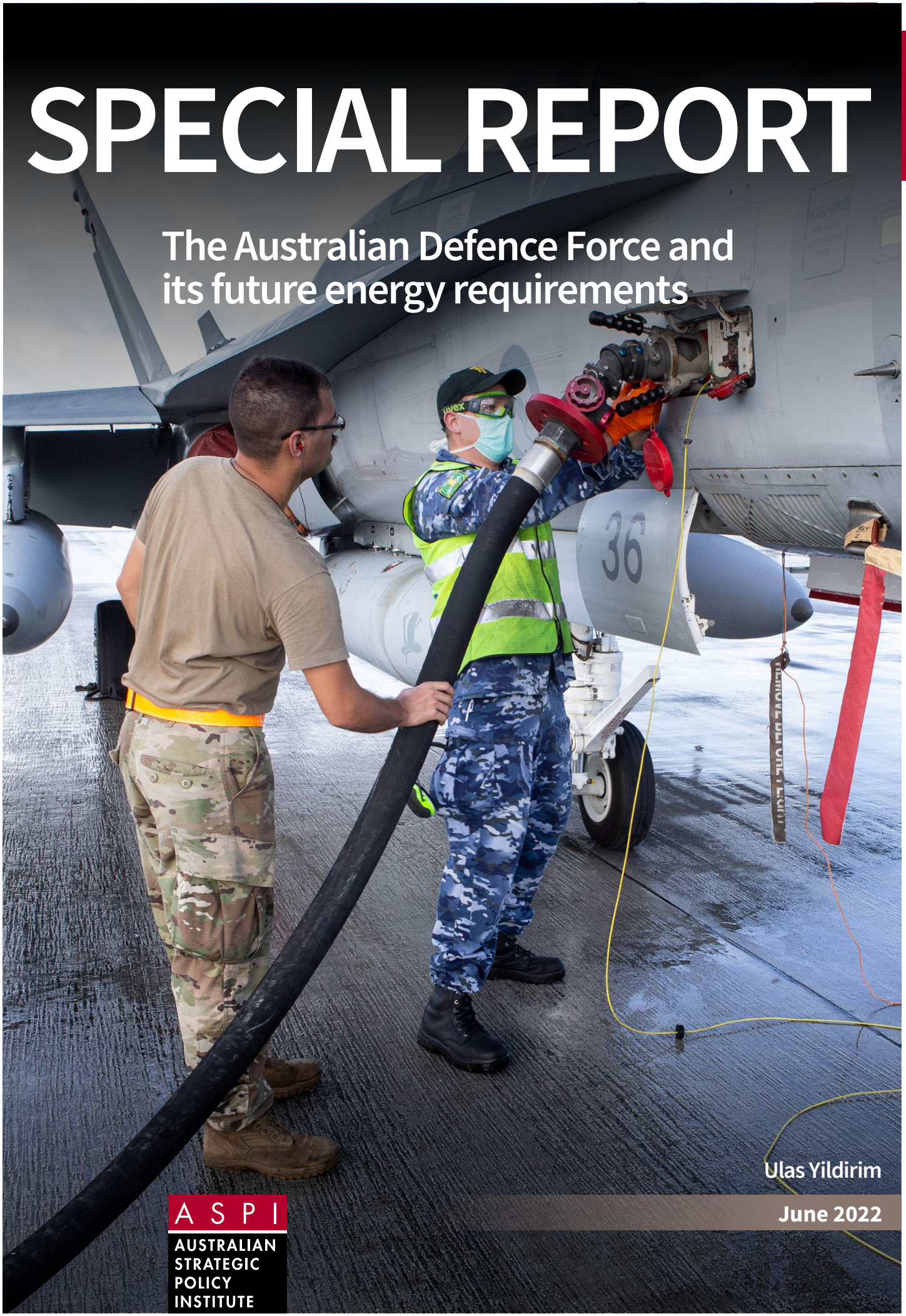
SPECIAL REPORT

The Australian Defence Force and its future energy requirements



Ulas Yildirim

June 2022

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About the author

Wing Commander Ulas Yildirim PhD is a Royal Australian Air Force visiting fellow at ASPI. The views expressed in this article are his and do not reflect the official position of the RAAF, Defence or the Australian Government.

