Well-to-Wheels Greenhouse Gas Emissions and Energy Comparison between Battery Electric Vehicles, non-Plug in Hybrids and Conventional Passenger Cars for South Africa

Sustainable Energy Africa have developed an open source spreadsheet calculator for comparing the greenhouse gas (GHG) emissions of conventional internal combustion engine (ICE) powered passenger cars to that of battery electric vehicles (charged from the national grid) and non-plug in hybrids[1] in the South African context. The emissions are estimated for the supply and production of the fuel and electricity as well as those from the vehicle itself (wells-to-wheels basis). The coal intensive electricity and synthetic liquid fuel supply in parts of the country make the local situation unique.

The user can vary all the input variables on different screens to explore the impacts of a less fossil fuel intensive grid, lower refinery emissions and direct solar charging of battery electric vehicles. The calculator tries to capture emissions arising in the energy chain only and a full lifecycle including the material inputs to the vehicle itself is not attempted. These may arguably be assumed to be largely similar for different types of passenger car, relative to the quite large range of effect of energy emissions in South Africa's fossil fuel intensive energy supply system.

Two basis for comparison were used; the European Union's standard emissions test cycle (ECE15 + EUDC) and the United States Federal Test Procedure (US FTP)[2].

Results

The results are shown below for GHG emissions arising in the ECE15 + EUDC test cycle with and without coal-to-liquids (CTL) synthetic fuel[3] included at its national average share of production. The US FTP based comparison is similar on a relative basis although this is a more severe test. The discretionary choice of whether to drive a big car or a small car makes a big difference to energy economy and small conventional cars currently give rise to lower GHG emissions than battery electric vehicles in the South African context if CTL emissions are not considered. In this case non-Plug in hybrids seem to give rise to the least GHG emissions. If CTL is included at its national production share, battery electric vehicles significantly outperform gasoline fuelled conventional vehicles on a GHG emissions basis but

[1] A non-plug in hybrid (e.g. the Toyota Prius) has a battery but it is charged either during braking or by the engine and is never plugged into an external electricity supply.
[2] See https://www.fueleconomy.gov/feg/download.shtml for the United States Environmental Protection Agency's database of test results by model
[3] The **CTL** production process produces liquid fuels from coal by first gasifying the coal and then liquefying the gaseous products by catalysis in a relatively energy and greenhouse gas intensive series of processes.

small diesel fuelled IC engine cars are comparable because the CTL refinery produces proportionally less diesel.

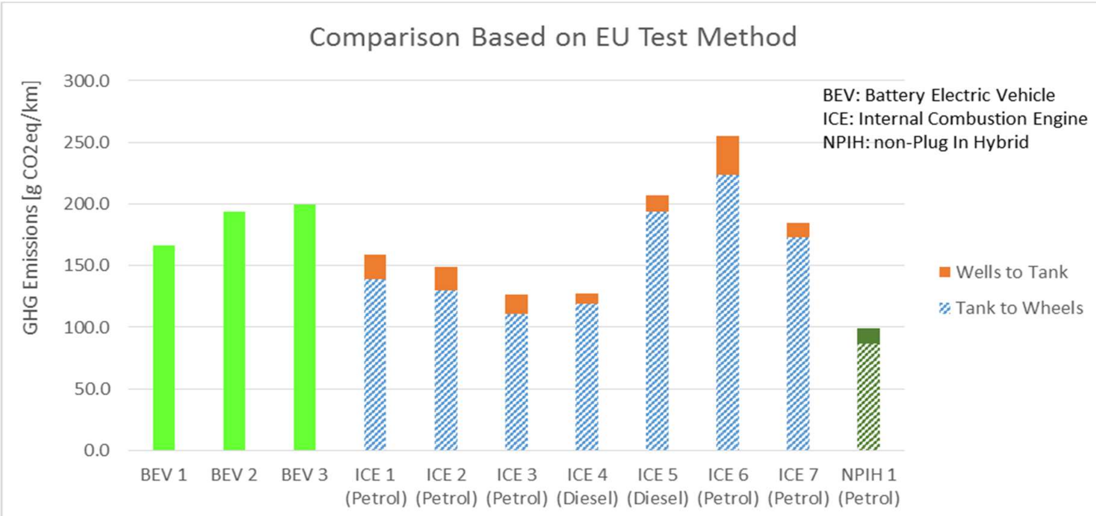

Figure 1: Wells-to-Wheels GHG Emissions for Selected Model Passenger Cars[4] when CTL production is excluded from Refinery Supply System[5]

