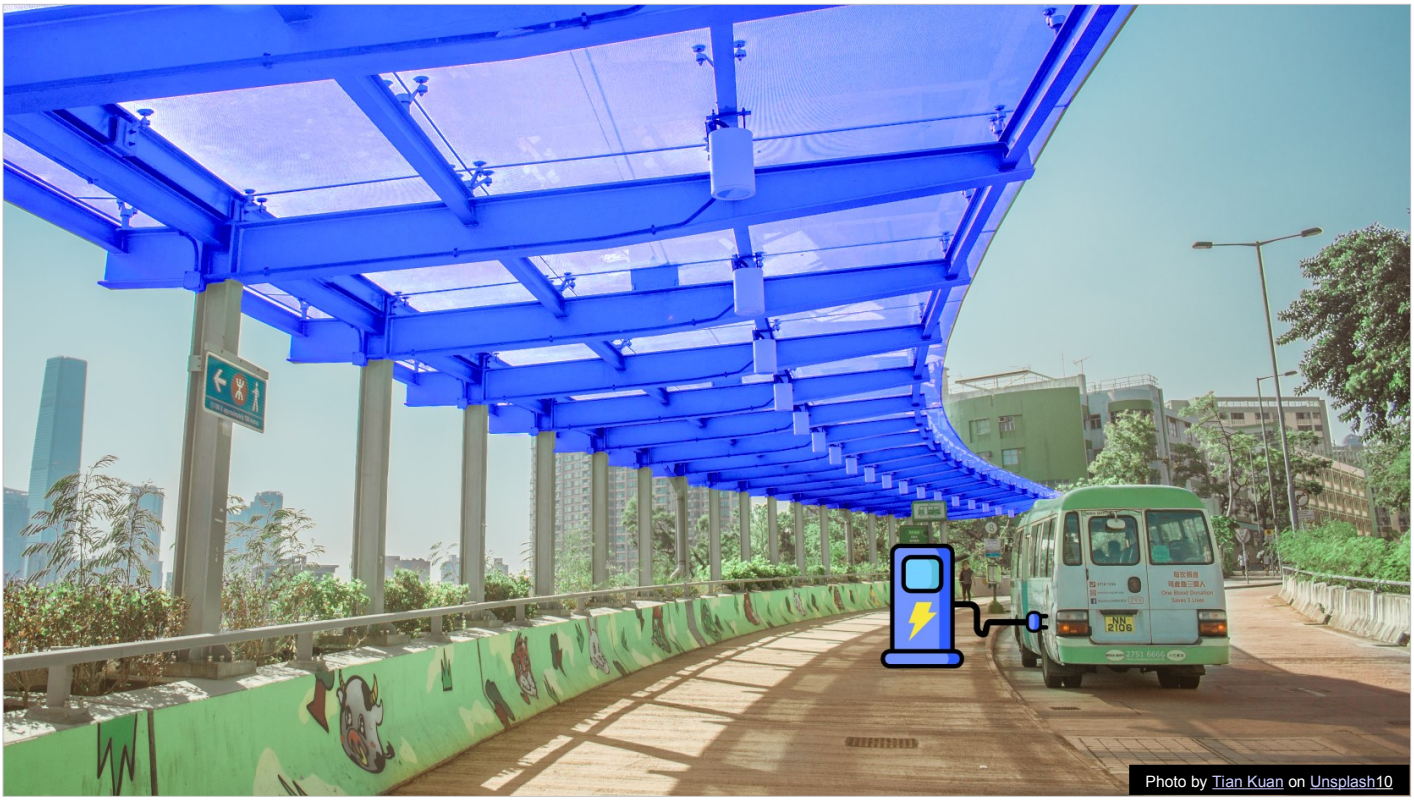


Taxis would become more appealing for all of us.

Fares ... cheaper, … all be using public transport, traffic … reduced ,

… and Africa will – once again – be the place where we can breathe…

If your videos were on, I'm sure I'd see a few people smiling skeptically. I know… This sounds like something out of a dream…

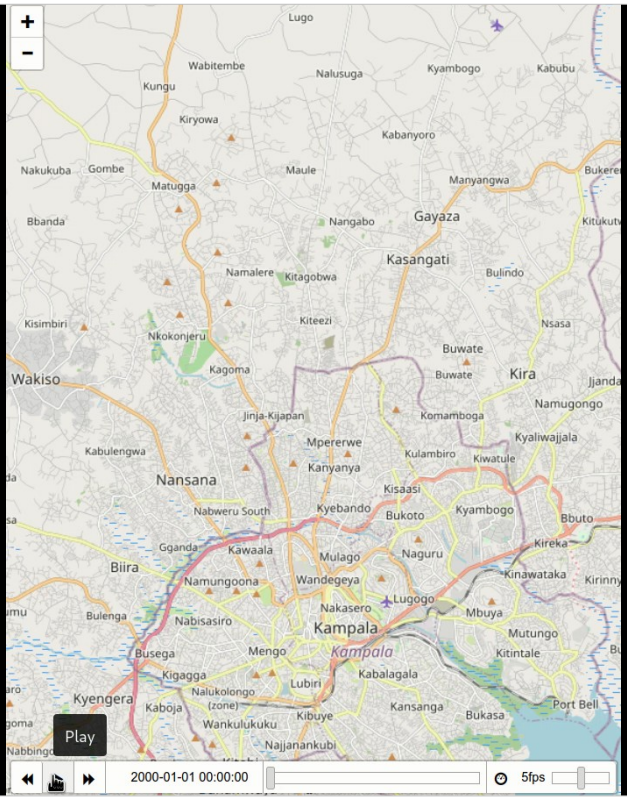
If only we had the data to show that it was possible.

That's where my research steps in.

We started by tracking ten taxis in Stellenbosch.
We used GPS trackers to see how much they move, and how much they stop.

If you know how much they move,
you know how much electricity they would use.

If you know how much they stop,
You know how much they can charge.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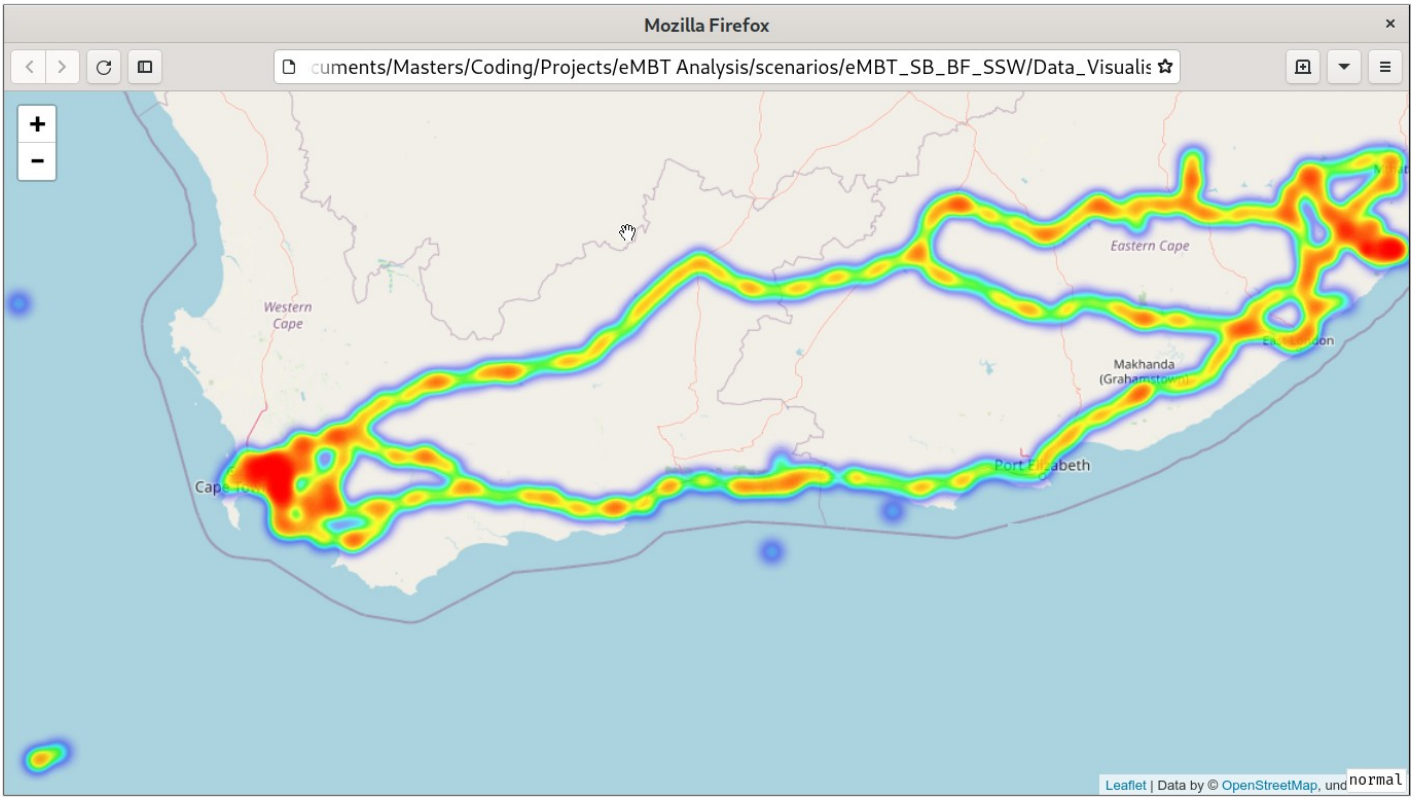
Let’s take a look at the resulting data, and see if we find anything interesting.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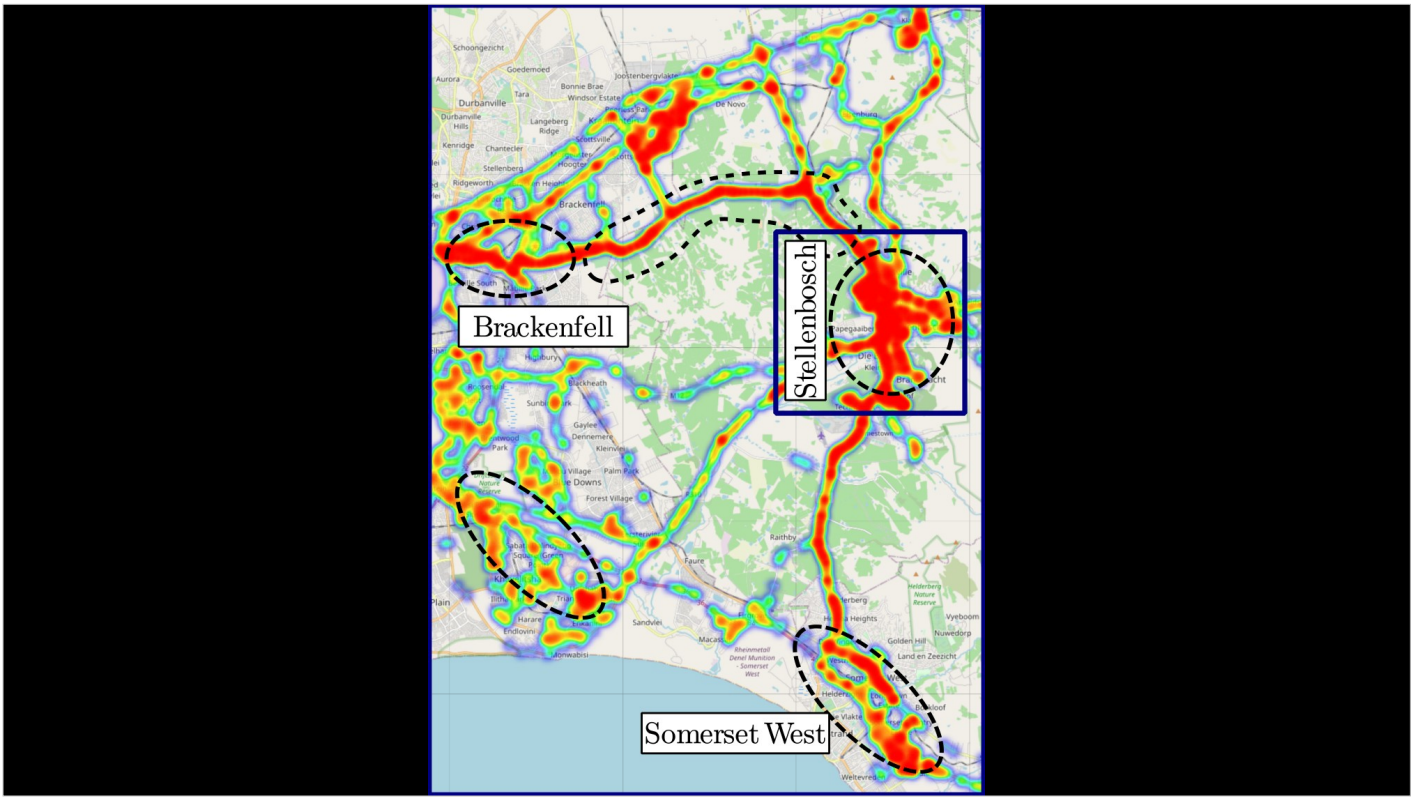
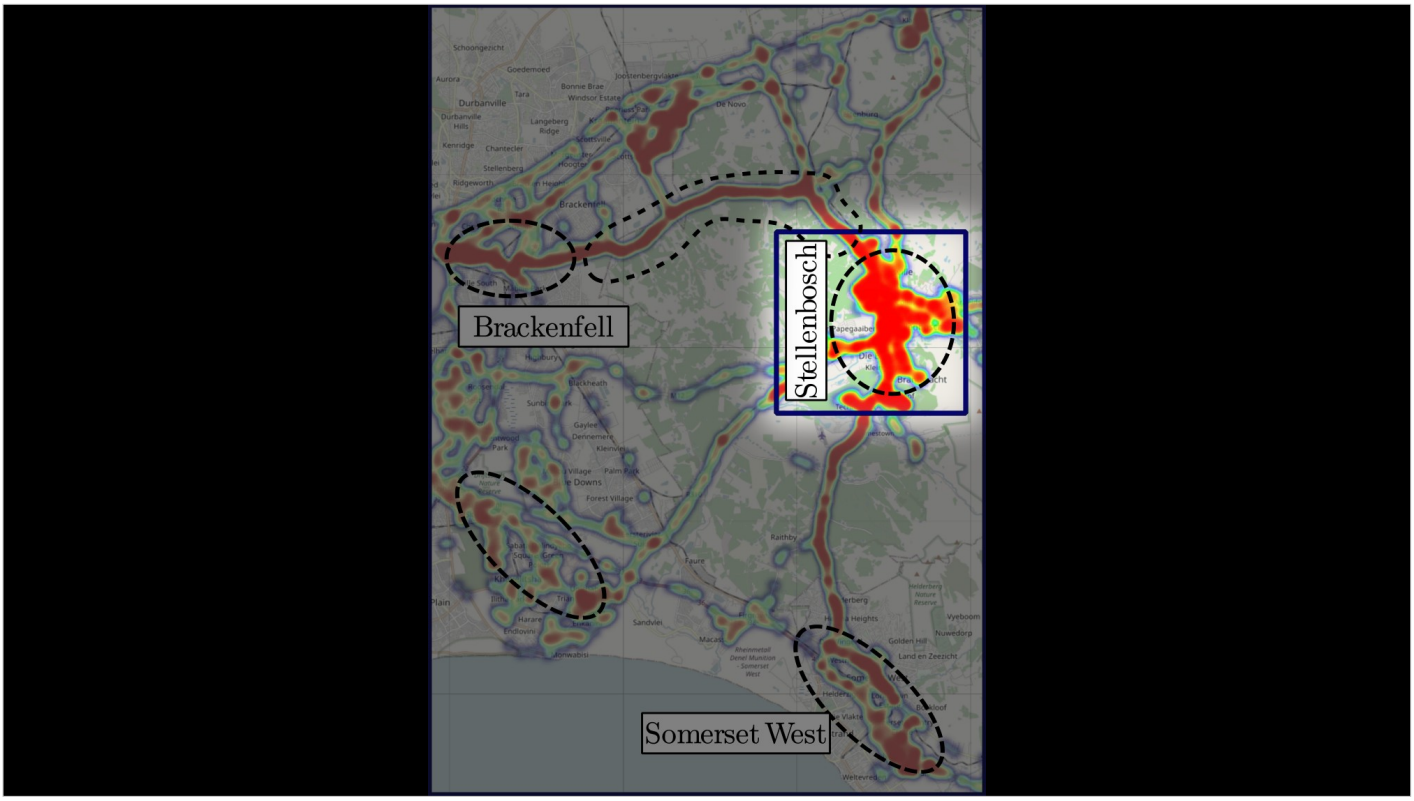
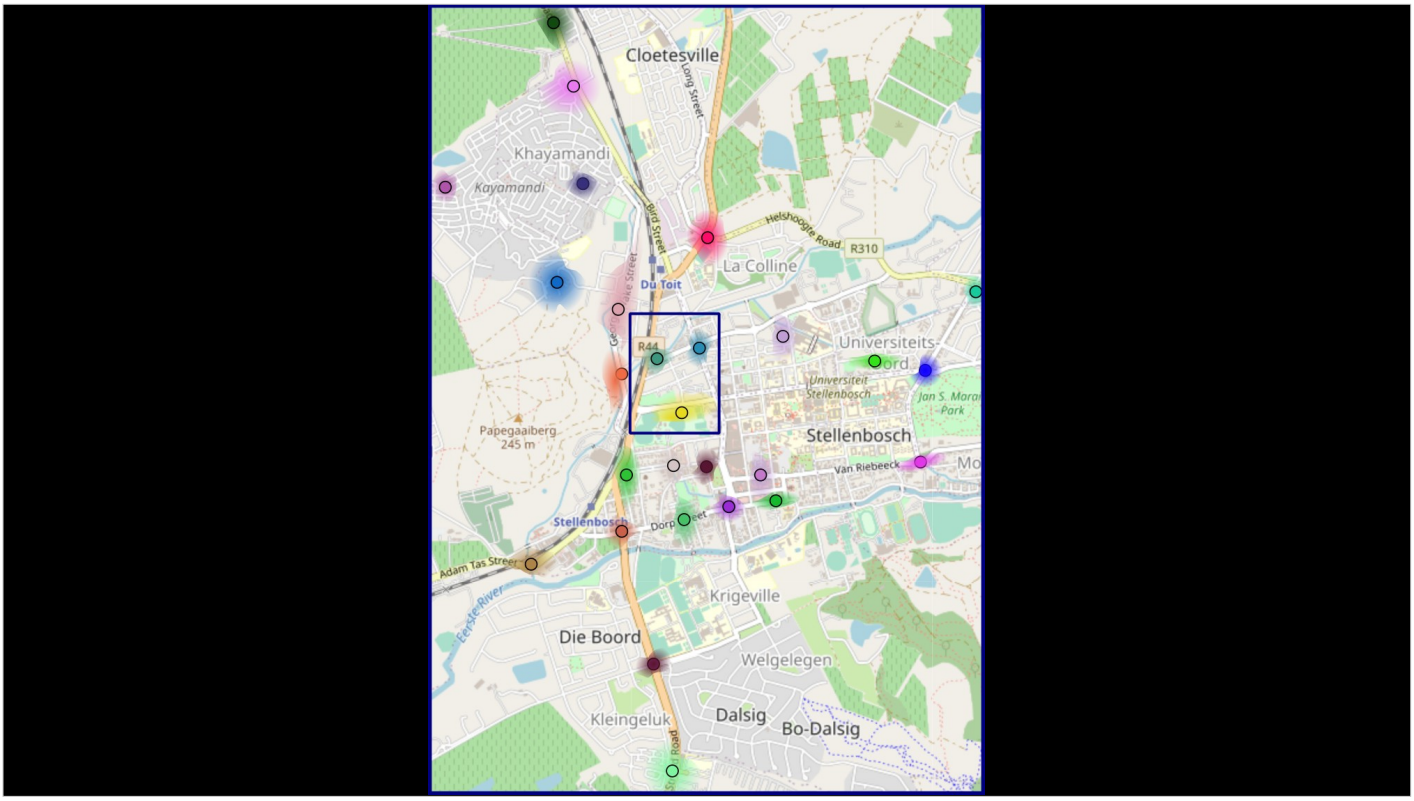