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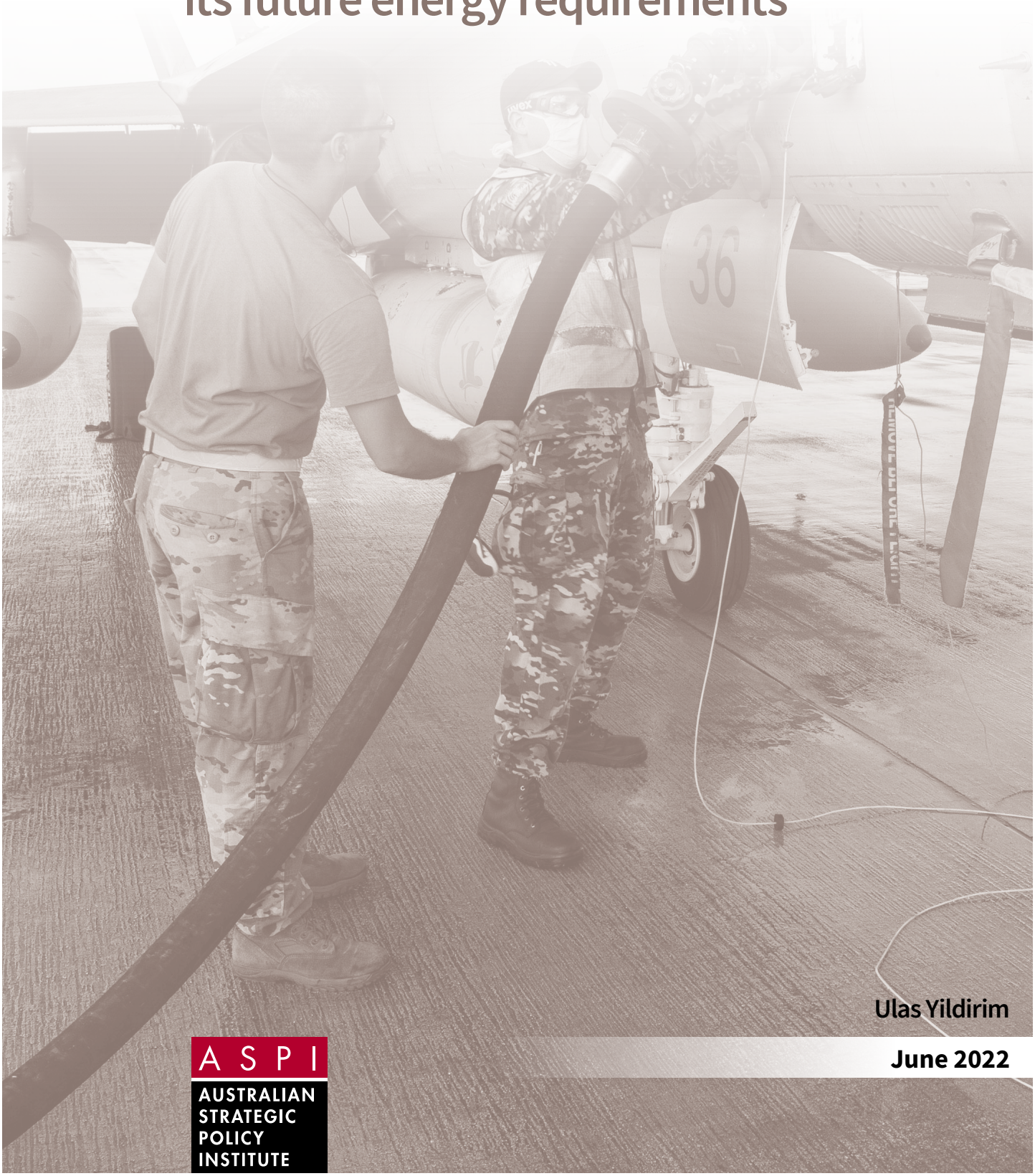

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Executive summary

The global energy system is undergoing a rapid and enduring shift with inescapable implications for militaries, including the ADF. Electrification and the use of alternative liquid fuels are occurring at scale across the civilian economies. Despite that, fossil fuels, such as diesel and jet fuel, will be around for a long time to come, given their use in long-lived systems like air warfare destroyers, Lockheed Martin's F-35 aircraft, M1A2 Abrams tanks, and in capabilities still in the design stage but planned to enter service beginning in the mid-2030s such as the Hunter-class frigates.

Australian supply of these fuels is provided by globally sourced crude oil flowing through a handful of East and Southeast Asian refineries. Supply arrangements for these critical commodities are likely to become more fraught, however. This is already occurring because of the fracturing of global supply chains and the drive for national resilience in many nations, driven by Covid-19, the return of coercive state power and, of course, Putin's war in Ukraine. Australia's dependence on imports for liquid-fuel security, at least as it pertains to the ADF, extends well beyond insufficient reserves and refineries.

The long-term nature of major platform acquisitions, as well as infrastructure investments, means that the Australian Government and the ADF must move beyond assessing the implications of this future and begin to plan and act to shape the ADF's energy future in ways that take advantage of the wider international and domestic energy transition that's underway. Futureproofing the ADF requires the growth of an alternative fuels sector in Australia to meet broader needs that include but aren't defined by the ADF alone. That can only be achieved through partnerships because no individual operator or enterprise has a monopoly on the energy sector.

Partnerships can be used to shape the alternative-fuels market in Australia by providing a secure source of investment for alternative-fuel providers. Those fuels can then supplement traditional fuel sources until a complete transition away from fossil fuels can occur. In this context, the golden thread for Defence is its need for rapid transition towards renewable energy sources as a means to operationalise its strategy among its many and varied plans and contracts. Without the appropriate investment and support, energy security, stable fuel costs and low emissions will remain elusive. Hence, partnerships and co-investments can achieve sustainable change, ensuring Australia's current and future energy security that the ADF relies upon.

The rapid and long-term shifts occurring in the global energy system are due to technological advances and the availability of cheaper renewable fuels. However, Australia's dependence on imports for liquid-fuel security places the ADF at risk. The risk isn't whether the ADF can get to an area of operations and perform poorly but whether it can get there at all.

In the absence of proactive change, Defence may ultimately have to 'own more and more of [the fuel] supply chain from well to bowser',[1] which would be a bad outcome from all perspectives.

In this context, the ADF's transition to renewable sources isn't a zero-sum choice that results in operational capability being undermined or degraded. A rapid transition to renewables will make the ADF more effective in doing what the Australian Government directs and demands in the more divided and dangerous world and region we're already experiencing.

The government and Defence must recognise this long-term risk to a fundamental input to our military capability and start acting to mitigate it for the future.

Recommendations

Plan on higher prices

Defence should build assumptions of higher energy prices into the budget across the enterprise over the medium and longer terms. Those assumptions should reflect a range of liquid-fuel futures and possible price points and take advantage of usage data and forecasts available to internal Defence planners.

