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SUBMISSION TO FUTURE FUELS STRATEGY DISCUSSION PAPER

Please find below a submission by the Australian National University Institute for Climate, Energy and Disaster Solutions (ICEDS) in response to the Future Fuels Strategy Discussion Paper.

We thank you for the opportunity to provide this submission. Transport emissions are an increasing fraction of Australia's greenhouse emissions but with the electricity sector on a path to rapid decarbonisation. The Future Fuels Strategy will be an important component of the plan to help meet our Paris Agreement emission reduction commitments and future emission reduction targets.

As well as providing expert advice in this submission from our researchers, ICEDS would like to offer its expertise to contribute to the ongoing Future Fuels Strategy process in whatever capacity is appropriate.

Sincerely,

Prof Mark Howden

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Electric vehicles – key to delivering long term transport emission reductions

Understanding the rapidly reducing costs of electric vehicles is important to develop an effective strategy.

The Future Fuels Strategy "*will become an important element of the Government's technology-based Long-term Emissions Reduction Strategy* (p8)".

Considerations of emissions must extend beyond the current situation and consider future opportunities and impacts on emission reduction. While a short-term analysis suggests that hybrid vehicles have the lowest running costs and the lowest cost of emission abatement in 2021, the situation is rapidly changing. Battery pack prices have already dropped by 85% from 2010 to $136/kWh and are forecast to be below $55 in 2030 [1]. Furthermore, Australian electricity will be increasingly decarbonised by the mid-late 2020s. This will decisively tip the balance of lowest cost ownership and lowest cost of emission abatement towards electric vehicles during the coming 5-8 years [2].

Australia needs to be ready for the pace of this transition. When prices make sense, markets can transform extremely rapidly. Electric vehicle sales in Norway have increased 150 fold in less than a decade with almost 75% of vehicles plug-in [3].

Consumers and policy makers need to have good understanding of the impacts of this change.

Marginal emissions of electricity – impact on electric vehicle emissions

Emissions calculations for the electricity input for electric vehicle demand should consider the marginal emissions intensity of generation not the average emissions intensity of electricity generation when considering the emissions intensity of electric vehicles. This approach is reflected in a range of studies of emissions intensities of electrical vehicle in other jurisdictions [4][5][6][7]. The emissions associated with an increase in demand better reflects the change in emissions associated with a switch to electric vehicles.

The difference between average and marginal emissions can be visualised in Figure 1. The left of the chart shows an example energy mix to meet 10 units of demand. In typical market conditions, wind and solar (green) are always fully dispatched since the cost of generation is low (no fuel costs). Dispatchable sources of generation, which is currently predominantly fossil fuels, are then used to fill the gap between renewable energy supply and demand. The average emission intensity of generation is then the sum of all the emissions for the generators used divided by the total demand represented by the red arrows.

The central stack in the chart represents adding two units of energy demand for electric vehicles into that system. The wind and solar is already fully utilised, so the extra generation has to be supplied by the fossil fuel generators as represented by the grey triangle. The extra supply to meet the electric vehicles demand in this example (grey arrow) therefore has a higher emissions intensity than the average emissions. This is referred to as marginal emission intensity.

