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The role of hydrogen in Australia's transport energy mix

Jamie Ally [a,*], *Trevor Pryor* [a], *Attilio Pigneri* [b]

[a] *School of Engineering and Information Technology, Murdoch University, Perth, Western Australia, Australia*
[b] *Talent with Energy Pty Ltd, Hobart, Tasmania, Australia*

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ABSTRACT

In this study we review the trends and trajectories of energy use and emissions in Australia's road transport sector. We find that energy use and emissions in heavy-duty vehicles are growing at a greater rate than light-duty vehicles, and that heavy-duty vehicle energy consumption will surpass that of light-duty vehicles by 2032. We explore whether popular light-duty alternative energy concepts, such as battery electric technology, are also competitive for heavy-duty vehicles. We observe that finding a sustainable energy technology that competes with the high energy density of diesel is a formidable challenge. Alternatives such as natural gas, propane and biofuels have managed to establish a beachhead. However, none have constituted a disruptive threat to diesel oil. The lack of any *silver bullet* technology indicates that further research into technology options is warranted. Hydrogen fuel cell systems have many characteristics which are attractive for the heavy-duty transport task, including complementarity with electric vehicles and a cross-benefit from developments in batteries and electric drivetrains. We conclude that for Australia, fuel cells may find their niche in the electrification of heavy-duty drivetrains, in markets where zero emissions are desirable, and where range, duty cycle or payload requirements exceed the capabilities of battery–only vehicles.

Introduction

In January 2014, a workshop was held by the Australian Renewable Energy Agency (ARENA) in Canberra, bringing together national experts to discuss the future of renewable transport fuels in Australia. Amongst the objectives of the workshop, ARENA was seeking an update on the status of the technologies that were being developed for renewable transportation, and to identify how ARENA might be able to assist with the Research & Development (R&D) of viable renewable transport fuels.

There was little discussion of Electric Vehicles (EVs) during the workshop. The discussion instead focused on the production of renewable liquid and gaseous fuels. While the development of electric vehicles is an extremely important

* *Corresponding author.*
E-mail addresses: jamieally@gmail.com (J. Ally), t.pryor@murdoch.edu.au (T. Pryor), attilio.pigneri@talentwithenergy.com (A. Pigneri).
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and disruptive technology, the application of EV technology is currently limited to the light duty and short range segments of the transport sector.

The concept of renewable transport fuels is often conflated with the development of electric vehicles. EVs are regarded by many as a likely enabler of a more sustainable future for cars and other light-duty vehicles. However, a disaggregation of transport energy use reveals that there is a large and growing segment of the transport sector for which EVs are not suitable, and which holds significant opportunity for other alternative energy technologies.

Several aspects of the Australian context are unique. The country has vast resources of both renewable and non-renewable energy, which could be drawn upon for hydrogen production and a transition to de-carbonise the economy. In addition, Australia has experienced a decline in oil production and has become a net importer of transport fuel. As this oil trade deficit widens, so does the energy security risk and drive to develop indigenous transportation energy resources. In terms of vehicle choice, the population is sparsely settled which compels people to use vehicles that are capable of long distance driving, reducing the market for battery-only vehicles while expanding the market for hybrid vehicles. These characteristics make the Australian market particularly attractive for the development and deployment of innovative renewable fuels and sustainable transportation technologies.

Policy context

The approach of the Australian government on greenhouse gas emissions reduction has been extremely volatile, with each successive government working towards a different policy approach. The most recent change is the Government's repeal of the Carbon Tax and associated Clean Energy Legislation [1]. Despite the vast difference in Party policies, Australia still has an enduring bipartisan and unconditional emissions reduction target of 5% from 2000 levels by 2020. While the preferred greenhouse gas reduction mechanism of the government of the day continues to be highly uncertain, the R&D effort must continue to bring new technologies to market that have the potential to deliver carbon emissions reduction.

Australia's growing oil trade deficit

Recent data shows that *peak oil* for Australia has already passed. The trend of decline in Australian oil production is well established. The BP Statistical Review of World Energy published in 2012 [2] was particularly important for Australia because it showed that by 2011 Australia's oil production had dropped to 41% from its peak in 2000, while oil consumption had increased to just over 1 million barrels per day, resulting in record oil imports which made up more than half of Australia's total oil demand.

As recently as 2002/03, Australia had a trade surplus in oil and liquid fuels, but by 2013 the gap between supply and demand had increased, with Australia producing only 44.9% of its consumption [3]. The gap continues to widen at an alarming pace, as illustrated in the historical data presented in Fig. 1. The Australian economy is increasingly dependent on imported petroleum products, and is exposed to the price volatility of global oil markets.

As a member of the International Energy Agency (IEA) Australia is required to hold oil stocks equivalent to 90 days of imports to contribute to any global oil emergency that might be declared by the IEA. Australia is the only IEA member state that does not meet this commitment, and as indigenous production continues to fall and demand continues to rise, the shortfall will continue to increase.

The Australian Government's 2013 *Energy White Paper (Issues Paper)* indicates that Australia may average only 60 days stock in 2014, and only 45 days stock by 2024 [4]. In a 2012 publication the IEA was unequivocal in its strong recommendation that Australia take action to become "fully and systematically compliant" with its stockholding commitment [5]. The Energy White Paper estimates that a build program to rectify this issue would require a $6.8 billion investment in domestic storage infrastructure. This magnitude of investment merits further investigation of the alternatives to Australia's growing dependence on imported crude oil and refined oil products.

Transport energy and the greenhouse gas abatement task

Australia's greenhouse gas emissions inventories have exhibited some remarkable changes in recent years. Most notably, total emissions from the electricity sector have fallen significantly for the past 5 years after peaking in 2008, reversing a trend of strong growth that had persisted for the previous 20 years.[1] However, emissions from the second-largest sector of the economy – the transport sector – have continued their steady year-on-year climb at a nearly linear rate of growth. The stark contrast between the trajectories of these two sectors is presented in Fig. 2. The emissions of the transport sector are linked to economic activity, population growth and oil prices, and are expected to grow unless the demand for transport starts to suddenly decline, a significant modal shift is made, or a technological change is made to reduce the emissions associated with transport activity [8].

The energy and emissions associated with Australia's transportation energy sector are comprised of Civil Aviation (17%), Road Transportation (75%), Railways (3%), Navigation and shipping (5%), and Other Uses such as off-road vehicles (<1%). Of these sectors, Road Transport is clearly the largest energy user and therefore can be considered the greatest potential source of improvement from any disruptive innovation that improves the sustainability of the sector.

The Road Transport sector can be disaggregated into Cars, Trucks and Buses, and Motorcycles. The breakdown of energy use in each sub-sector is presented in Fig. 3.

Energy use in cars is the dominant end use of road transport energy at 57%, with trucks and buses consuming most of

[1] This striking reversal is attributed to a moderation in electricity demand, driven by a combination of factors including consumer response to higher electricity prices, mandated energy efficiency standards, increasing availability of energy efficient appliances, greater awareness of energy saving opportunities, uptake of renewable energy sources, and structural changes in the economy [6,7].