Support increased liquid-fuel reserves and preserving refinery capacity to meet Defence needs as part of a whole-of-government fuel-security strategy

This should include alternative-fuels production capacity so that the ADF is not wholly dependent on liquid fossil fuels. Perversely, transition in global energy systems makes conventional liquid-fuel reserves more important, not less. There are several dimensions to this requirement:

- The current policies preserving Australia's limited refining capacity to 2030 should continue beyond that point.[2] This is because any external shocks, such as the Ukraine war, will heavily affect Australian markets, given that 90% of Australia's fuel requirements are imported.[3] The best value-for-money that delivers assured supply could involve more than current subsidies: options include part public ownership, for example.
- Alternative-fuel production capacity makes sense as part of the policy mix, particularly if the remaining fossil-fuel refineries become simply unaffordable because of their market power when dealing with a government that has clear dependencies on them. To achieve this outcome, partnership between Defence and commercial enterprises must be front and centre.
- Other policy levers that can be considered include initiatives such as providing greater certainty to commercial operators and accelerating the modernisation of fuel infrastructure at our ports and airports. For example, in combination with co-investment in alternative-fuel production that delivers affordable, sustainable liquid-fuel alternatives to the ADF and civil air operators based in Australia, the government could regulate for progressively higher percentages of sustainable aviation fuel to be used by Australian-based airlines.
- Australia should continue to increase its liquid-fuel reserves. The previous government began this work, and new policy should continue in the same manner.[4] The reserves should be onshore and substantially higher than the minimum holding recommended by the International Energy Agency (IEA). Substantial analysis and policy work on this subject has already been done and doesn't need to be rehashed.

In many ways, these policy recommendations aren't novel, because they're part of broader energy transitions occurring within Australia and internationally. Their value is the focus on the ADF's energy future and the connection between that future and key elements of our wider economy, including other major users of liquid fuels.

Make targeted research investments now

The ADF isn't alone in confronting a large-scale and challenging energy transition. The scale of investment required to make headway into something like alternative maritime fuels or hydrogen in aviation is far greater than the spend available to any single player, even a relatively large national organisation such as Defence. Therefore, it makes sense for the Australian Government and Defence in particular to partner with commercial entities to make targeted research investments, at both the basic and commercialisation stages, in support of operations at a viable scale. Such targeted research can position Defence and its commercial partners, who have parallel needs for sustainable alternative fuels, to build new fuel types into a planned transition. Such targeted investments could include the following:

- Establish partnerships with airlines such as Qantas and Virgin, and the academic and scientific sectors (including CSIRO and Defence Science and Technology Group), to investigate and trial small-scale alternative-fuel production facilities to meet specific fuel requirements, ideally at an already shared airport such as RAAF Williamtown / Newcastle Airport. 'Power to liquid' (PtL) technology appears to be among the most promising technologies in the long term and should be a high priority in such a partnership.
- Consider developing technologies that can produce fuel at the point of delivery.
- Partner with a major shipping company attempting to develop or commercialise alternative-fuel use out of an Australian port.

Target internal experimentation and collaborate with partner organisations facing parallel challenges

The ADF faces a similar set of challenges to partner militaries and commercial entities such as airlines, so it makes sense to collaborate with those partners on future energy-related experimentation and energy transition solutions.

At a minimum, Defence should seek to liaise with partners on relevant experiments and avoid duplicating research, analysis and experimentation that's already underway or complete.

The British Army, for example, is currently conducting extensive trials of hybrid drive technology in a number of tactical vehicles.[5] The US Army is paying a range of companies to explore how electric vehicles can be charged in austere field environments.[6] As already noted, the US Air Force is pursuing PtL innovations.

Similarly, the ADF, the US Air Force and the Royal Air Force are each seeking to develop modular, portable kits to produce jet fuels using approved feedstock. Such kits have the potential to disrupt existing fossil-fuel production and delivery methods and to potentially reduce emission life cycles while creating resilience of distribution. That's because they hold the promise of production at the point of use instead of reliance on complicated distribution systems in often difficult locations (Afghanistan comes to mind as a recent example). This recognises that Defence is facing disruption similar to that which large electricity providers are currently experiencing. There are particular advantages from partnerships domestically and internationally where the ADF and its partners operate the same or equivalent platforms (Boeing jet aircraft, in the case of local airlines, and common military platforms such as the Lockheed Martin F-35, Boeing F/A-18E/F Super Hornet, and Hunter-class frigates are all examples).

Evolve infrastructure requirements to support this energy transition and alternative fuels

Defence estate planners should include ease-of-delivery of energy to military bases as part of their future plans and work with federal, state and territory partners to ensure that integrated planning includes Defence's energy transition needs.

The Defence Fuel Transformation Project is about delivering 'a safer, simpler and assured Defence fuel supply chain in partnership with industry' and runs until 2045–46.[7] It's 'primarily intended to improve the quality of fuel storage and delivery facilities', not to increase available capacity or evolve the energy infrastructure available to Defence.[8] This indicates that a conceptual shift is needed to consider how future energy types and supply might break the long-held assumption that it's unlikely that Defence can operate if separated from a larger national support base for its energy needs. Point-of-use production and renewables bring the potential for disconnected operations domestically and on deployment.

However, a substantial part of Australia's domestic freight is conducted via coastal shipping relying on import ports.[9] Therefore, interruption to supply can't be addressed by using those import ports without land transport also being required. Access to certain regions in regional areas can be hindered by seasonal rains, as evidenced by the effects of La Niña in the most recent wet season. As disruptions from extreme weather become more frequent, this creates a lack of resilience within Australia's distribution network.

Additionally, gaining access to future fuels such as PtL and the benefits from point-of-delivery production will require the uninterrupted supply of feedstock such as hydrogen at local bases. That can be achieved via many means, including direct pipelines.