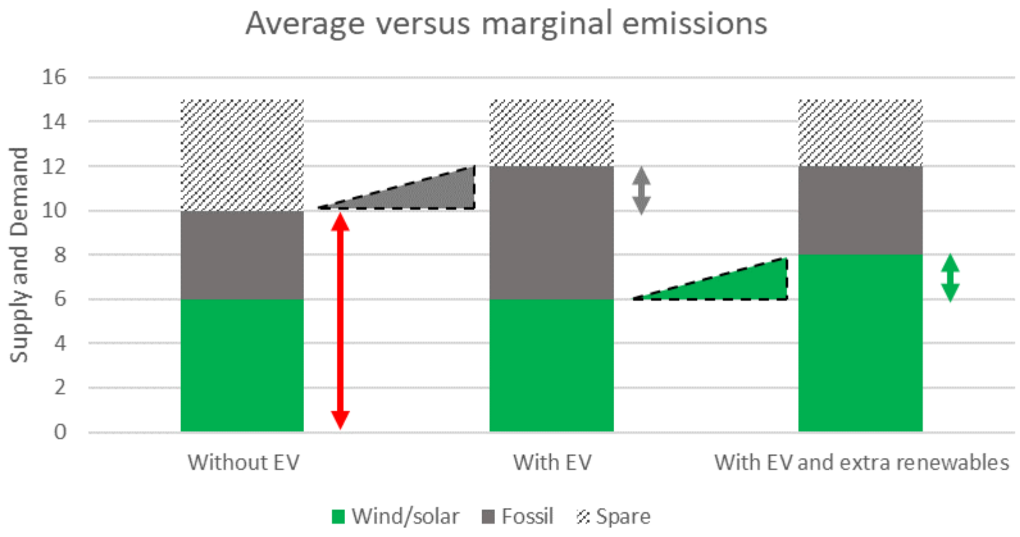

FIGURE 1. SCHEMATIC OF MARGINAL EMISSION INTENSITY

Electric vehicles can have a low marginal intensity if extra renewable energy supply is added as electric vehicle demand is added. This is represented by the green triangle on the right of Figure 1. The marginal intensity of the electricity supply for electric vehicles would then be zero. Demonstration of the additional renewable energy supply could be undertaken by the purchase and surrender of Renewable Energy Certificates (RECs) as discussed later.

Marginal emissions intensity of the National Electricity Market

The National Electricity Market comprises five individual state markets, however these markets are strongly interconnected. Provided interconnectors are not constrained, the marginal generator that sets the price in a particular region (marginal generator) can often be located in another region if the lowest cost solution to meet the last increment of demand is interstate.

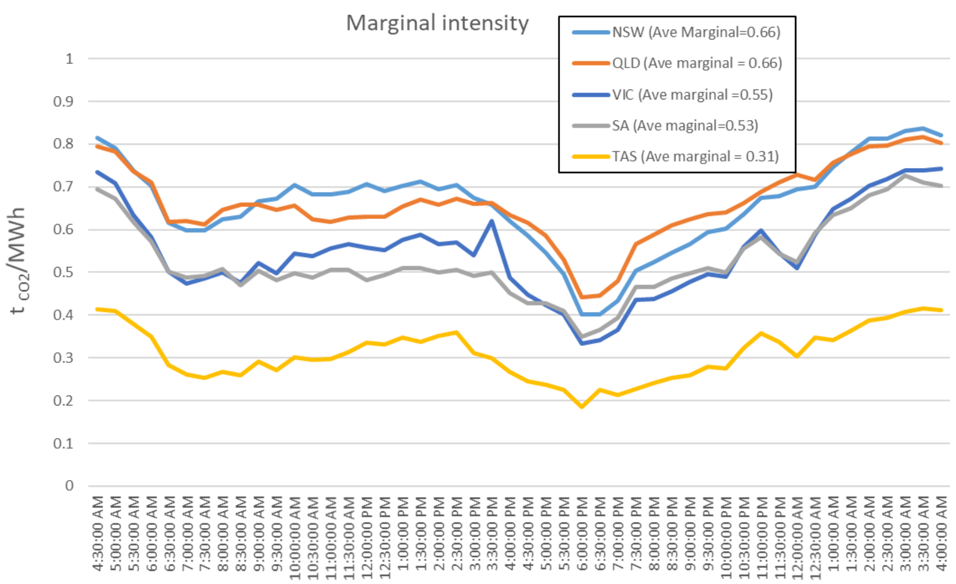

FIGURE 2. MARGINAL EMISSIONS INTENSITY OF GRID ELECTRICITY IN MAINLAND NEM STATES

Figure 2 is the average marginal intensity by time of day for the different mainland states over the 2019/20 financial year. This is calculated based on the average emissions intensity of the marginal (price setting) generators for each time period over the year.

What emerges from this analysis is that the marginal intensity for the mainland states is very similar varying from an average of 0.53kg/kWh in SA to 0.66kg/KWh in Queensland and NSW. The NEM is relatively well interconnected with the marginal generator only differing between states if there are constraints in the system. This leads to similar marginal intensities across the NEM markets. It makes little difference in which state the electric car is owned and operated in the mainland NEM states. Tasmania's marginal emission intensity (0.31kg/kWh) does diverge from the mainland NEM states, but is significantly higher than Tasmania's average emission intensity.

This results in a very different conclusion to the EV emissions results presented in Figure 5 of the FFS report. Based on the Nissan Leafs WLTP consumption of 0.15kWh/km, the emissions intensity of the Leaf is less than 100g per km across the mainland NEM states based on average marginal intensity.

This contrasts with the much larger variation in average total emission intensity from 0.43 kg/kWh in SA to 0.98 kg/kWh in Victoria reported in the National Greenhouse Accounts Factors [8] and used in the Discussion Paper calculations. These do not reflect the additional emissions associated with electric vehicle changing.