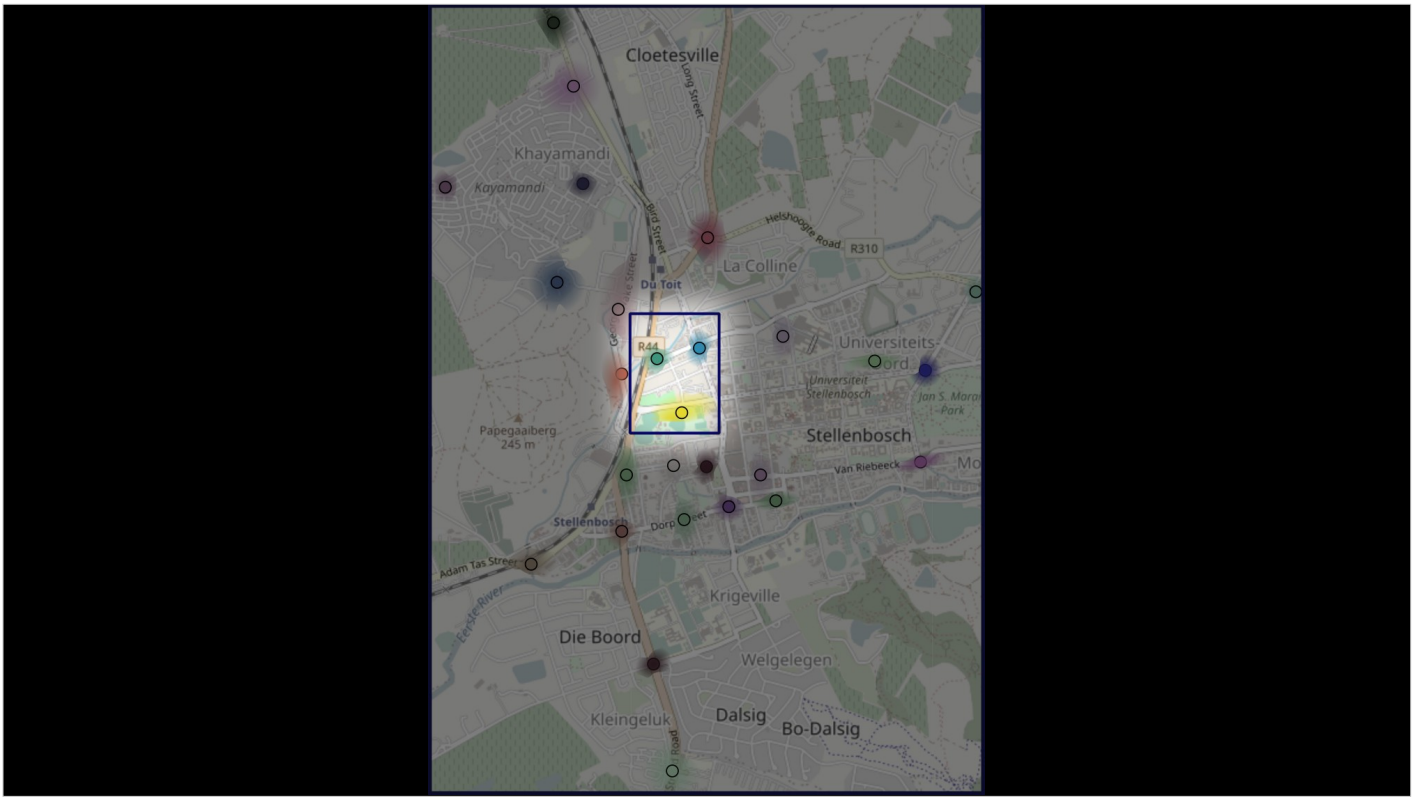
Here is a heatmap of one of the taxis... More red areas indicate a higher density of gps coordinates recorded at that location. So this taxi was based in Stellenbosch, and on a typical day, it did a few trips to Brackenfell in the morning and a few trips to Somerset West in the late afternoon.



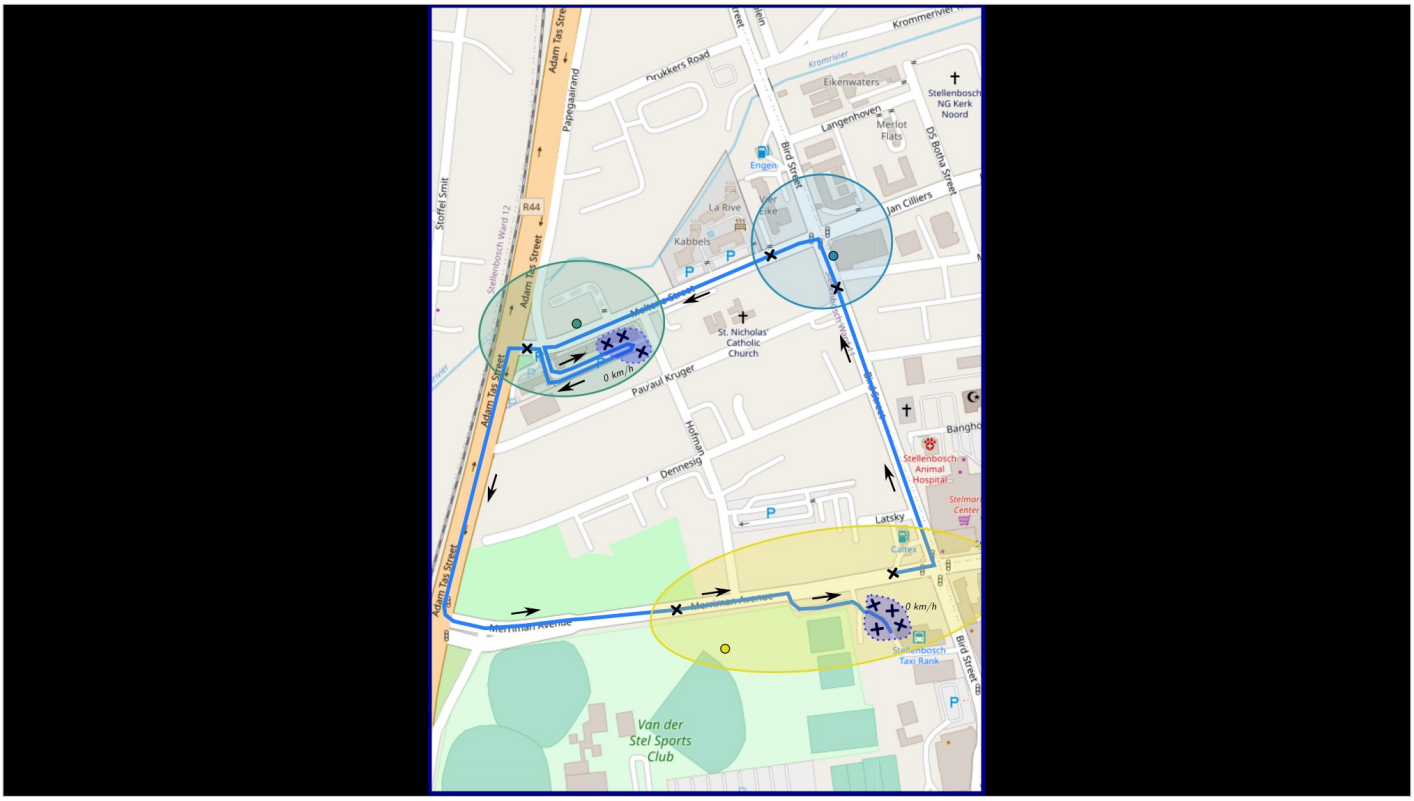
Let's drill down into Stellenbosch and see if we can find anything interesting.



Here, you can see a few colorful dots. I used a clustering algorithm to find the places where the taxis stops. Hmm… These could be optimum sites for charging stations...

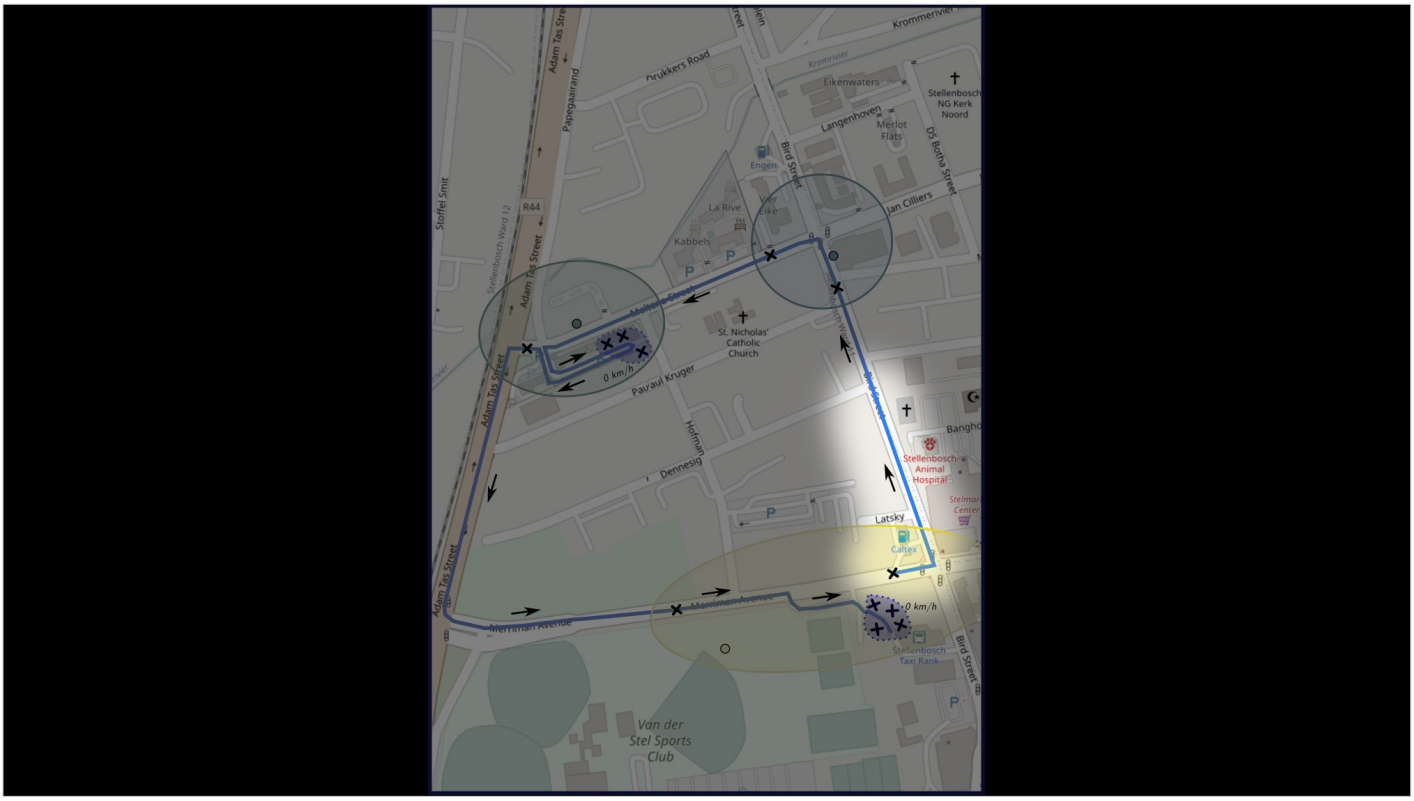


Let's drill down into a neighbourhood. Specifically, we are zooming into the Merriman—Bird Street junction.