Mitigate energy demand increases and transition away from legacy fuelled systems where possible

Defence should take the opportunities already available to transition away from traditional liquid fuels, given that many low-risk options exist today. This can include the following:

- Shift the enterprise's 'white fleet' reasonably rapidly to an electric vehicle (EV) solution. This will include substantial infrastructure investments across the Defence estate to support a light EV fleet, taking into account up-front reinvestment costs and cash flows. This mature technology is an achievable first step away from fossil fuels that's likely to produce running cost savings over time.
- Adopt niche electrification opportunities across the ADF, for example by acquiring modern solar panels to supplement generator use in field settings. While bottom-up innovation is commendable and driving the adoption of such systems, these initiatives clearly already make sense across the force and should be adopted as quickly as possible, at scale, as a deliberate enterprise-level strategy.[10]
- Include the adoption of solar power, batteries and other renewable energy sources as a routine part of progressive base upgrades across the Defence estate.
- Aggressively invest in simulation systems, as well as other technologies that can reduce the energy demands, and particularly liquid-fuel demands, of the future force. Simulation is already being applied in Defence in various other ways, such as minimising operating costs and wear and tear on platforms; putting downward pressure on fuel demands is another logical application of simulation. This works with the grain of current simulation applications and plans, through which, ideally, not only well-prepared training activities can be simulated, but mission rehearsals can be conducted and operational plans tested in deployed and 'real world' settings.

Liquid fuels and the Australian Defence Force

The ADF relies on weapons systems that use combustion technologies, which are dependent on the availability of liquid fuels. Those systems include capabilities that will be around for a long time (air warfare destroyers, Lockheed Martin F-35 aircraft and M1A2 Abrams tanks) and capabilities still in design stage but planned to enter service beginning in the mid-2030s, such as the Hunter-class frigates.

This is, of course, not a unique problem: the energy density of fossil fuels has been a critical component of major weapons systems since their displacement of animal and sail power. Liquid-fuel dependence is a feature of all modern militaries, with the obvious major exceptions being nuclear-powered military platforms and small electric systems such as drones.

Contemporary operating data for major weapons systems and the history of previous major conflicts both highlight access to energy supply as a critical strategic consideration. The internal tanks on an F-35A fighter hold around 8,000 kilograms of jet fuel.[11] That doesn't take the aircraft terribly far, so the RAAF's KC-30A tanker aircraft extend that range. To do so, they can carry over 100 tonnes of fuel.[12] The major warships of the Royal Australian Navy (RAN) are unsurprisingly thirsty, too, and two of its previous oilers, HMAS *Success* and *Sirius*, carried approximately 9,000 tonnes and 35,000 tonnes of F-76 marine diesel, respectively, for replenishment underway.[13] The prospective RAN class of nuclear-powered attack submarines will, in fact, be the only major ADF weapon system not dependent on liquid-fuel supplies. Helicopters, armoured vehicles and the mundane mass of light vehicles and trucks that are key to any military operation also consume large volumes of fuel. There's currently no use of alternative fuels by the ADF. While batteries are critical to the operation of certain critical systems, such as tactical radios and small uncrewed aerial vehicles, they remain dependent upon electricity generation by traditional generators or fixed power infrastructure to recharge.

Energy, particularly oil, has played a major, if often poorly understood, role in international conflict.[14] While the connection between oil and war is very context specific, in some cases, access to stable supplies of oil for national economies and militaries has been at least a contributory cause of conflict. The 1990–91 Gulf War and Japan's response to the US oil embargo in 1941 are two examples.[15] There's also historical literature examining the military – energy system connection, particularly regarding the shift (preceding the civilian economy) from coal to oil in the early 20th century in major warships.[16] Oil was inextricably a part of that era of naval arms races and offered superior performance to the legacy fuel: coal.[17]

The fuel crisis of the 1970s raised questions about the risks of dependence on oil supplies, while also highlighting price volatility as a concern.[18] Between 1972 and 1985, the price of a barrel of oil rose from under $20 to reach a peak of over $120, only to drop below $20 again.[19] In a more recent example, the 2019 drone attacks on a major refinery in Saudi Arabia led to a 13% increase in fuel prices within days. And Putin's war in Ukraine has caused a major spike in energy prices internationally and energy-supply or price crises in several economies.

Contemporary global shifts away from fossil fuels are therefore significant for militaries, including the ADF. While there's been analysis of the security implications of climate change, much of that work has focused on demands for humanitarian assistance and disaster relief operations, as well the impacts of warming on key physical

infrastructure and the operating environment.[20] Less has been written on the parallel rapid shift and long-term risks and opportunities for the ADF and the world's militaries presented by changes to global energy systems. Those changes are about global responses to climate change, but also the fact that green energy innovations are displacing legacy energy systems on a cost basis, in some cases far more rapidly than many organisations have planned for or anticipated, leading to messy, patchy transitions.

The rapid shift away from fossil fuels is anchored on the continued need for energy security, stable fuel costs and, now, low emissions. In this context, what constitutes 'long term' is open to debate; one possibility is that a rough political consensus on 'net zero by 2050' will see legacy-fuel supply slowly decline from the middle of this century. But faster shifts in particular sectors and economies are also more likely, given the political desires of populations, including Australia's. Contention about the pace and timeline of shifts away from legacy fuel systems doesn't change the basic shape or nature of this trend. It's quite likely that, once most of the civilian transport sector has transitioned away from legacy-fuel systems, supply will be harder to obtain and more costly for militaries that haven't made a parallel or anticipatory shift.