The time of day charging, as shown in Figure 2, has a much greater impact than location in the NEM. The lowest marginal emissions intensity would result from charging in the evening peak due to the increased frequency of hydro and gas providing the marginal generation. However, this would not be the best time to charge from a grid congestion/integration perspective so correct incentives will need to be considered to balance emissions reductions and costs.

Importantly, that emissions intensity for the additional electricity demand for electric vehicle charging can be zero through installation of additional renewable energy generation as per the right column in Figure 1. A Leaf travelling the average 15,600 km per year requires 2.4MWh of electricity. This additional supply can be demonstrated through purchase and surrender of 2.4 Large-Scale Generation Certificates (LGC). The current LGC price of around $32 requires a payment of only $77 per annum to consider the electricity generation emissions emission free. Forward prices are much lower, decreasing this cost in future. At 100g per km carbon avoided, this would equate to a carbon price of <$50 per tonne to have zero emission electric vehicles.

It is also important for owners of solar systems to understand that they have effectively sold their renewable generation if they sold their Small Scale Technology Certificates (STC) at the time of installation. Charging from home solar still results in additional emissions required to meet the additional demand as this generation would no longer be exported. The electric vehicle owner would benefit from lower charging costs but additional low emissions generation needs to be built to offset the emissions associated with the increase in demand.

Legacy emissions – need for rapid transition

It is important for consumers and policy makers to understand that decisions on vehicles made today, and the pace of the low emission vehicle transition, affect emissions decades into the future.

The average age of vehicles in the active fleet is currently 10.6 years. This corresponds to a much older average vehicle age at end of life of more than 20 years. This is consistent with approximately 8% of vehicles being removed from the fleet in each year due to accidents or end-of-life mechanical failures. Approximately two thirds of vehicles on the road are less than 10 years old, one quarter 10 to 20 years old and a further eighth of vehicles are more than 20 years old.

The legacy emissions from vehicles purchased in the coming decade are important to achieve future emission reductions. If the fleet was to linearly transition between now and 2040 to all zero emissions vehicles, with the remainder of the fleet 100g/km vehicles, then the average emissions intensity of the fleet in 2040 would still be more than 40g/km. The weighted emissions in 2040 for different ages of vehicles can be seen in Figure 3. The area in red is the legacy emission intensity due to vehicles purchase prior to 2020. The orange section is the vehicles purchase between 2020 and 2030 while the blue is contribution due to non-zero emission vehicles purchased after 2030. Vehicles purchase in the next decade have a significant impact on 2040 emissions.

The benefits of a faster transition is also shown in Figure 3. The black dashed line is the weighted emissions if the fleet transitions to all zero emission vehicle purchases by 2030. All vehicles less than ten years old in 2040 would then be zero emissions vehicles and not contribute to 2040 emissions. The area in orange is dramatically reduced due to the lower number of high emission vehicles still in the fleet resulting in halving of the emissions intensity of the fleet in 2040 to around 20g/km.

