The Potential for Vehicle Integrated Photovoltaics in Australia

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The transport sector accounts for 23% of global CO2 emissions with road transport accounting for the majority (73.9%) of that sector, split roughly half between heavy duty vehicles and light passenger vehicles [1]. Electrification of road transport is anticipated to be the principle means for decarbonising the sector with renewable electricity used to charge battery electric vehicles or produce hydrogen for fuel cell electric vehicles. A less obvious opportunity exists for providing photovoltaic electricity from the vehicle itself. In 2016 Toyota demonstrated a modified Prius vehicle that could achieve 30km/day from conventional c-Si PV panels mounted on the vehicle [2] and last year, demonstrated 50km/day from another Prius with 34% III-V multi-junction solar cells on the vehicle [3]. While these distances sound modest, 30km/day covers over 70% of vehicle journeys in Japan and even in Australia, the average commuting distance is 16km [4]. Photovoltaic power generation from the bodywork of an electric vehicle therefore has the potential to significantly reduce the number of times an EV needs to be recharged.

Since the area available on a vehicle is limited, the efficiency of the PV technology used and the vehicle drive efficiency are the principle factors for determining the overall solar range of an EV. Figure 1 shows the estimated solar range for vehicles of different area and drive efficiency assuming a 22% photovoltaic technology. Small EVs typically have an electric drive efficiency around 10km/kWh. Heavy vehicles, such as public buses and trucks typically achieve efficiencies around 1km/kWh. The larger area available for PV on the heavy-duty vehicles is almost exactly cancelled out by their lower drive efficiency, so all these vehicles sit on the same 20km/day line. Two pathways for increasing the solar range are evident. If the PV efficiency is increased, the solar range will increase proportionally. At some point in the future it is conceivable that manufacturable PV technologies with an efficiency double of that today might be available. Improvements in vehicle drive efficiency are also possible. Toyota's prototype solar Prius is already operating at 17km/day drive and the UNSW 'cruiser class' solar car racer built by the SunSwift student team achieves 34km/kWh, delivering a solar range over 100km/day. To illustrate the dramatic potential for improved vehicle efficiency, it is worth noting that the world record for vehicle efficiency was set by Duke University, achieving 1283km/kWh [5].

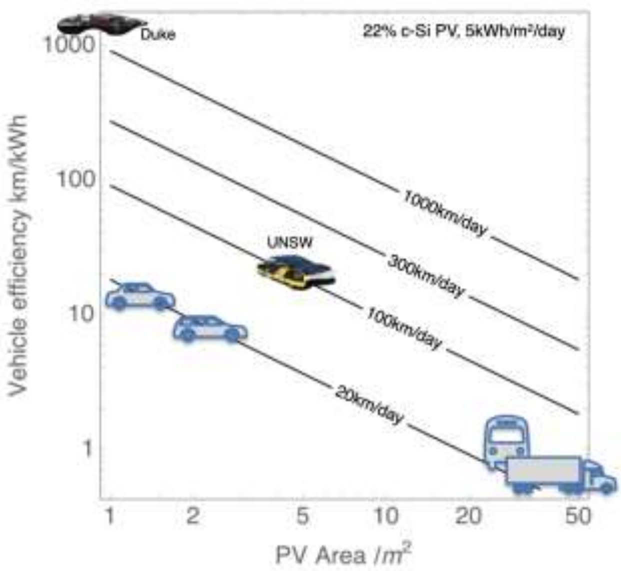

Figure 1. Solar EV range as a function of available area on the vehicle and the vehicle drive efficiency.

One of the key questions when assessing the practical benefit of vehicle integrated photovoltaic power generation is the degree to which a vehicle is parked in the shade or dark garage. An autonomous solar irradiance logger was used to make irradiance measurements from a vehicle and transmits the data a central database via the mobile data network [6]. At the time of writing, prototype units have been deployed in a few locations worldwide with more units in the pipeline to assess the solar irradiance that falls on vehicles under realistic conditions. Preliminary results from a trial in Melbourne are shown in Figure 2, showing irradiance data collected over a 43 day period from March – May 2020. By the time the conference is held, we can report on a more complete dataset and provide estimates of a performance ratio from VIPV systems.

Figure 2 : Data from a vehicle in Melbourne equipped with a mobile solar irradiance monitor. The magnitude oft he irradiance measured is illustrated by the radius of the datapoint.

While the technical potential for VIPV appears to be compelling, the attitude of consumers towards the new technology will be critical if the technology is to become commonplace in the future. To assess this, almost 1900 individuals were surveyed across 8 cities in Australia with questions about their perception of EVs and the extent to which integrating PV into the vehicle would influence their purchasing discussion [7]. The survey showed that consumers were will to pay an additional $31/km of solar range and a further premium for PV that is colour coordinated with the vehicle [7]. This study therefore concludes that a capacity cost of several dollars per watt is tolerable for VIPV applications providing a new market opportunity for premium, high-efficiency PV solar cells.

In summary, VIPV represents a new application for PV where, with present PV and EV technologies, a solar range up to 20km/day can be achieved from the vehicle surface. Improvements in vehicle drive efficiency and PV efficiency can significantly increase this distance, potentially reducing the density for on-street charging points. Consumer perception surveys suggest that VIPV technology is viable today and could become a standard feature in future electric vehicles.

References

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