Nonetheless, a substantial body of work has examined liquid-fuel supply issues for the ADF.[21] A large portion of that literature has repeatedly examined national-level fuel supplies and the state of Australia's strategic fuel reserves. The Australian Government signed an agreement with the US in 2020 to store oil in the US Strategic Petroleum Reserve—a partial solution to Australia's longstanding failure to meet the IEA-mandated 90-day domestic oil reserve that's been described as an 'accounting trick'.[22] Critics point out that not only would such oil reserves need to be transported vast distances in a crisis, but Australia lacks significant refining capacity to make use of it if and when it arrives. There are also more granular concerns related to such reserves, such as the limited storage and refining capacity proximate to major Australian military bases.[23]

Research on the threats and opportunities that future fuels present for the ADF has also been published. For example, almost 20 years ago, the Defence Science and Technology Organisation examined the implications for the future Army of alternative fuels and propulsion systems, surveying relevant disruptive technologies.[24]

ASPI's own Marcus Hellyer has framed the key issue clearly:

> … the transition to a post-carbon economy raises fundamental fuel-supply challenges for the ADF. As the civilian world moves towards a post-carbon future, it may seem like there will be less competition for liquid fuel and the ADF will enjoy bountiful supplies of cheap fuel. But it's more likely to be the opposite case; as the world's transportation systems electrify, the infrastructure for carbon-based fuels will atrophy as all links in that supply chain become increasingly uneconomical. At some point in time, liquid fuels will become 'niche'.
>
> What does that mean for an ADF that's used to relying on the civilian world for the supply and distribution of its liquid fuels? As the ADF doubles down on huge, liquid-fuel-reliant platforms such as infantry fighting vehicles, it may need to own more and more of that supply chain from well (or synthetic fuel plant) to bowser, increasing its logistics costs and challenges. Or it can choose a different path that will allow it to sustain itself on deployed operations without unwieldy, unsupportable logistics trains.[25]

The military implications of the changing international and domestic energy system are multiple. The first, Hellyer's focus, is the issue of supply and cost: how does the military ensure it has robust access to the energy sources required for various platforms to function, and how much does that cost? The second is one of operational trade-offs, the focus of the Defence Science and Technology Organisation's now-dated work: what advantages and disadvantages do various energy sources, fuels and means of propulsion lend a military? Third and broader are questions of geopolitical power and energy-system dominance: where do nations and their militaries need to source their energy and their energy technologies from (a dominant provider of renewable-energy systems will have significant strategic and economic leverage, for example, much as Russia's dominant supply position for Europe worked until the war in Ukraine began).[26] Finally, environmental impact itself is an important consideration, as carbon-intensive fuels are known to be the major contributors to dangerous climate change.

Those dimensions are of course linked. For example, oil allowed navies to operate faster and longer range capital ships, which at the same time demanded access to what was then a new resource at a scale that significantly shaped the foreign policies of the major powers before and through World War I.[27] Importantly, these challenges are as relevant for the ADF today as they are for the civilian sector. Solutions will require collaboration, as they're likely to affect the entire nation.

The remainder of this paper is in four sections. In the first, I summarise the ADF's current energy (that is, liquid fuel) supply arrangements. I then provide an outlook on the future energy system, from which militaries such as the ADF must ultimately draw, followed by an examination of the risks present in this outlook for the ADF. The final section turns to alternative fuels and propulsion technologies for the potential opportunities they present, before I offer some concluding remarks.

Existing supply arrangements

Defence spends large sums on fuel, commensurate with how thirsty major platforms are. While Defence doesn't regularly publish consumption or usage data, fuels and lubricants have previously fallen within the top 30 sustainment costs, which are published. While this item fell out of that list in recent years, in 2014–15 the Navy, Army and Air Force spent $524 million on fuels and lubricants.[28]

A 2018 Australian National Audit Office report on Defence's fuel procurement provided slightly more up-to-date figures. It stated that 'Fuel is Defence's largest single commodity expenditure, amounting to an annual spend of approximately $423m in 2016–17.' It also provided a breakdown of spending between the services of $2.1 billion spent between 2012 and 2017: $1.4 billion was spent by the Air Force, $630 million by the Navy and $139 million by the Army.[29]

Except when the ADF is deployed far afield (for example, during a contingency), most of its fuel is sourced from what's available to the Australian domestic market, although the supply of fuel and energy to distant operational forces must be a core factor in thinking through Defence's energy transition. The now-ended Afghanistan deployment provided an example of the vulnerabilities and challenges in supplying large volumes of liquid fuels to remote, austere, dangerous operating environments. Avoiding such vulnerable and costly logistics arrangements is operationally and strategically attractive.

Where the fuel is acquired depends on supplies of both the base product (oil) and refined products. Oil supplies matter as an input for refineries, but, ultimately, refined products are the key requirement for an end user such as the ADF: various aviation fuels, diesel, lubricants and other niche products.

Some of that need is met through domestic refineries. In 2020–21, the (then) four remaining Australian refineries produced 21,737.3 megalitres (ML) of refined petroleum products.[30] Notably, of Australian domestic refined product, just 840.9 ML was 'aviation turbine fuel' (that is, jet fuel).[31]

In the same period, Australia imported a total of 36,057.4 ML of refined product.[32] Most of Australia's refined petroleum product imports, including for critical products such as jet fuel and lubricants, are from a handful of countries in Asia. Table 1 is a snapshot of those import sources, using data from the most recent financial year.

Table 1: Top 5 refined product sources, by source country and product

Country of origin	Volume (megalitres)	Share of (imported) total (%)
Jet fuel		
Malaysia	1,088.9	40.4
Singapore	650.1	24.1
India	345.2	12.8
South Korea	277.6	10.3
China	211.1	7.8
Lubricating oils, greases and base stocks		
Singapore	261.5	52.6
South Korea	114.6	23.0
Malaysia	25.9	5.2
Belgium	15.7	3.2
Thailand	13.9	2.8
Aggregate refined petroleum products		
Singapore	9,262.1	25.7
Malaysia	5,579.1	15.5
South Korea	5,498.4	15.2
China	5,063.4	14.0
India	3,331.5	9.2

Source: Department of Industry, Science, Energy and Resources, *Australian petroleum statistics*, Australian Government, issue 301, 2021, 10, online.