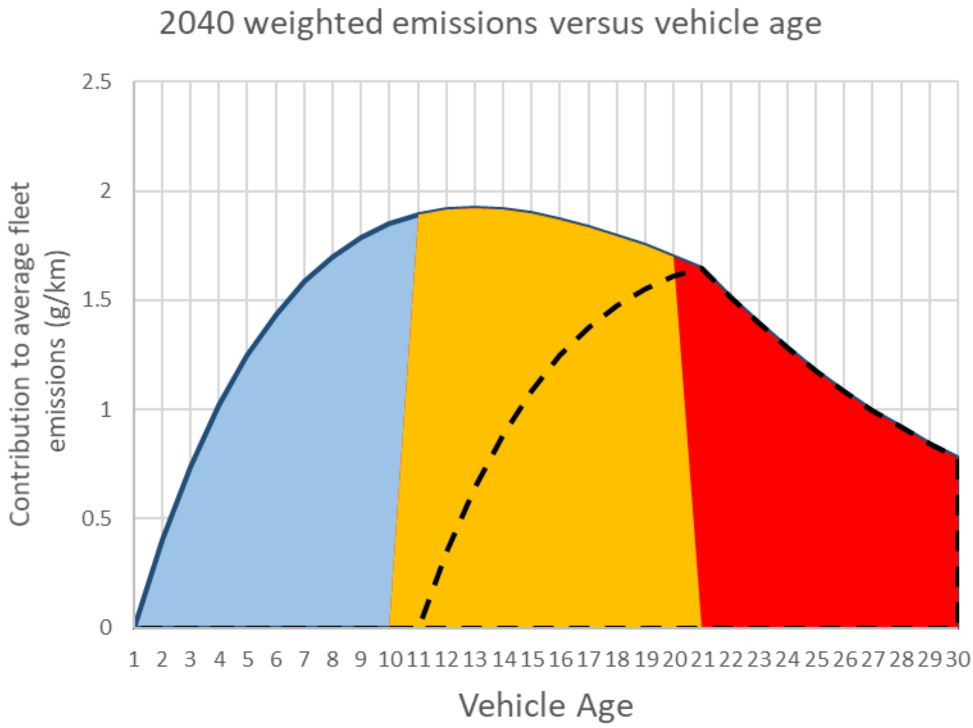

FIGURE 3. WEIGHTED EMISSIONS (FRACTION OF FLEET X EMISSIONS INTENSITY) OF VEHICLES IN 2040 TRANSITION SCENARIO (AREA) AND 2030 TRANSITION SCENARIO.

Understanding lifetime emissions is critical to making good decisions about vehicle choice. Consumer information (discussed in next section) would benefit from lifetime emissions information. Purchase decisions being made today are impacting Australia's emissions for decades to come. Accelerating the transition has strong long term benefits.

Consumer information

It is pleasing to see that provision of information regarding vehicle costs and emissions is a key part of the strategy document. Good decision making requires good information.

*P19 **Question 1. What is the most important information to provide to motorists and fleets about new vehicle technologies and future fuels?***

The costing methodology provided in the draft relies on a limited set of input assumptions. Motorists have very different circumstances and have very different motivation for making vehicle purchases. These can have a significant impact on the running costs and the associated implied carbon costs of vehicles. Information provided should be able to be adjust according to the inputs of the consumer. Input variables that have significant impact on lifetime costs include:

- Financing costs: A buyer with cash has low term deposit returns (~1%), vehicle purchases through mortgage have effective rates approximately (2.5%) which are much lower than car loan rates (~5.5%)
- Ownership period of vehicle: Based on current attrition rates of 4.4%, the average life before retirement of an Australian vehicle is more than 20 years which is consistent with the average operating fleet life of 10.5 years. Some

fleets turn vehicles over at 12 months while some purchases are made for the life of the vehicle.
- Vehicle comparisons should be flexible: A purchaser of a $50,000 vehicle is likely to be comparing vehicles at a price point, rather than a purely equivalent vehicle based on vehicle size. Private or fleet consumers should be able to select the vehicles they are comparing
- Electricity emissions: The cost of offsetting electricity emissions through purchase of RECs (see earlier) should be an option to have a zero emissions electric vehicle. This should be noted as a small but additional cost.
- Electricity supply: Cost of electricity increasing depends on time of use. Pricing on some plans vary with time of day, varying from maximums at peak periods to lower costs at off-peak. Behind the metre solar charging will likely be lowest cost as new feed-in-tariffs are now usually less than off-peak rates.
- Vehicle distance travelled: The relative costs of depreciation and financing decrease as vehicle distance travelled increases. This will be particularly important for fleet and regional consumers.

Changing some of these assumptions can have a significant impact on the relative costs of abatement. Comparing a Hyundai Elantra, to a Hyundai Ioniq Hybrid to a Hyundai Ioniq Electric over 5 years at vehicle financing rates leads to the conclusion of high abatement costs around $400 per tonne for the hybrid and electric vehicle relative to the Elantra. However, considering a 10 year comparison at mortgage rates and 20,000km per year, both the hybrid and the EV have lower total cost of ownership, resulting in no cost for emission reductions.

As identified in the previous section, the calculations should also include the relative emissions costs over an assumed life of the vehicle, beyond the current buyers assumed ownership period. Once a vehicle is purchased, it continues to produce emissions until it is removed from the road. This would help buyers understand the emissions implication of their purchase beyond the period of ownership.

Biofuels

P11: Sustainable biofuels can be used in conventional vehicles with little or no modification, and offer a low-carbon alternative for commercial fleets.

P27: Biofuels offer opportunities for emissions reduction, particularly for heavy duty vehicle fleets.

Bioenergy can be a CO_2-neutral energy source that absorbs the carbon emissions during its energy conversion through the photosynthesis process. However, biomass harvesting is often neither sustainable nor carbon neutral, and the combustion of biofuels contributes to local air pollution and increased ozone-related health risk. Photosynthesis has an energy conversion efficiency of only 1% (solar irradiance to energy content of biomass) while, by contract, photovoltaic can be 20% in conversion of solar irradiance to electricity. This means that only one-twentieth of land area would be needed to capture the same energy from the Sun in a photovoltaic system compared with biomass.