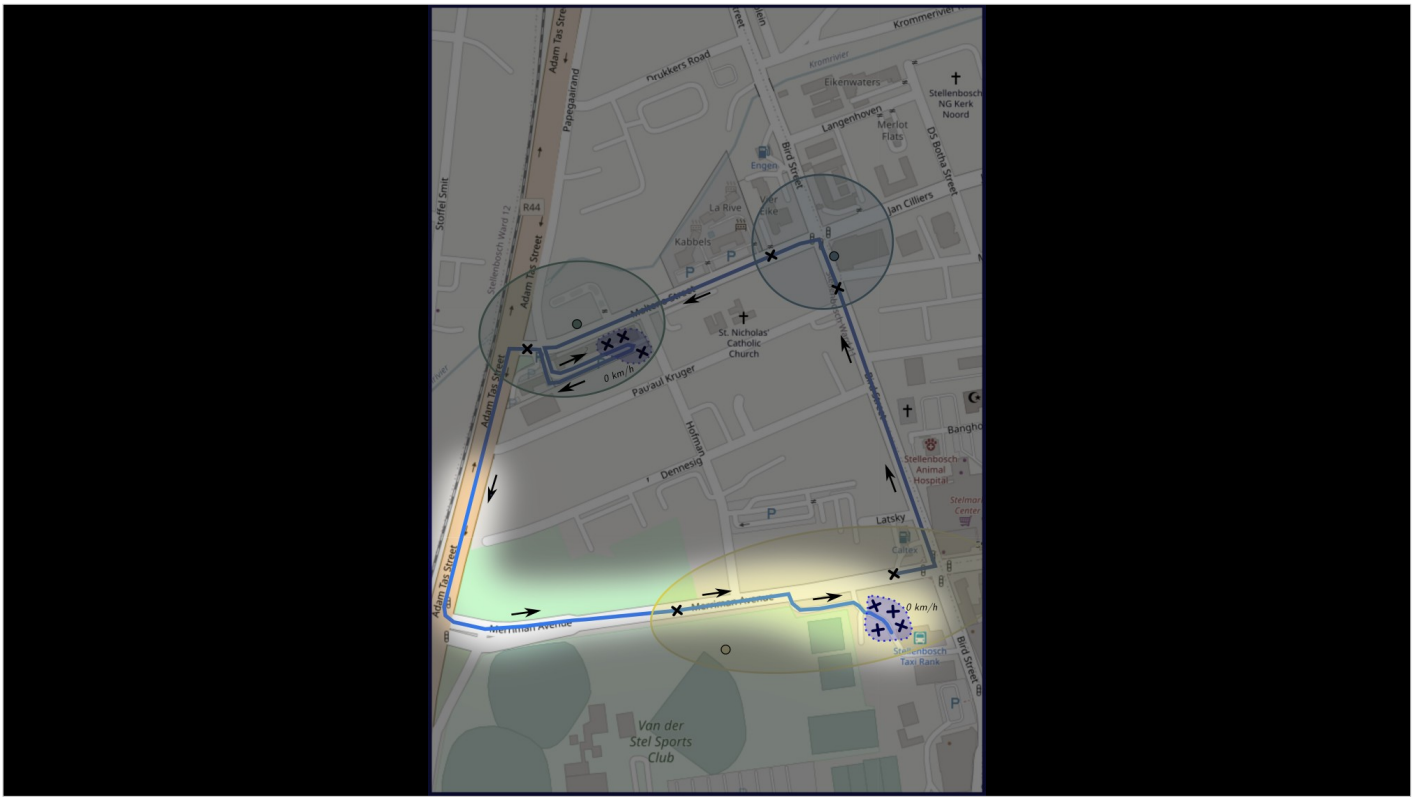


Here we are. The three colorful circles are the three spatial clusters which were identified in the previous step.

In this particular trip, the taxi starts at the yellow spatial cluster at the bottom.



The yellow spatial cluster was a good guess by my clustering algorithm! It represents the taxi rank on Bird Street. In this trip, the taxi leaves the taxi rank, and goes up bird street.



And in the evening it returns back to the taxi rank and parks there.

Distance: 230 km

Petrol: R 550

These are the characteristics. On average, a taxi drove 228 km in a day.

That's around R500 of petrol per day. Ouch.

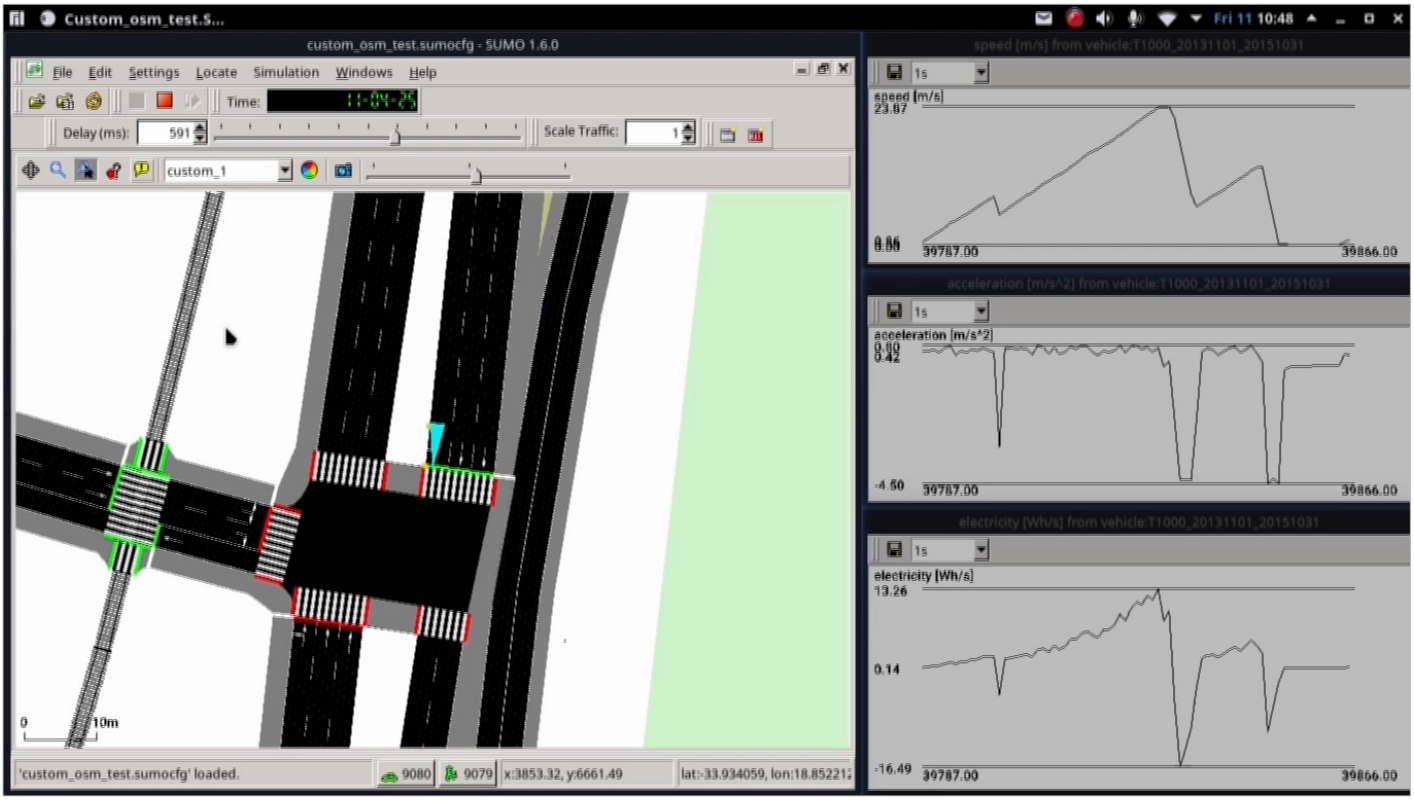
Let's see if we can beat that with electric vehicles.

Stops: 8–11 h

Another thing that we noticed was that the taxis have around 8–11 hours of chargeable stop time in a day. So these would be the times were they may get an opportunity to charge.

Btw, taxi drivers get no sleep… Their overnight stops were only 5–6 hours!

So we then took these above GPS traces and simulated them.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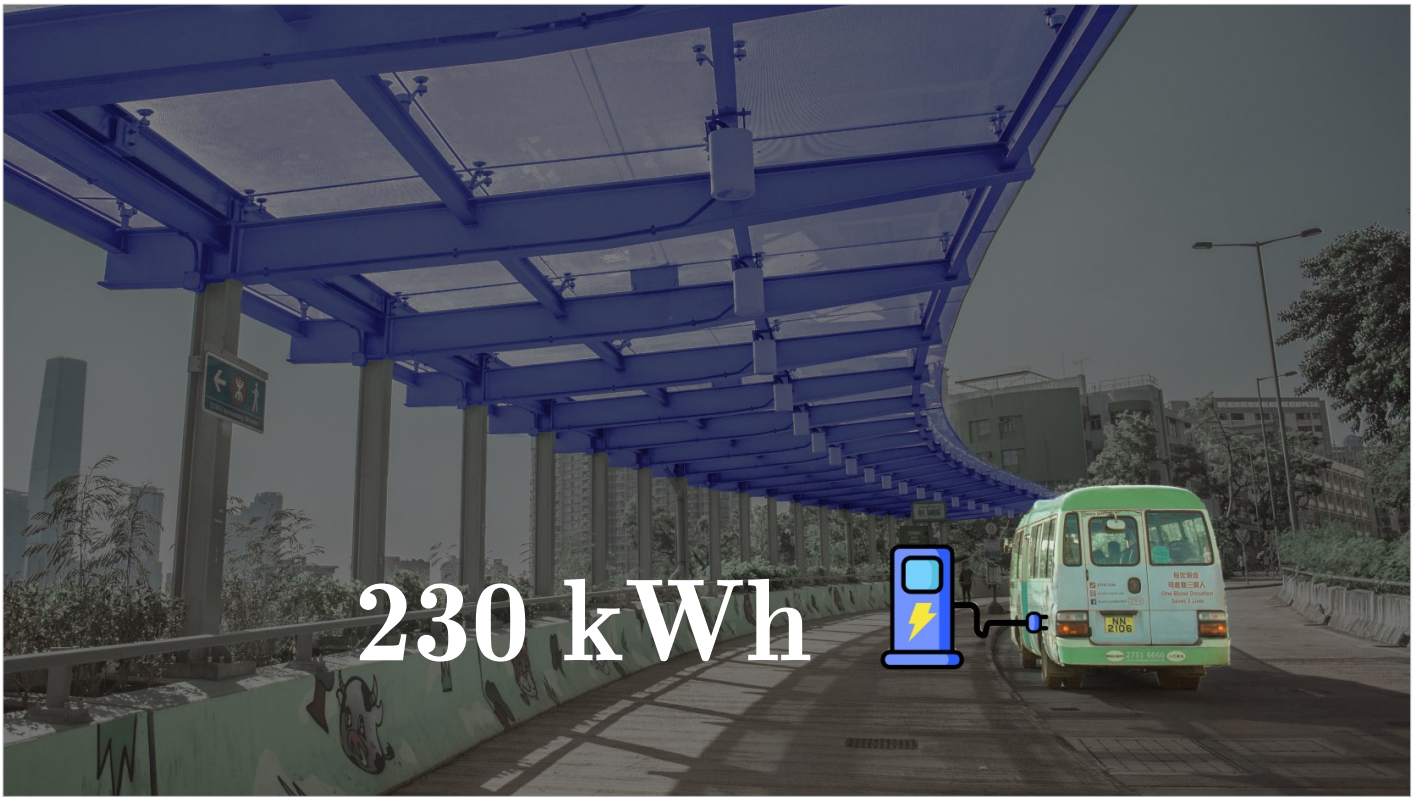
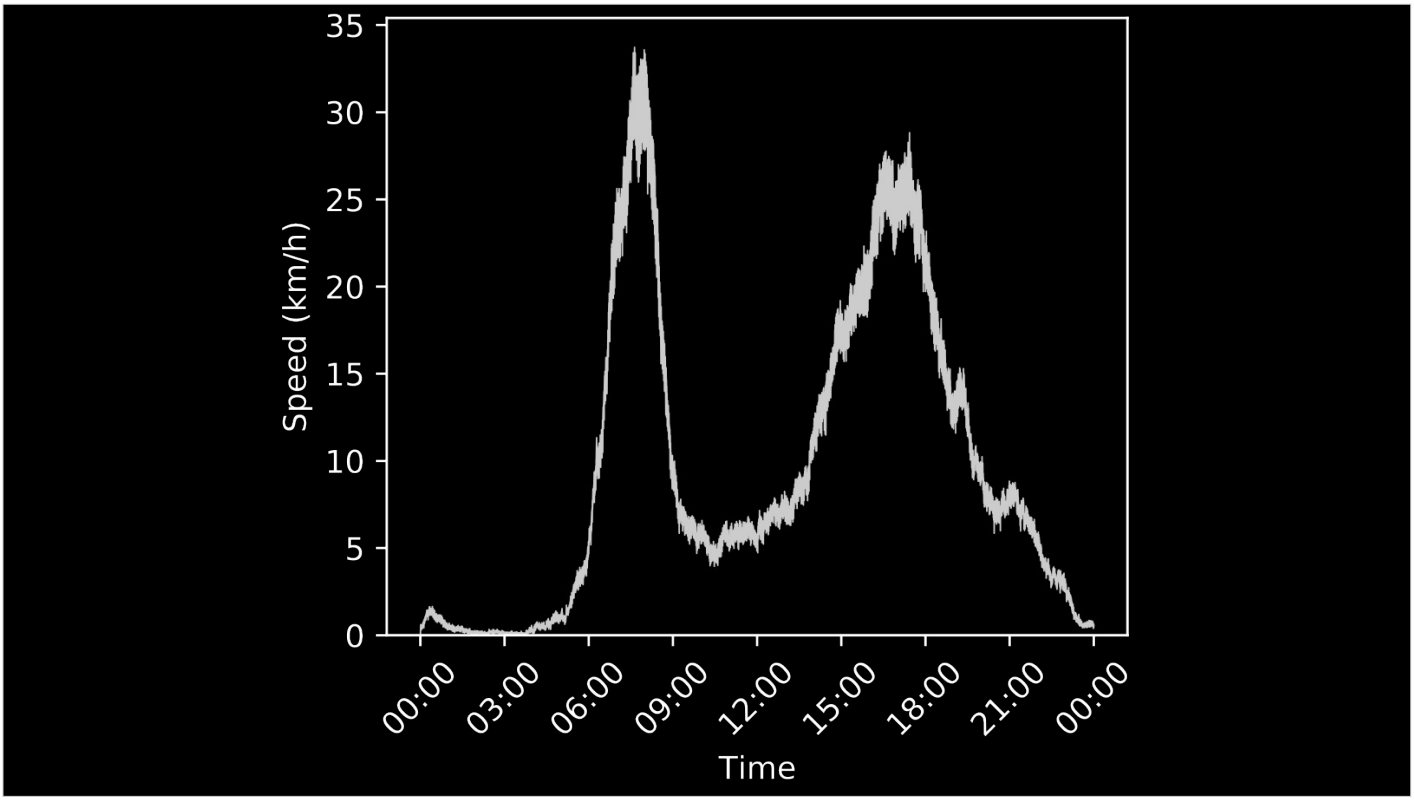

230 kWh

That's around R400 on electricity.