The concentration of import sources, potentially in areas where military tensions are credible and the type of conflict involving the ADF that's outlined in the 2020 Defence Strategic Update might occur, combined with ever-declining Australian domestic refinery capacity, have been consistently identified as issues of concern.[33] At the time of writing, Australia has just two remaining refineries: one at Geelong, Victoria, operated by Viva Energy Australia, and one operated by Ampol in Brisbane, Queensland.[34] The most recent shutdown was of ExxonMobil's Altona installation, which is being converted into an import and storage facility.[35] The federal government now underwrites production at the two remaining refineries to ensure that they remain on line under a plan running until at least 2030.[36]

While, to date, attention has been focused on our lack of national fuel reserves, there's been some recognition that the burgeoning global energy transition will present risks and opportunities for Defence. Defence has 'approached the market' for consultancy services on its Future Fuel Strategy. The challenge for Defence in this context is in determining what to ask from the contractor and by whom in Defence should the report be reviewed, particularly as the response to the report will help to determine what technologies and operating models the ADF might follow into the future.

The approach to market directs that the chosen consultant will consider the work occurring in the civilian aviation and maritime sectors, 'Risks to ADF capabilities associated with the transitioning energy markets and opportunities to increase resilience', and 'Alternative energy sources to reduce fossil-fuel dependency particularly in the land domain'.[37] This clearly signals that Defence has some appreciation of how consequential shifts in energy supply will be.

In sum, Defence meets its large demand for liquid fuels from the Australian market, which in turn is heavily dependent on offshore commercial suppliers. Fuel supplies are operationally critical to the ADF's ability to respond to directed tasks and constitute a significant annual sustainment spend. Australia has very limited onshore refinery capacity and imports most of its liquid-fuel needs from a relative handful of Asian producers. Defence understands that the long-term shifts now underway in the global energy system will be consequential for military planners.

Future energy outlook

Transitioning energy markets and the growth of alternative-energy sources constitute key starting points in understanding the future energy system within which Defence will operate.

We can roughly break the energy future into two components. The first is power to the grid: the power that domestic and commercial users draw from baseload power production to go about daily business. The second is the transport sector: motor vehicles, shipping, aviation and so on.

The power grid is, of course, already electrified; the change occurring here's a shift from fossil-fuel generation to renewables, along with some disconnected micro-grids. This shift is well underway. Investment in new coal generation has fallen dramatically in many countries, Australia included.[38] Gas generation is replacing only a portion of retiring coal installations in Australia, as renewable sources are typically more cost competitive.[39] The investment outlook for new gas generation appears to be poor in the medium term, despite the current spike in prices. The Australian Energy Market Operator confirms that gas generation is needed in the Australian market for stability purposes. It also notes, however, that demand from industrial users isn't forecast to grow for 20 years, could well decrease (given growing renewable capacity), and is likely to be increasingly 'peaky' (that is, required only in certain circumstances, rather than persistently).[40]

Importantly, the greater take-up[41] of home batteries for the storage of electricity from energy sources such as solar power has by and large disrupted[42] the traditional electricity markets around the globe, leading large energy providers such as Origin to review[43] their operating models. This has also led to the controversial requirement for government intervention in support of new installations, highlighting the ongoing questions about the cost competitiveness of fossil-fuel electricity generation even in the near-term. The most obvious case here's the Kurri Kurri plant in the Hunter Valley in NSW.[44] The macro end state in this area is relatively clear: wind, solar and other renewables, with batteries and other storage 'firming' fluctuations in this supply across unfavourable weather on the assumption that production at scale of that power is viable and feasible.[45]

The energy sources underwriting transport systems are the other major component. Innovation is proceeding apace in this sector—EVs are the clear example.[46] Broader electrification of land transport systems now appears to be a matter of infrastructure investment, ongoing improvement of technology (for instance, in battery capacity and vehicle range) and displacement of the legacy vehicle fleet. Some major car manufacturers and large jurisdictions have pledged to cease the manufacturing and use of conventional internal combustion engines in the 2030s.[47] Take-up and investment seem to be stoking the virtuous cycle required to apply similar technologies to heavier and heavier road vehicles,[48] as well as trains.[49]

In other parts of the transport sector, the picture is mixed. There's no replacement for liquid fuels for medium- to long-haul flights within the aviation sector. While niche projects such as solar-powered light aircraft have captured headlines,[50] there's no indication that any such technologies are scalable to international passenger or freight aviation, in contrast to land transportation. Commitments from the aviation industry to net zero emissions targets frequently rely on the replacement of traditional jet fuels with alternatives, some of which, while an improvement upon oil-derived products, appear to be far from genuinely carbon neutral.[51] The carbon neutrality of long-haul

aviation thus hinges on the specific alternative liquid fuels in question, some of which are discussed further in this report.