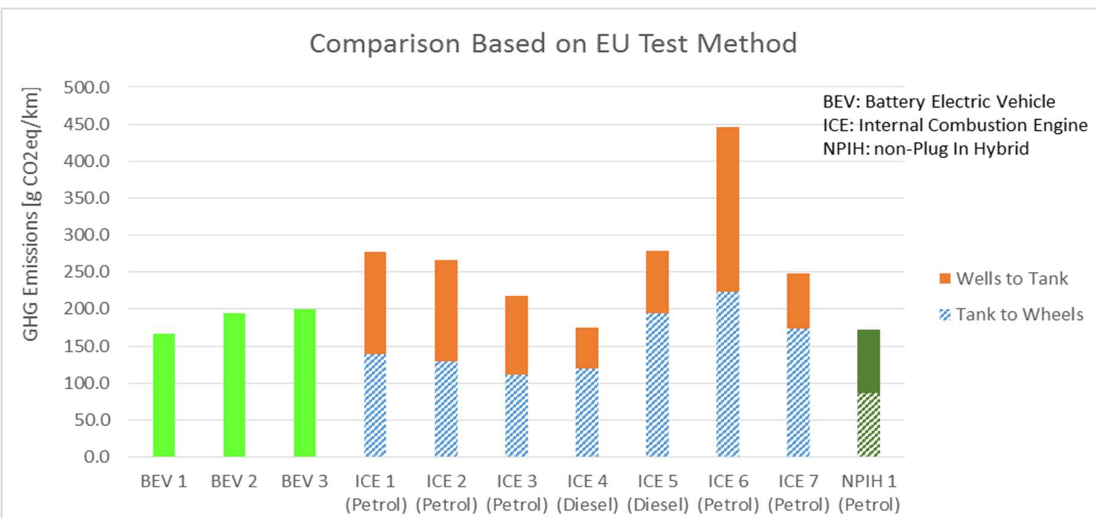

Figure 2: Wells-to-Wheels GHG Emissions for Selected Model Passenger Cars when CTL production is included in the Refinery Supply System

If we assume that 25% of battery charging is shifted from using the national grid to off-grid solar embedded generation at home and the workplace and that nuclear and renewable

[4] The models have been selected to cover a range of manufacturers and illustrate a range of emissions. For ICE vehicles the higher emitting models are heavier vehicles with bigger engines.

[5] See the comparison for the US Test procedure in the calculator itself. These are consistent with the EU data on a relative basis and the EU test has been used in preference because the US EPA database included no diesel cars. The wells to tank and tank to wheels energy split is also shown in the calculator.

generation rises to a 25% share of grid electricity, then GHG emissions from the operation of battery electric cars drop to around half of even small conventional cars and non-plug in hybrids as shown below.