Okay, the savings aren't that much, especially considering the high initial investment of buying an EV.

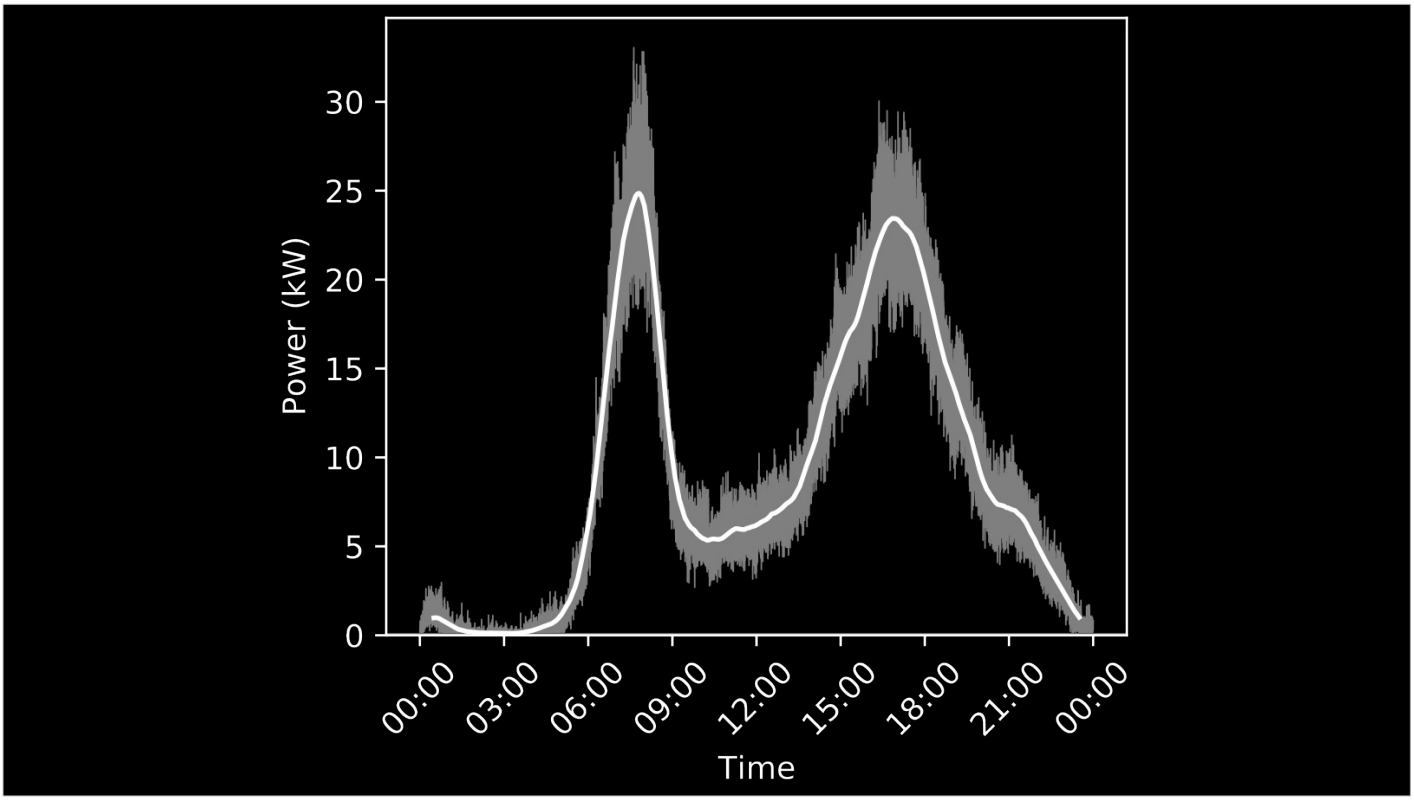
But this saving of R100, over 15 years, would save the taxi owner roughly R400 000!

Let's look to solar energy to sweeten the deal further.



This is the average velocity profile of the taxis. You can see two profound peaks of activity. One in the morning at around 7 AM, and the other at 5 PM. It's very clear that there's no activity at around mid-day. This is because taxis often struggle to make a profit during this time, due to reduced passenger demand. They therefore sit around at the taxi rank.

Now, we simulated these GPS traces with an electric vehicle model. And this is the energy demand profile:



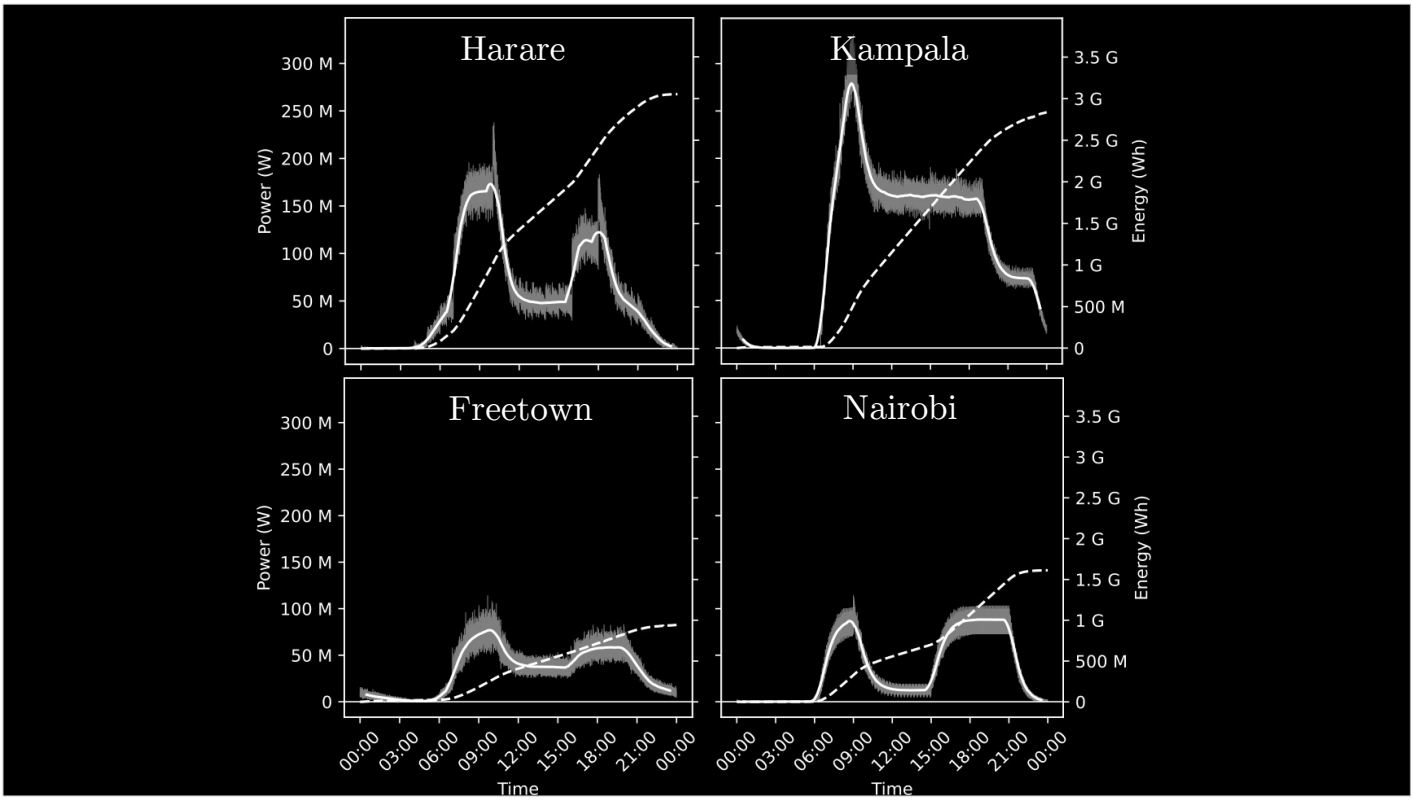
As expected, it’s very similar to the velocity profile. When the taxis move more, they use more.

We plotted a curve for each taxi, and there was very tiny variation between them.

That dip in power usage in the middle of the day, is an excellent time for the taxi to top-up its battery. That is the same time when the sun is up at its peak.

[redacted]

Multiple other cities across Africa. For each city: Not just one fleet, but the **whole** taxi system.



Kampala: Largest population, reliant on MBTs

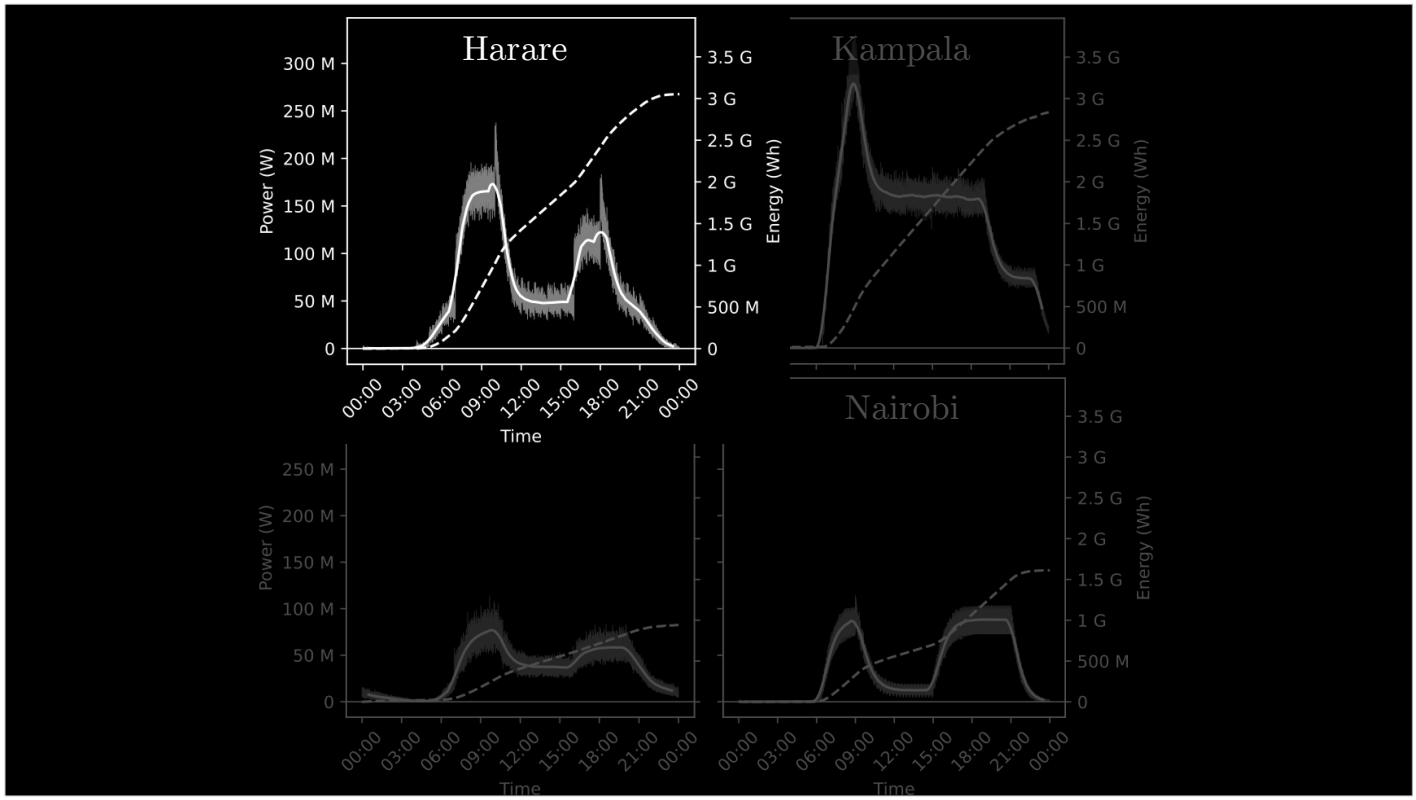
Harare: Medium population, reliant on MBTs

Nairobi: Large population, not so reliant on MBTs (formal public transport also exists, as well as Pvt Transport).

Freetown: Small population. Not so reliant on MBTs (also have smaller forms of paratransit, such as Tuk-Tuks and sedans/“Amaphela”).