Global shipping remains a difficult problem.[52] Shipping carries most global trade, with far more hulls operating at far greater intensity than naval shipping.[53] There have been some recent moves to use 'green' methanol in minimally modified freighters, notably by shipping giant Maersk,[54] but this has been described by some analysts as a 'dead end', given the huge hurdles to methanol production at the necessary scale to replace oil in the global merchant fleet.[55]

Hydrogen technologies loom as a possible solution in these two difficult sectors. In land vehicle production, while hydrogen technologies remain under development, it appears that EVs may have already 'won the race' to dominate the next generation of passenger and freight vehicles (perhaps in an echo of the VHS–Beta video recorder format battle, which hinged on which technology won the distribution and market-capture battle first). Hydrogen combustion engines are likely to fill certain niches where operating conditions or very high-power requirements militate against EV adoption.[56]

However, substantial research is being conducted on the use of hydrogen in commercial aircraft, and some demonstrators are already in the air.[57] Airbus has notably made public a very ambitious trio of concept hydrogen aircraft for the 2030s.[58] A range of significant barriers remain to operationalising these concepts, and perhaps the most difficult is overcoming hydrogen-fuel storage challenges for medium- to long-range aircraft, due to hydrogen's lower energy density per volume compared to liquid fuels.[59]

Hydrogen, or relatedly ammonia, may also provide a significant part of the solution in the maritime sector. A Finnish company is trialling ammonia-fuelled engines, and Germany's MAN and Korea's Samsung have partnered to develop the first ammonia-fuelled oil tanker by 2024.[60] While a range of formidable challenges remain,[61] at least some experts view ammonia as the only currently viable alternative to liquid fossil fuels for future shipping.[62] Although, even if hydrogen and ammonia prove technically viable, dramatic infrastructure change would be required in parallel, in an echo of the EV infrastructure investment required now.

Of course, hydrogen and ammonia will ultimately provide an alternative to fossil fuels—in terms of carbon emissions—only if the production of the hydrogen fuel itself is sustainable. Most hydrogen production today isn't 'green'; indeed, some forms of so-called 'grey', 'blue' and 'brown' hydrogen production are more emissions intensive than oil and gas use.[63] Green processes produce hydrogen via the electrolysis of water, powered by genuinely renewable electricity. While interest and investment in this form of hydrogen are promising, it hasn't yet been achieved at commercial and cost-competitive scale.[64]

The synthetic production of liquid fuels may be a transition option for a country like Australia, offering a source of liquid fuels independent of oil reserves, and some of those processes promise a lower emissions profile than conventionally refined fuels. For instance, based on trends before Covid-19, commercial aviation's contribution to global emissions was estimated to be 2%–3%.[65] That figure is misleading, however, because the emissions footprint is more severe due to the fuel's emissions release at altitude.[66] Before Covid-19, the aviation industry's emissions were increasing, and its overall fuel consumption was expected to grow by 38% between 2008 and 2025.

To leverage the advantages provided from alternative fuels, the aviation sector has sought to use 'drop-in' alternative fuels that are suitable for existing aircraft. Investment in drop-in alternative jet fuels has been driven by the time and cost involved in engine and aircraft design and development. These fuels are interchangeable with conventional fuels, produce no degradation in performance or safety, and don't require any modifications to engines, airframes or infrastructure.

Drop-in alternative fuels are divided into two broad categories. The first includes synthetic jet fuels produced from coal, natural gas and other hydrocarbons. The second includes bio-jet fuels produced from biological matter such as plant oils and animal fats. Synthetic jet fuels can be produced through gasification of organic matter, the results of which are further synthesised through the Fischer–Tropsch (F-T) process invented in Germany in 1938,

which enables the production of synthetic fuels from coal and natural gas.[67] Bio-jet fuels are produced through hydroprocessing (removing chemically bound oxygen from the initial product to bring it to the desired jet-fuel boiling range) of biological matter. The F-T method of converting coal and natural gas into liquid fuel is perhaps the most prominent example, established at scale in Qatar and South Africa.[68] However, the conversion of coal is heat intensive during the fuel production phase, reducing the overall benefit of the entire emissions life cycle of the process from production to use. Hydroprocessing of oils and fats, known as 'HEFA', as well as 'alcohol to jet' pathways are other candidate processes with Australian potential.[69]

Further, PtL methods may now be emerging as a more attractive alternative to older synthetic fuel processes. PtL uses (green) electricity power electrolysers to produce hydrogen. Carbon dioxide is then captured and converted into a feedstock, and finally those products are synthesised (by existing synthetic processes such as F-T) to generate liquid hydrocarbons.[70] This process promises a dramatically more climate-friendly source of hydrocarbons and one that's decoupled from fossil-fuel reserves and traditional refineries, but it does require very large amounts of renewable power to achieve at scale. The US Air Force has funded a pilot of this technology, which has reportedly proved successful, and is examining subsequent steps to trialling the process at greater scale.[71] As with existing synthetic processes, it's unclear whether such a process will ever constitute a broad-based replacement for legacy liquid fuels. The potential of PtL for certain sectors or users (potentially, international aviation and military users) nonetheless appears clear. With appropriate funding, they're envisaged to be able to be produced at the point of delivery. Northern Australian transport hubs and military bases, with extremely large potential supplies of renewable power, are well positioned for this kind of infrastructure.

The establishment of industrial-scale alternative-fuel production facilities in Australia has traditionally been deemed uncompetitive and hasn't been widely pursued. A 2013 study by Qantas and the Australian Renewable Energy Agency estimated that a reference facility capable of producing 20,000 barrels a day of sustainable aviation fuel from natural oils would cost approximately $1 billion.[72] The lack of private-sector initiative to establish such facilities by now, as well as long-run preferences for truly net zero options, clearly suggests that in Australia, without change, alternative fuels aren't seen to constitute a viable replacement for most of the crucial fuel imports outlined above.[73] This has meant that, while other parts of the globe transition to alternative fuels, and even though plenty of feedstock to produce those fuels exists in Australia, the alternative-fuels market and the required infrastructure remain embryonic at best. This has largely been due to a desire to rely on market-based solutions to meet the nation's energy needs. While this has been acceptable in the past 30 years, it has prevented the growth of an alternative-fuels industry in Australia. Fuel security is neither a problem for nor solvable by any single entity, military or commercial. A collaborative approach is accordingly needed to achieve a transition to an alternative-energy future.