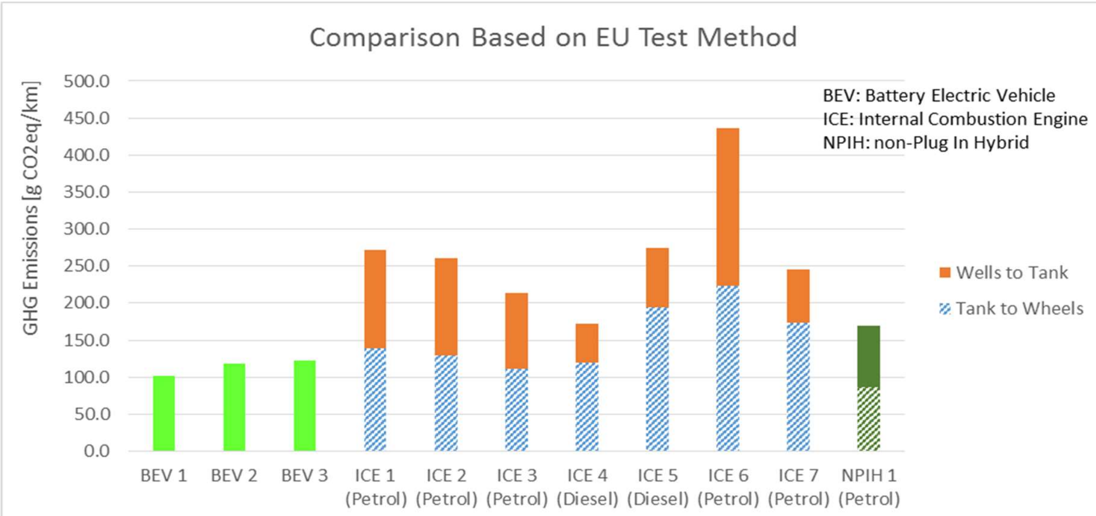

Figure 3: Simulated Wells-to-Wheels GHG Emissions for Selected Model Passenger Cars when CTL production is included in the Refinery Supply System and 25% of BEV Charging is Embedded PV and Grid Electricity is 25% Nuclear/RE

Conclusions

In general, South Africa's coal intensive electricity supply means that the operational wells-to wheels GHG emissions from battery electric passenger cars are comparable to compact conventional passenger cars operating on crude oil distilled liquid fuels despite the far superior energy efficiency of the electric vehicles. This gives non-plug in hybrids a GHG emissions advantage in areas solely supplied by conventional refineries.

There is however significant synthetic CTL[3] fuel production in South Africa and if this is taken into account at its national share of production, then battery electric cars start to offer significant GHG emissions advantages over compact gasoline fuelled cars. Diesel fuelled cars are still comparable[6] because the CTL production is more gasoline heavy. Clearly then, in areas that are exclusively or mostly CTL supplied (such as areas of Gauteng), electric cars are significantly lower emitting on a relative basis with the caveat that if fuel demand were to drop in those areas because of electric cars, the CTL fuel would simply be distributed elsewhere given the nature of the supply system in the country. If 25% of Battery electric vehicle charging is however shifted from the national grid to embedded solar supply at home and work and the grid electricity supply shifts to 25% nuclear and renewable sources, both attainable targets, then the operational GHG picture shifts unambiguously in favor of battery

[6] Diesel passenger cars still only account for around 10% of the car market if SUVs are included, with few compact models to choose from. In general, the fuel savings attained with diesel passenger cars have also not offset the capital and maintenance premium in South Africa.

electric cars. Clearly then, in principle, South African policy supporting electric cars should incentivize small scale embedded charging as much as the cars themselves.

Caveats

Standard emissions test cycles have been used as the basis for comparison however the real world relevance of these procedures is in serious question given that the deviation between the fuel economy as measured in the EU test method, for example, and real world measurements by motorists has been steadily increasing and has now reached 40%, according to the International Council on Clean Transportation (ICCT)[7]. Three quarters of the gap is attributed to manufacturers exploiting loopholes in the procedure, which electric car manufacturers have no motivation to do because their vehicles have zero tailpipe emissions. Against that, electric vehicles offer the driver greater potential to accelerate beyond the level of acceleration in the test cycle, especially at low speeds, while on the other hand electric vehicle owners may have more range anxiety and drive more sedately. Indicative figures from a Tesla owner's forum[8] seem to indicate around a 30% higher real world consumption than the US FTP test and so we might console ourselves that, since test methods underestimate real world emissions for both technologies, the current emissions test cycles offer the best readily available basis for comparison

A detailed account of South African refinery emissions by refinery type is not easily accessible in the public domain and the source data of the SATIM model[9] as published by the University of Cape Town's Energy Research Centre was used as a basis to estimate these. The numbers used are believed to be sufficiently representative for this type of indicative analysis but may not be precisely the current process emissions.

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[7] http://www.theicct.org/news/real-world-vehicle-fuel-economy-gap-continues-widen-europe-press-release

[8] Author's calculations comparing data from https://forums.tesla.com/en_CN/forum/forums/model-s-1-year-kwh-consumption to that published by US EPA (www.fueleconomy.gov – see footnote above)

[9] http://www.erc.uct.ac.za/groups/esap - Link to source data from overview of the South African TIMES model on this page

[10] Supporting African Municipalities in Sustainable Energy Transitions (http://samsetproject.net/)