Energy usage:

- Kampala: 30 GWh/day
- South Africa: 650 GWh/day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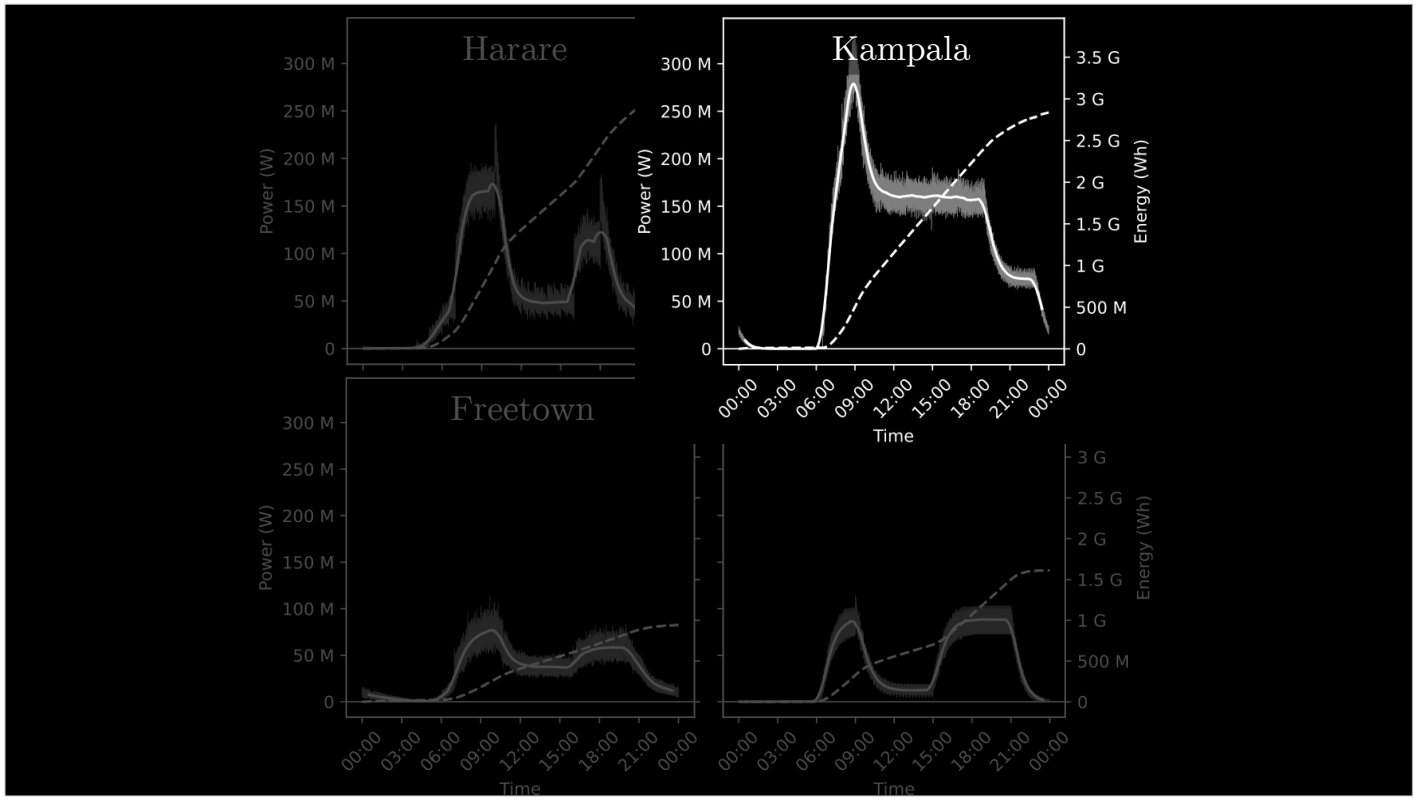
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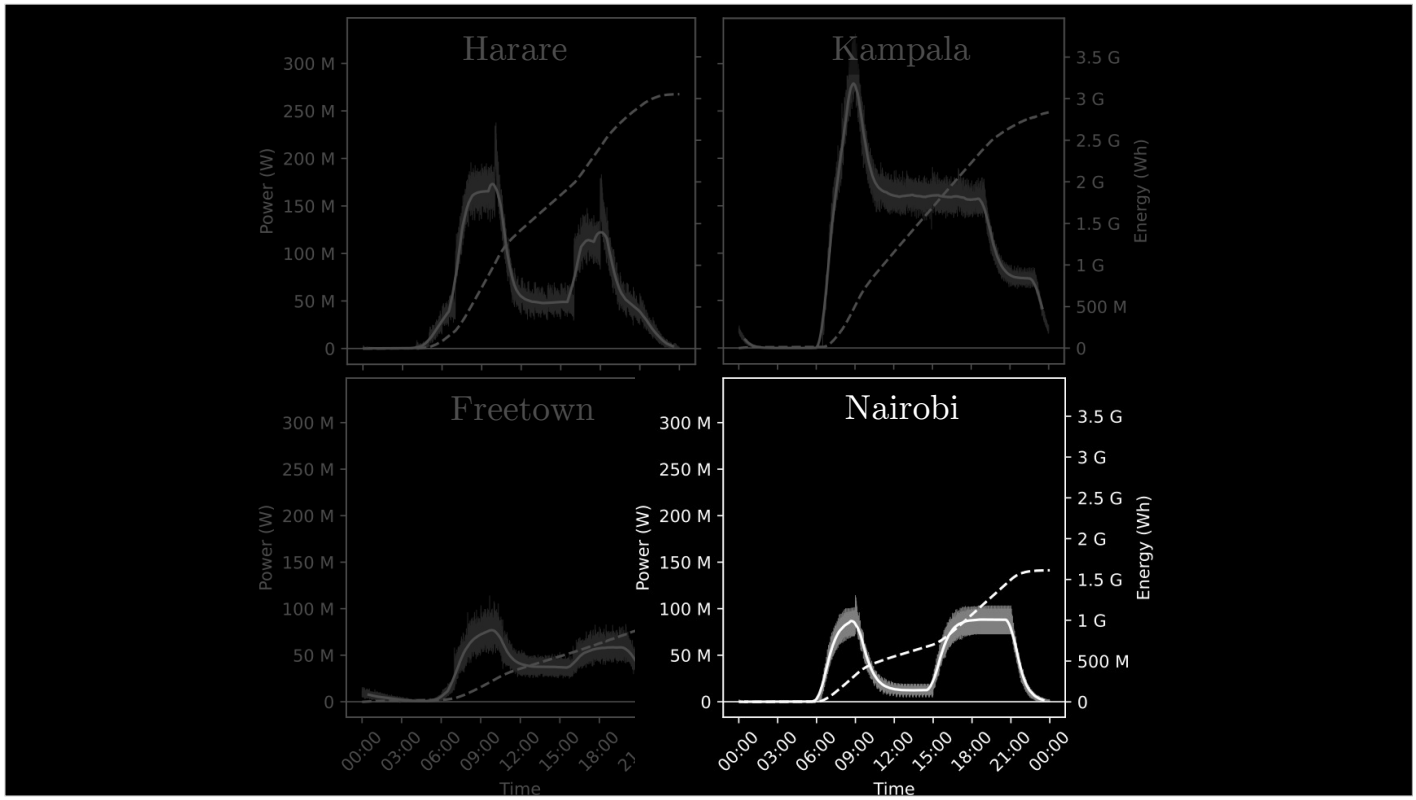
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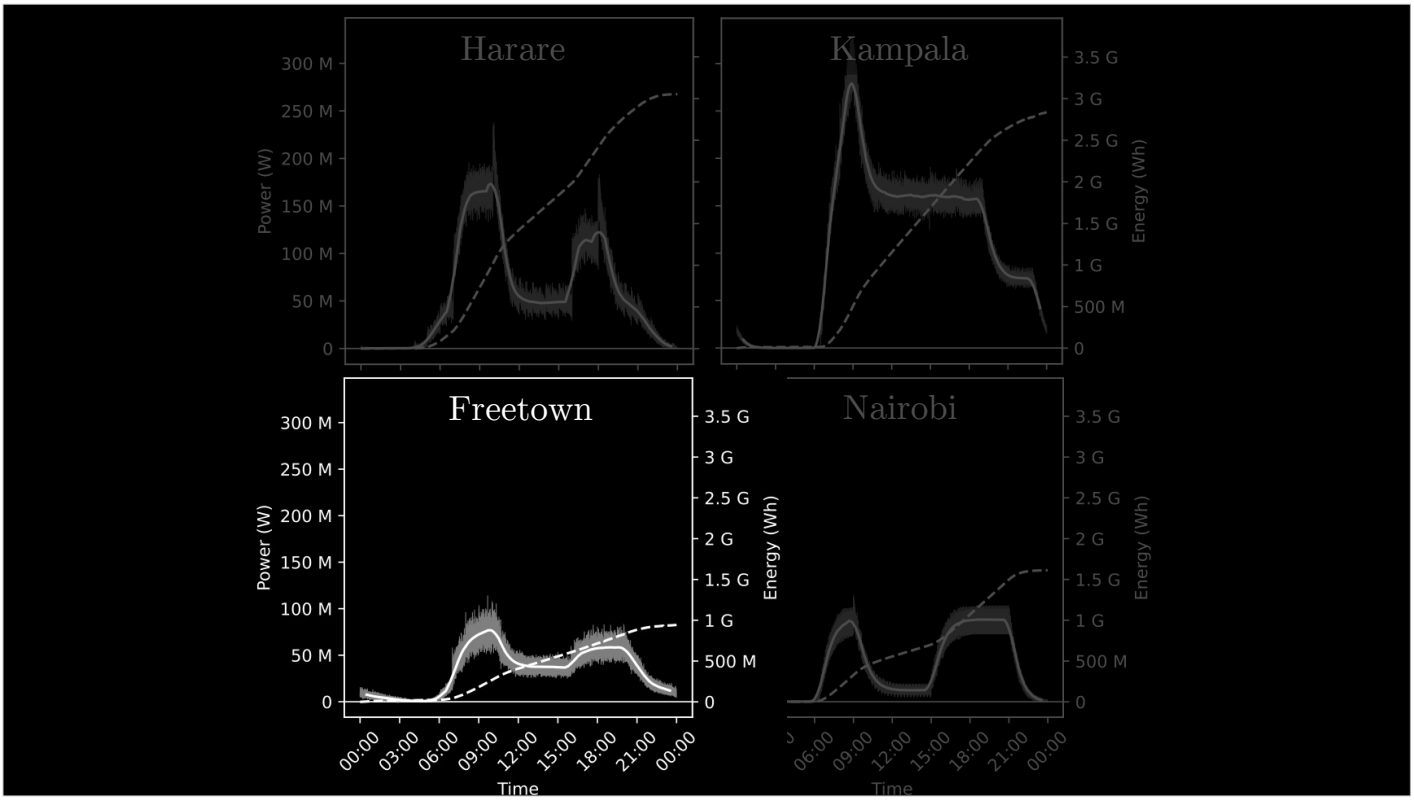
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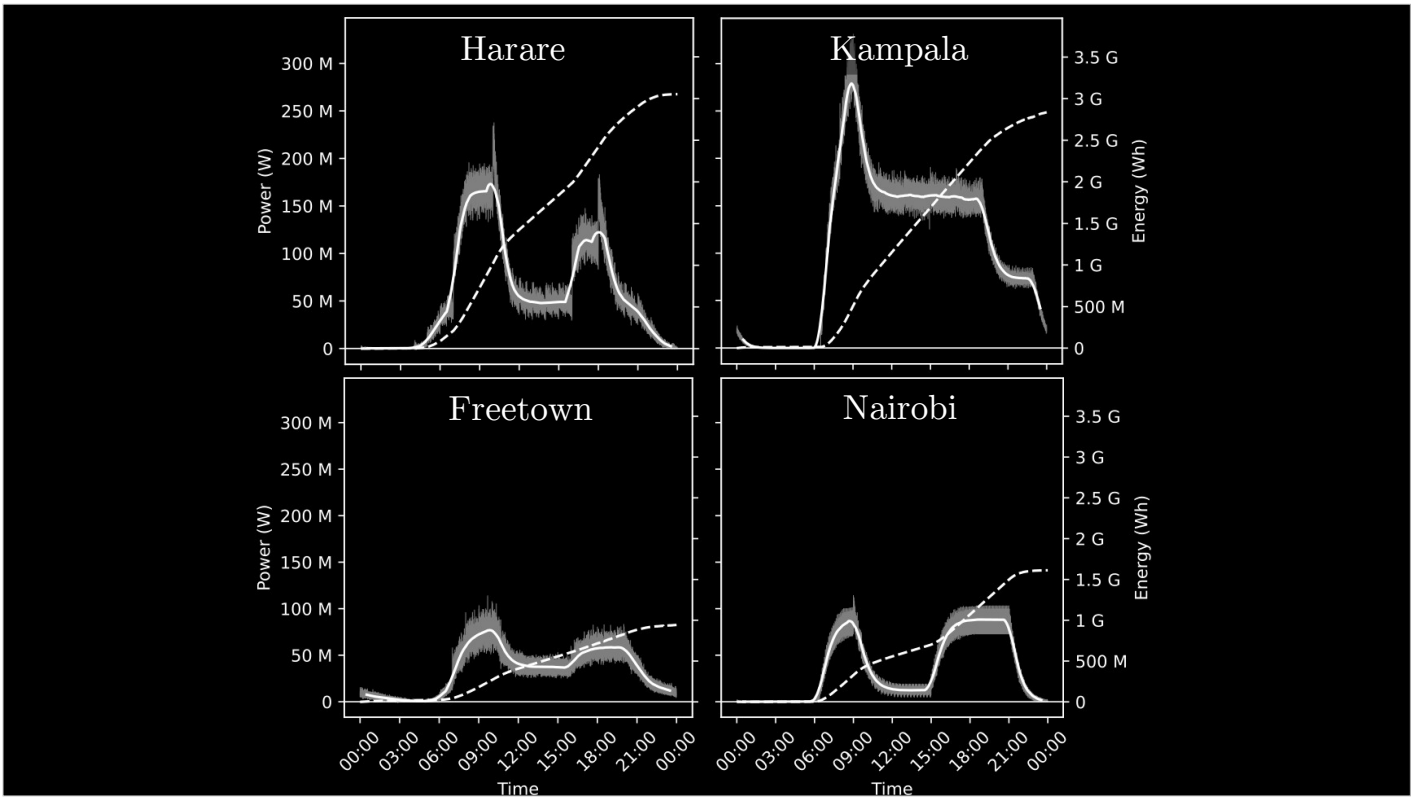
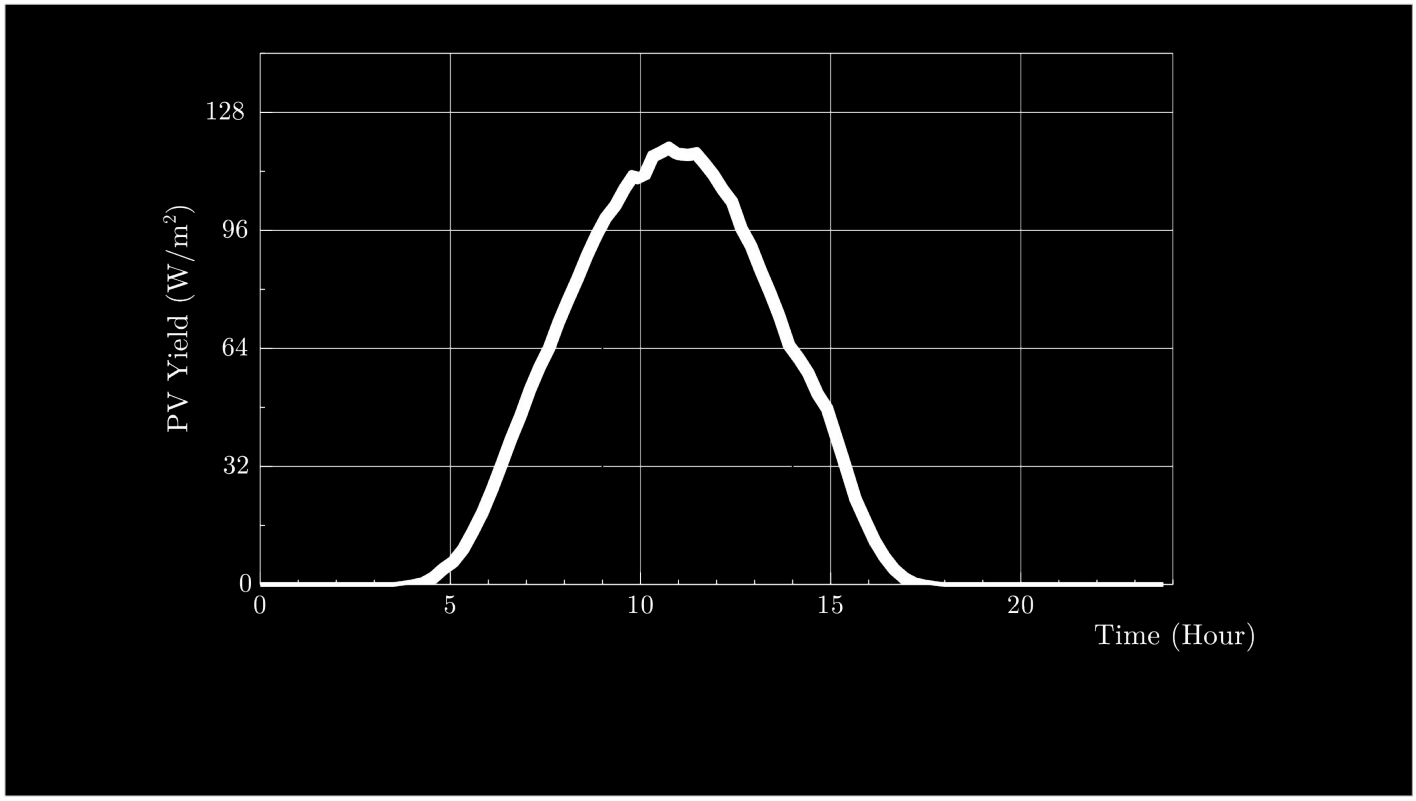