The electric motor is far more efficient than combustion of biofuels for electric vehicles, or for heating (heat pump). The overall fuel efficiency can be increased by a factor of 3-4 using electric vehicles compared with conventional internal combustion engines. In light of the rapidly declining cost of solar photovoltaics and the advantages of the electric motor, it will be increasingly difficult for biofuels to compete with renewable electricity from solar and wind energy.

Despite the range of operation for battery electric trucks being currently constrained by the weight of the battery storage system, the operational range of the electric truck is expanding to 500-800 km as the technology advances e.g. Tesla's Semi model https://www.tesla.com/semi. In addition, alternative zero-carbon solutions for long-haul, heavy-duty road transport can include:

- Battery electric trucks + battery swap stations
- Battery electric trucks + e-highway https://www.mobility.siemens.com/global/en/portfolio/road/ehighway.html
- Battery electric vehicles + supercapacitor (for urban rail transit) https://infrastructuremagazine.com.au/2018/09/12/the-energy-technology-that-could-overhaul-tram-systems/
- Hydrogen fuel cell trucks https://nikolamotor.com

Renewable energy-based fuels such as hydrogen, ammonia and synthetic hydrocarbons via water electrolysis and chemical synthesis can be zero-carbon alternatives to aviation jet fuel, and heavy oil fuel for shipping.

Electric vehicle integration

P22: Bidirectional charging, including vehicle-to-grid and vehicle-to-home applications, offer the potential for battery electric vehicles to serve as distributed energy storage.

*P23: **Question 1** - **What are the highest priority issues to consider when integrating large numbers of battery electric vehicles into the electricity grid?***

Electric car batteries can contribute significant storage capacity as well as large demand flexibility to the electricity system. Enabled by smart grid technology, these kilowatt/kilowatt-hour scale storage systems can be aggregated and utilised for gigawatt/gigawatt-hour scale demand response. Electric car batteries typically have a high round-trip efficiency of 80-90%, which can be ideal storage for large-scale energy day-night shifting.

A high-resolution analysis of the role of electric cars in supporting a zero-carbon renewable energy future in Australia was undertaken at the Australian National University https://doi.org/10.1016/j.energy.2020.119678. In this study, the charging of 80% of the passenger cars was assumed to be fully flexible and regulated according to a real-time energy supply-demand balance, subject to a minimum state-of-charge constraint of 25%. The modelling outcomes show that the electricity prices as well as the storage requirements can be largely reduced with flexible charging of electric cars. This represents a promising future for active demand-side participation in the Australian energy market.

Future research can also look into the interaction between electric vehicles and solar power e.g. alleviation of the network congestion by integrated "PV + EV" technology.

References

[1] A. Phadke, A. Khandekar, N. Abhyankar, D. Wooley, and D. Rajagopal, “Why Regional and Long-Haul Trucks are Primed for Electrification Now,” 2021.

[2] Bloomberg New Energy Finance, “EVO 2020,” 2020. https://bnef.turtl.co/story/evo-2020/page/3/1?teaser=yes (accessed Mar. 29, 2021).

[3] OFV, “Bilsalget i desember og hele 2020 | Opplysningsrådet for veitrafikken.” https://ofv.no/bilsalget/bilsalget-i-desember-2020 (accessed Mar. 19, 2021).

[4] Y. Fang, F. Asche, and K. Novan, “The costs of charging Plug-in Electric Vehicles (PEVs): Within day variation in emissions and electricity prices,” *Energy Econ.*, vol. 69, pp. 196–203, Jan. 2018, doi: 10.1016/j.eneco.2017.11.011.

[5] C. E. Thomas, “US marginal electricity grid mixes and EV greenhouse gas emissions,” *Int. J. Hydrogen Energy*, vol. 37, no. 24, pp. 19231–19240, 2012, doi: 10.1016/j.ijhydene.2012.09.146.

[6] R. Garcia and F. Freire, “Marginal life-cycle greenhouse gas emissions of electricity generation in Portugal and implications for electric vehicles,” *Resources*, vol. 5, no. 4, 2016, doi: 10.3390/resources5040041.

[7] N. C. Onat, M. Kucukvar, and O. Tatari, “Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States,” *Appl. Energy*, vol. 150, pp. 36–49, 2015, doi: 10.1016/j.apenergy.2015.04.001.

[8] “National Greenhouse Accounts Factors,” 2020.