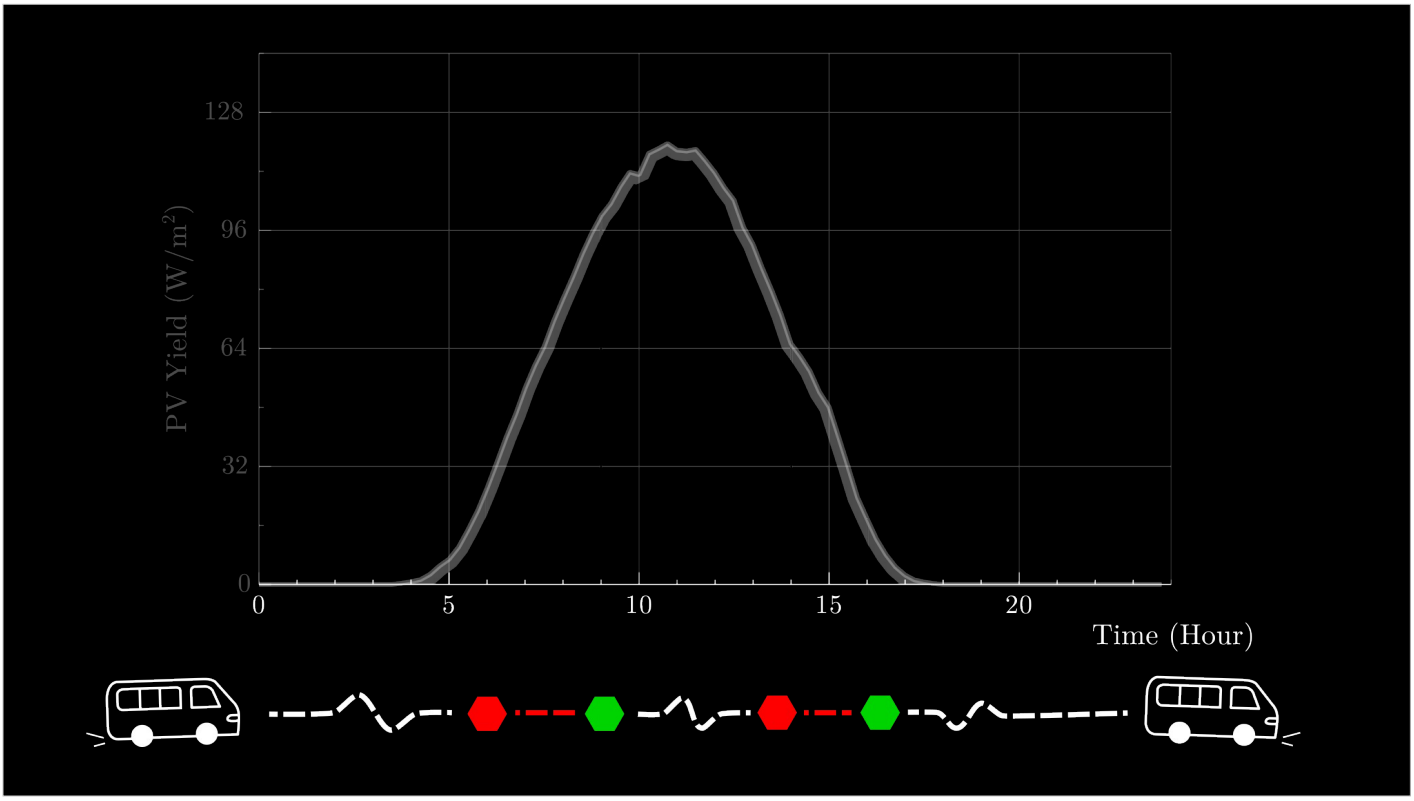
They all have a mid-day dip in energy.

[redacted]

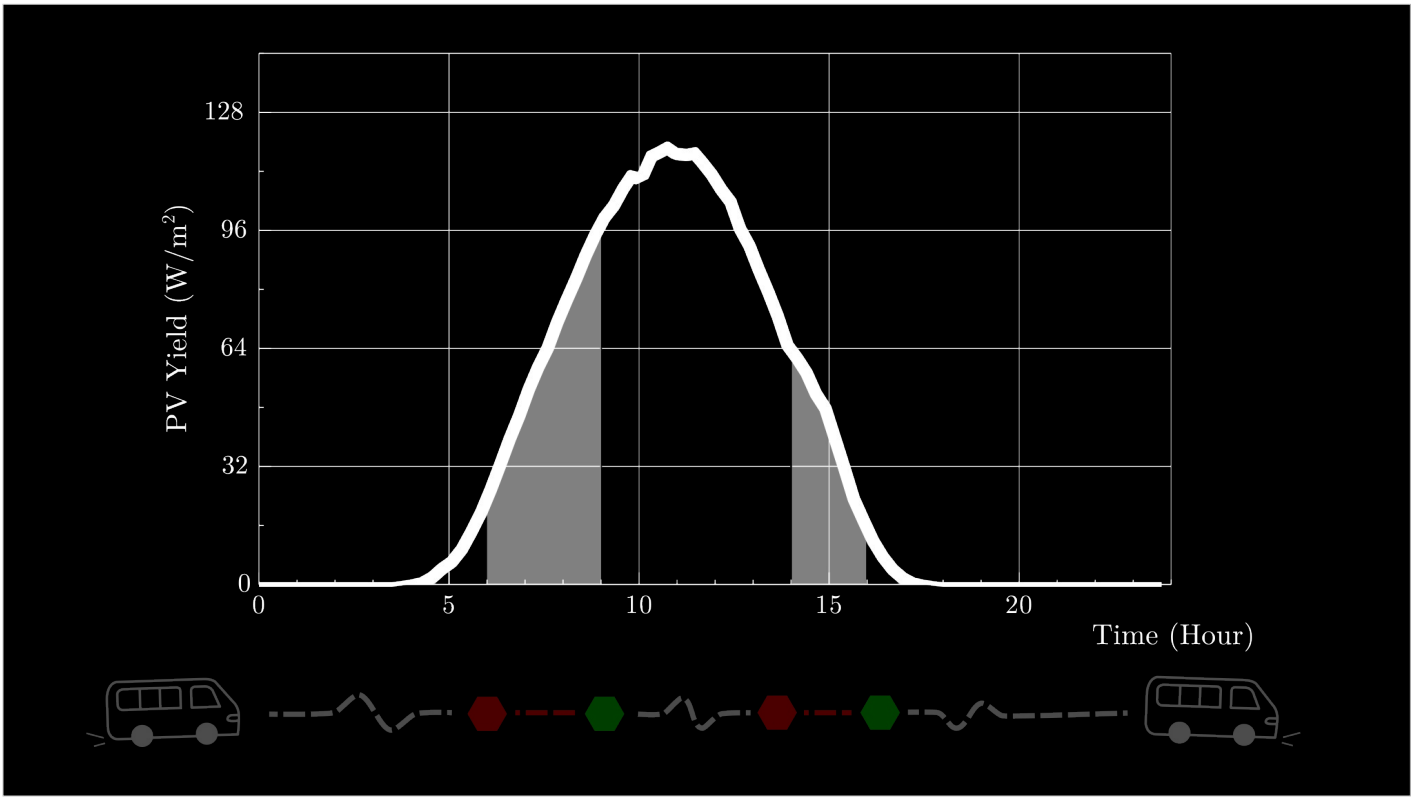
Looks good for PV.



Now, this is a profile of the average solar energy per square meter. It was measured on top of the Engineering building over 1 year. As expected, there is a peak at mid-day. That peak would be lower in winter months, and higher in summer months.



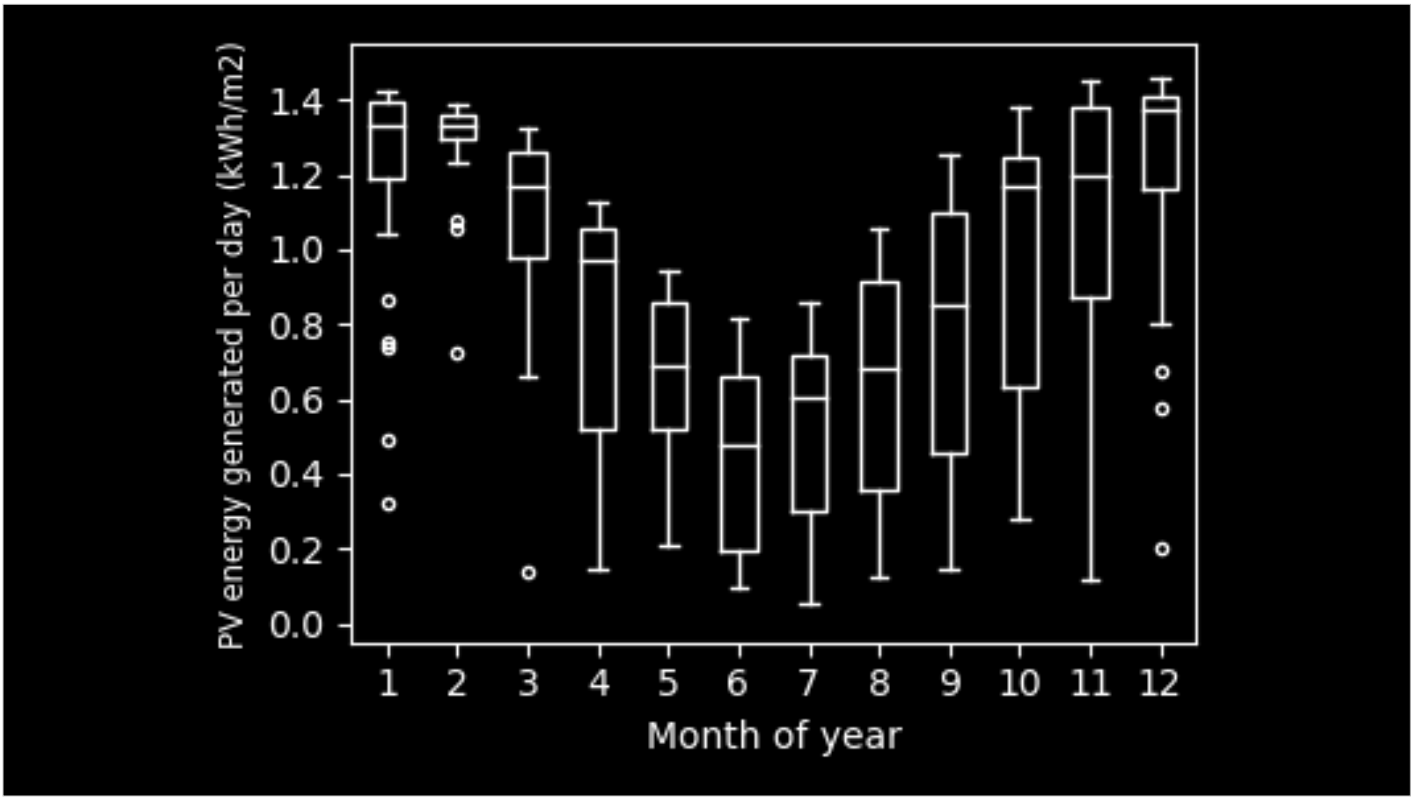
Let’s say our taxi makes two major stops during the day.



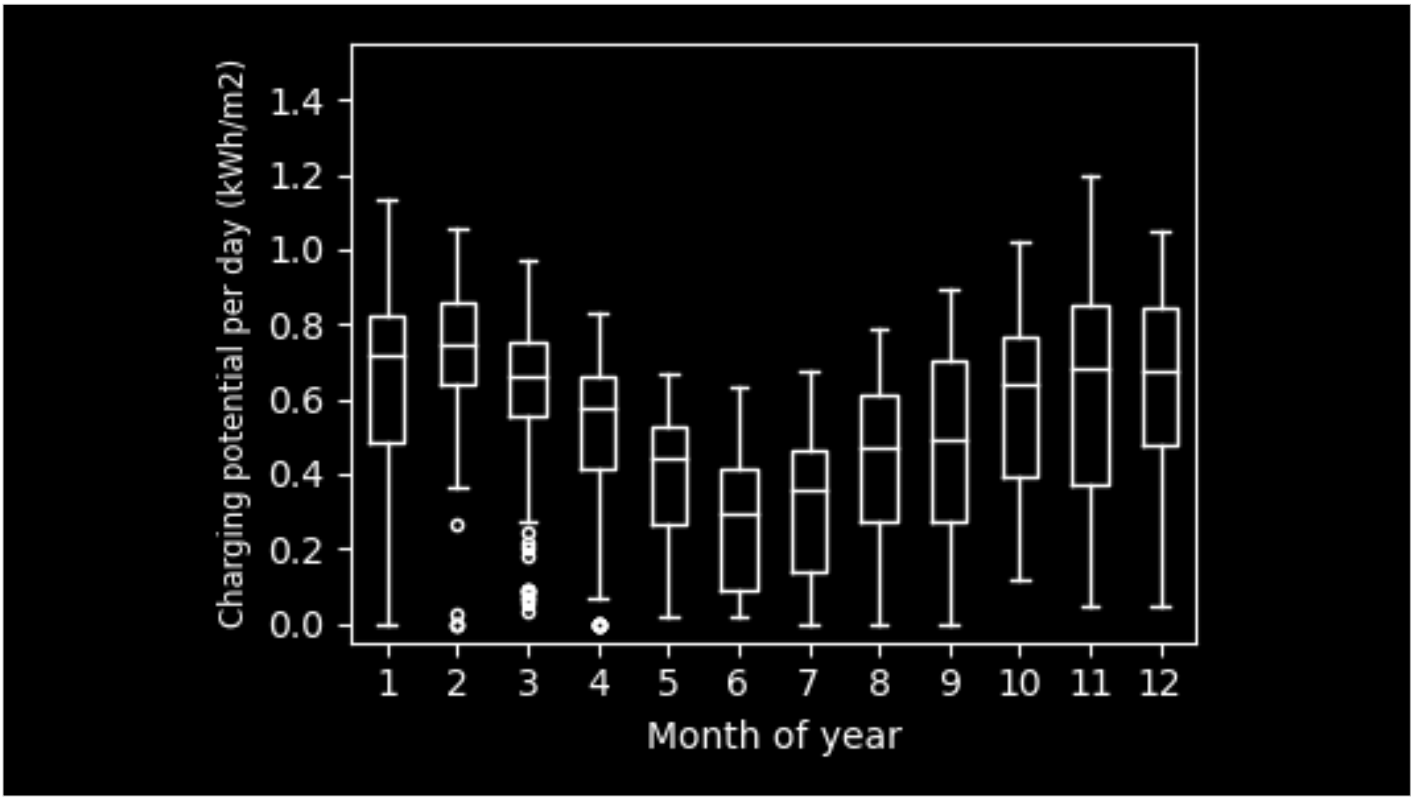
Then we can integrate this irradiance curve, and apply an efficiency constant to get the amount of solar energy extracted at those stops per sq. m of PV.

[redacted]

So let’s see how much solar energy our taxi’s can extract during various months of the year.



These box plots show the *total* PV energy generated per day. The average is1 kWh/m².

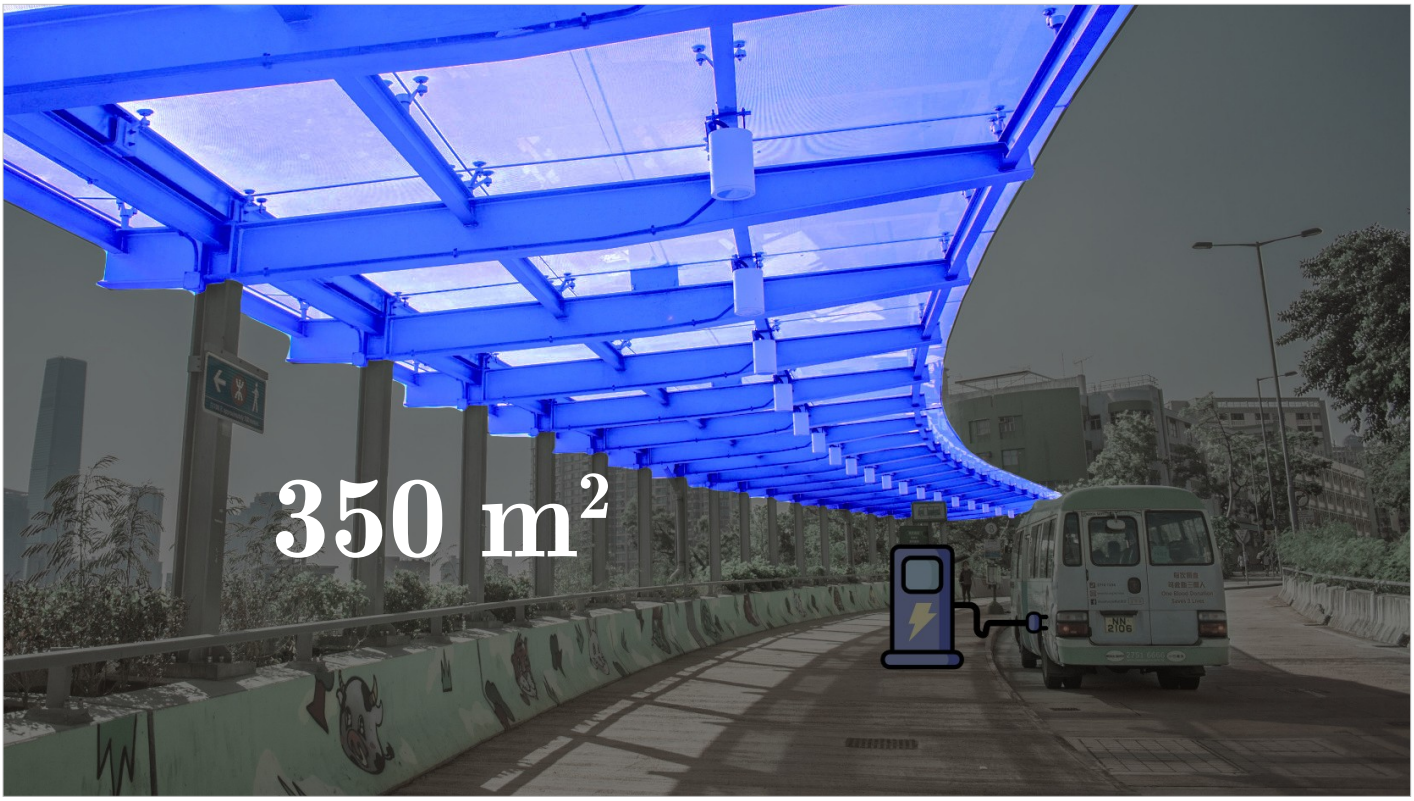


Now, we see the amount extracted by the taxis for each of the months. On average: 0.6 kWh/m².

So depending on season, the taxi uses 50–70% of the generated solar energy. The rest could be sold to the grid, or can be stored in stationary batteries at the charging station.

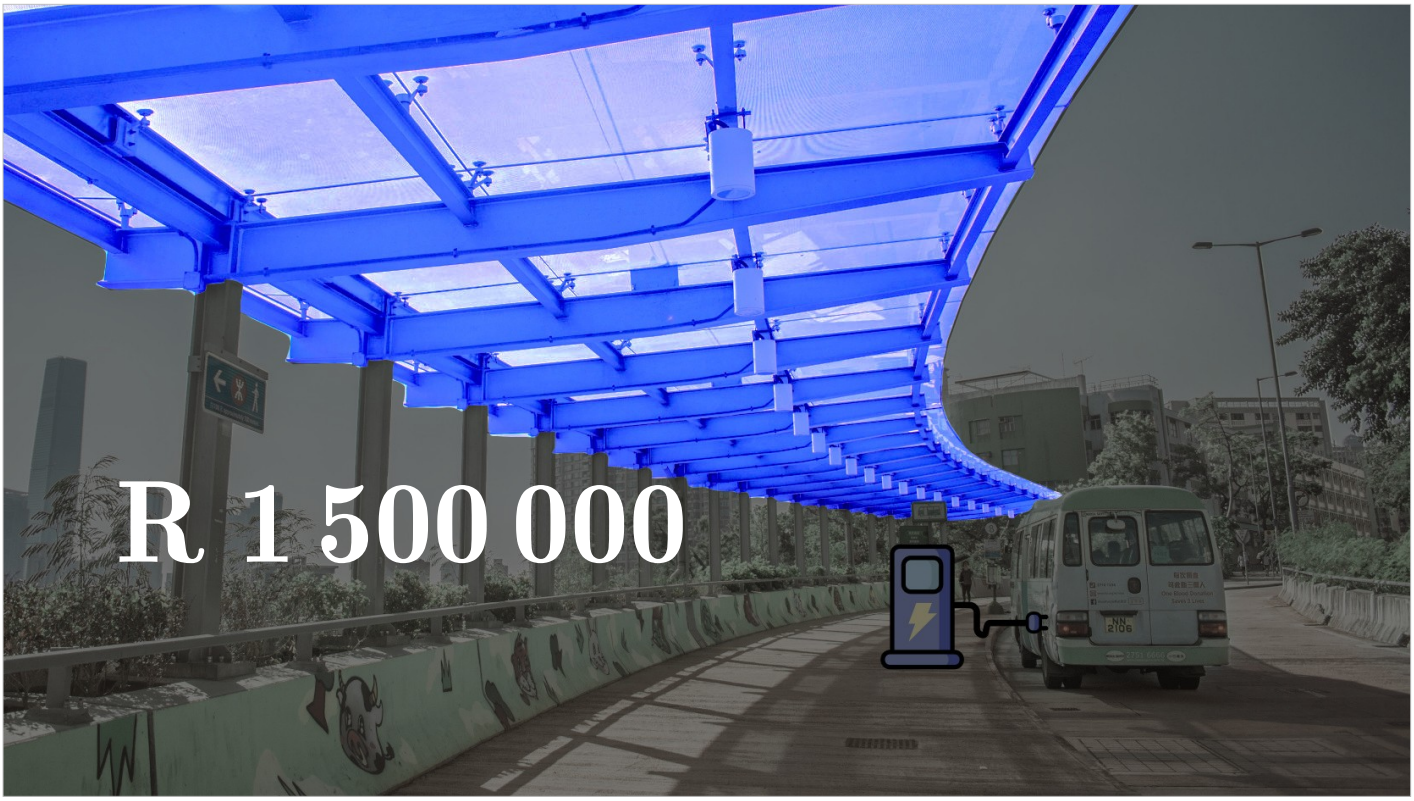
[redacted]

So if a taxi can directly gain 0.6 kWh/m^2, how much solar panel area would we need to meet the taxi's total demand of 210 kWh?



The answer is 350 m^2. Or if numbers don’t sit well with you...

Half a tennis-court of PV.



This would be around a 1.5 million rand investment and would run a taxi for mahala for 25 years! At no cost to the environment.

(Around R230 per day)

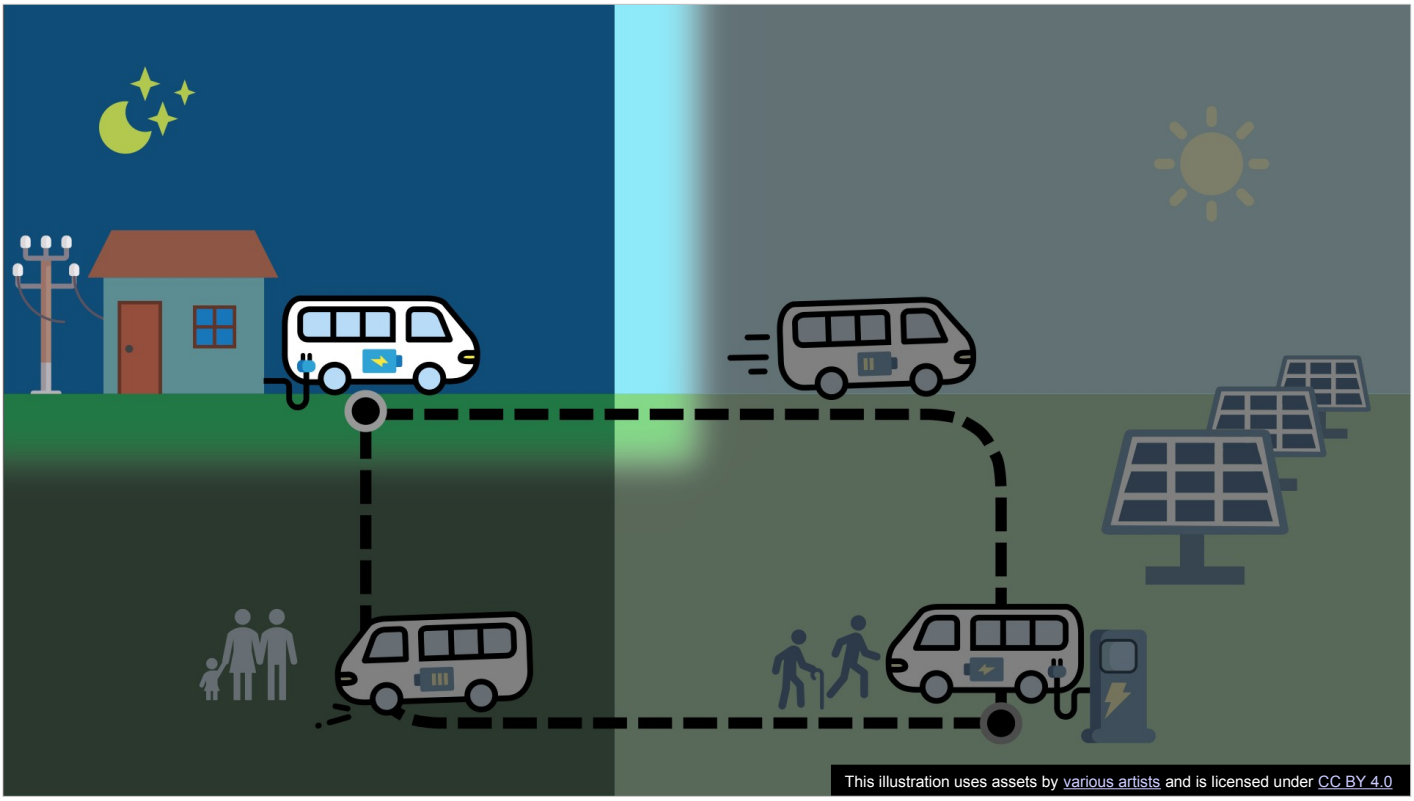
And the good news doesn't stop there. These costs should get lower and lower as RE technology improves.

The equivalent petrol price over 25 years would be 3.5 million rand, and would only get higher and higher.

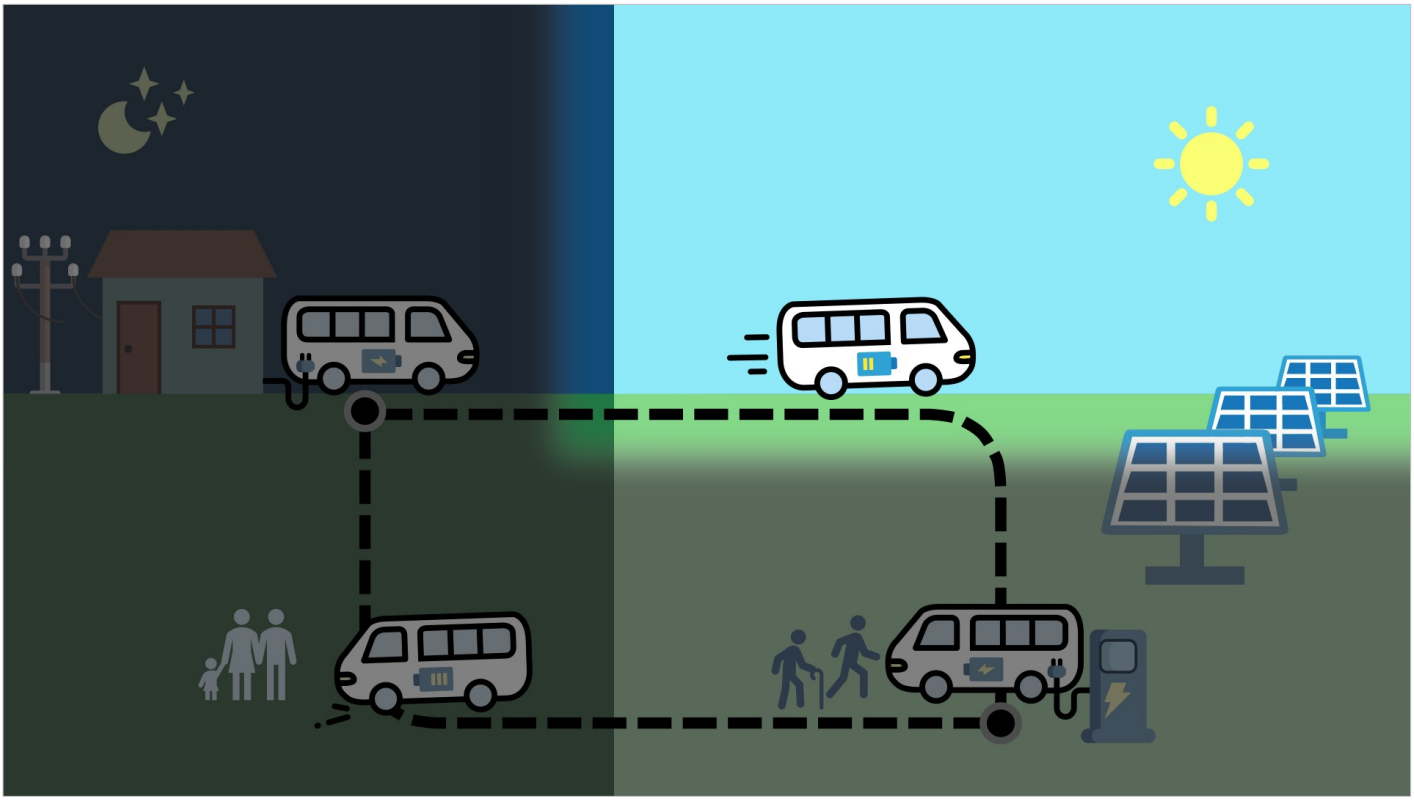
At the end of this journey, we were left with this awesome piece of software. You give it GPS traces of a bunch of vehicles. Which you can even collect with this <show smartphone>, and it gives you all these statistics and plots which inspire new possibilities.

So we tried it on a bunch of other cities, across Africa, and we found very similar results.

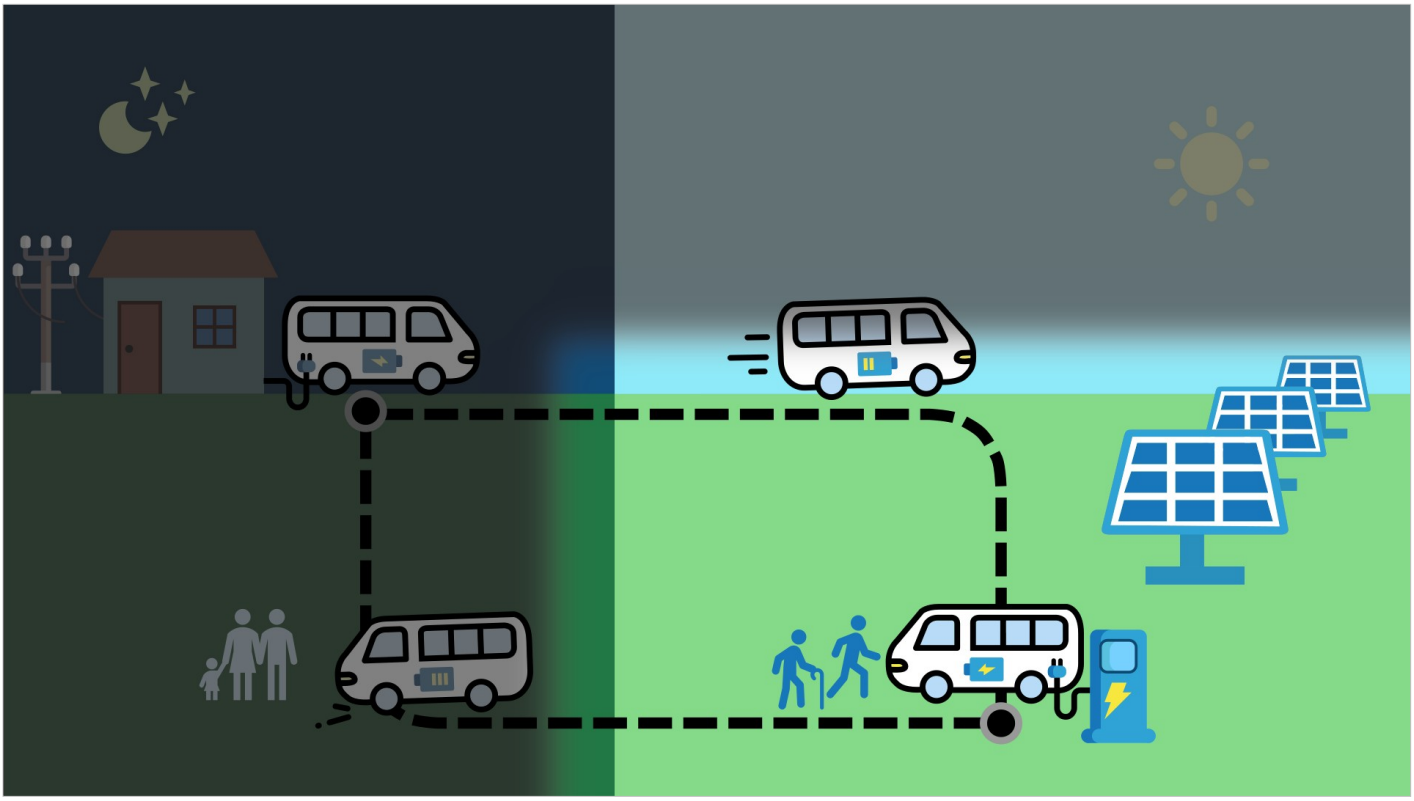
So, I have a vision...



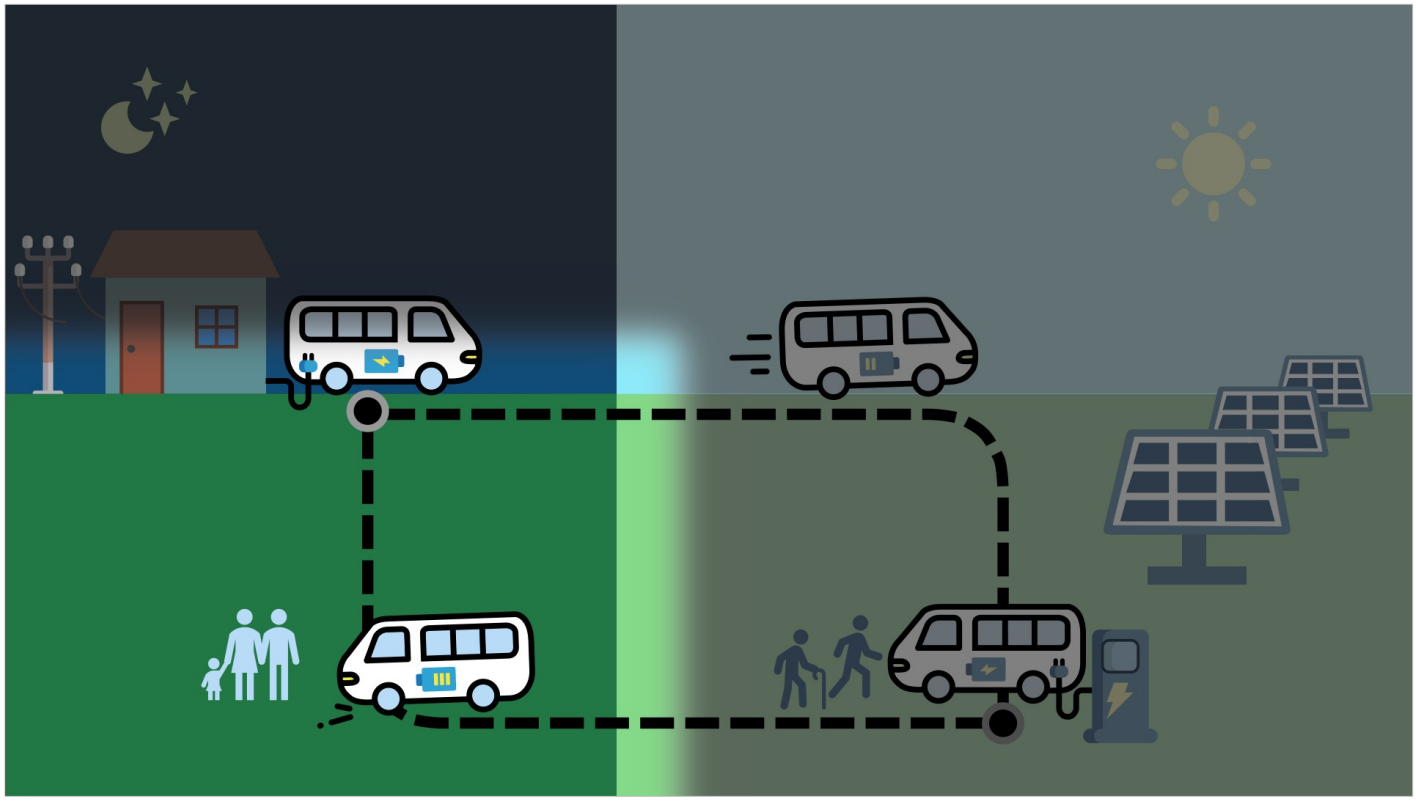
I envision the taxi of the future, charging from cheap electricity overnight.



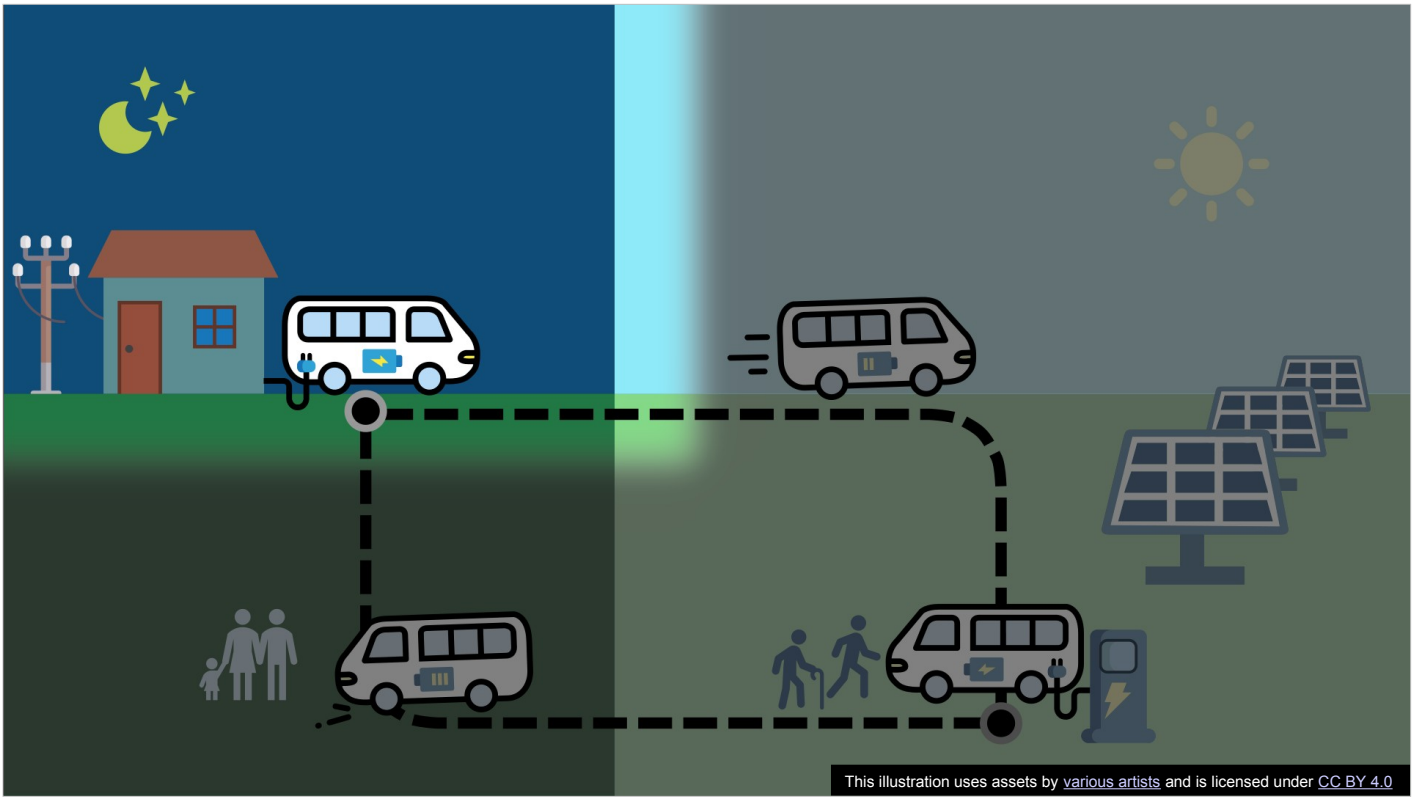
Using that energy to do its morning trips.



Stopping at mid-day to charge from renewable energy. With solar panels that are owned by the taxi association.



Using that clean energy to do its evening trips.



And returning home, and charging from the grid again.

As you can see, the software and its results allow us to imagine and dream of renewable energy opportunities which didn't exist before.

It can be used in practically any fleet, not just taxis. Fleet of delivery vans… Ubers… Rickshaws…

I have a dream! I dream of transport that is more affordable—now and in the future. I dream of transport that respects nature and is inspired by it. Renewable energy is like a flower—it blooms when the sun is out. And when it dies, it leaves behind seeds for future generations to grow more flowers than there was before.

As a Xhosa proverb goes: “Akho nkanga idubula ingethi.” “There’s no flower which doesn’t bloom before it dies.” Renewable energy will bloom in our generation. Labour is always necessary to yield the first harvest. But let us sow the seeds now, so that it can bloom, and release more seeds for future generations.

Thank you.

Before I take questions, I just want to express my acknowledgements.

MTN South Africa and Eskom.

Last but not least, I want to thank my supervisors, Thinus and Dr Rix. Who have helped me and had trust in me.

But above all, I thank God.

researchgate.net/profile/Chris-Abraham-5

doi.org/10.1016/j.esd.2021.08.003

gitlab.com/eputs/ev-fleet-sim

Please follow me on ResearchGate if you are interested in my future research. The research paper which accompanies this presetnation is published open-access, and can be found in the 2nd link.

I'll send this presentation and the links onto the chat.

Questions?

Thank you. Any questions? I hope my research was controversial enough…

“How will taxis find time to charge?”

With modern fast chargers, 1 hour is enough to charge a taxi to 80%. Electric taxis can also be designed to have hot-swappable batteries. This would allow the driver to swap in their depleted battery at a retailer, similar to how we swap in our gas-canisters which we use for cooking.

This is how it *really* looks like. Definitely not a funny scene.

The WHO estimated that the number of deaths caused by air-pollution per year in Africa is more than 1 million…

That's even more deadly than Covid! Traffic congestion accounts for a large percentage (23%) of localised air pollution. So you can say that this is another invisible pandemic that needs to be tackled.

On top of this… <DRAFT>

So I have a friend, Bonga, who owns a taxi business. Just the other day, he was telling me how his profits are getting lower and lower because petrol prices keep getting higher and higher. As a result, he can't afford to repair his taxis and replace them when they're old. Old taxis – break down frequently, and release toxic pollution into the air.

These problems are common in taxi industries throughout Africa. Taxis – provide a valuable service: public transport for the masses, and countless jobs. It therefore needs to be protected and made more sustainable. Additionally… Let me put it this way… How many of you have used