In summary, we can expect that:

- supplies of oil and oil-derived liquid fuels will gradually become more constrained as parts of the supply chain atrophy
- support for EVs will continue to grow; the infrastructure requirements will need to keep up if seamless transition is to occur, given that various EV technologies, charged by increasingly 'greened' electricity infrastructure, are likely to dominate land transport
- various forms of hydrogen propulsion and production will displace legacy forms of propulsion in parts of the transport sector, although, large technical barriers in their adoption remain
- demand for and the production of alternative fuels such as PtL will grow due to the time and cost involved in engine and aircraft design and development for the medium to long term.
- there's a risk that innovation will disrupt the aviation and shipping *status quo* much more quickly than anticipated, but massive technical challenges remain in those sectors
- the need for a collective approach will continue to grow due to the fragility of Australia's liquid energy market as it becomes apparent that energy security is a national security matter.

Threats and opportunities

The future presents a range of threats and opportunities to militaries around the world, including the ADF.

Threat: energy insecurity due to unreliable supply chains

The robustness of the international and domestic supply of traditional liquid fuels is likely to be increasingly dubious.

As has been described, the government has already been forced to underwrite Australia's two remaining domestic refineries. There's essentially no redundancy built into a domestic production capacity provided by only two facilities. Beyond the guarantees provided by current government policy, the closure of one or both of the remaining facilities is within the realm of the possible, should international market forces continue to render Australian refinery operations economically uncompetitive.

Similarly, there's a range of reasons why supply from international sources might be disrupted. While the Covid-19 pandemic has exposed the vulnerability of various significant supply chains around the world, oil and refined liquid fuels have continued to flow. Some experts continue to express confidence that the 'international market' will provide, adopting a critical view of concerns about the apparent vulnerability of fuel-import-dependent states such as Australia.[74] That was certainly the case when the issue was last examined by the Joint Parliamentary Committee on Foreign Affairs, Defence and Trade. For those analysts, the global diversity of crude oil supply and refinery capacity means that supply disruptions are unlikely to be catastrophic. Industry advice continues to assure government that Australia's access to a plethora of sea routes and trading partners would mean short-lived disruption at worst.[75] It's much less clear, however, that that confidence will be robust as investment in new production falls and alternative-energy systems supplant the *status quo*.

The war in Ukraine has demonstrated the difference between 'the energy market' being able to provide supply and the collision of state power in this market—both by Putin's Russia by embarking on the conflict and in the response of nations that want to rapidly remove their dependence on Russian energy. For instance, Germany has announced that it hopes to be bring forward its goals to reach almost 100% renewable power supply by 2035—years ahead of schedule. [76] Since then, the EU has released its REPowerEU plan for rapidly reducing its dependence on Russian oil 'well before 2030'.[77] That's cold comfort for Ukrainians who are living through an unprovoked war with Russia, which continued to supply oil and gas to Europe and receive payments in return in the meantime. The US has had to tap into its strategic reserves to reduce the impact of that war on the price of oil, while assisting Europe's decoupling from Russian oil.[78] Against this backdrop, the confidence exhibited by Australia's traditional oil suppliers appears ill-founded at best, without the availability of short-term solutions. As noted above, most refined products are sourced by Australia from countries in East and Southeast Asia that are potentially vulnerable to disruption by China in a crisis. In such a situation, Australia would be dependent on the rerouting of supply from other major producers, such as the US, the production and shipping capacities of which would simultaneously be under great strain. The Covid-19 pandemic may have given us an inadvertent glimpse of the supply-chain risks inherent in this approach.[79]

The risk of cascading supply disruptions because of conflict or natural disaster and the imposition of production and export controls by affected countries appears to be increasing in the absence of secure, sustainable and resilient energy supplies. It's also unclear whether what may be short-lived disruption to Australia's civilian economy would equate to an acceptable short-term degradation of the ADF's ability to deploy domestically or project force abroad.

The federal Minister for Climate Change and Energy retains powers to control domestic stocks and the production of crude and liquid fuels, as well as to impose rationing.[80] The ADF, alongside critical sectors of the economy, could accordingly expect to receive protected supply of liquid fuels in a national emergency. It's unclear, however, what plans exist for the implementation of those powers at the national level; nor is it certain how their untested exercise would play out in practice.[81] Furthermore, the government and the ADF are ultimately interested in crisis prevention: the need to declare an emergency in order to meet operational energy requirements would signal that Australian freedom of action has already been constrained and a crisis has already occurred. The ADF needs to operate continuously in our region and accordingly needs continuous, assured fuel supply. The bigger issue will be what diverting fuel supplies to ADF use would do to the wellbeing of Australians domestically.

This is made more complicated by the ADF requiring seven different grades of liquid fuel, which undermines potential economies of scale that could be gained by combining the total fuel requirement into a single grade of fuel. Conceptually, the ADF uses commercial fuels containing additives that cater for its diverse operational conditions and to cater for its materiel, which could be brand new or relatively old. The military-specification fuels include NATO grade F-34, F-44 and F-76, which are commercially produced Jet A1, aviation carrier turbine fuel for shipborne operations, and commercial diesel fuel. Following production, military additives are added to commercially produced fuels to meet Defence's requirements. Accordingly, the ADF's liquid-fuel requirements also add the complication of separate logistics tails for each fuel grade and a lack of economy of scale. For instance, F-44 is the most stringently produced fuel, and it meets and often exceeds the performance characteristics of F-34 and F-76. F-44 can be used in *all* Defence assets equipped with gas-turbine or diesel engines without deleterious effects. This is a process that occurs routinely for naval and army helicopters. Similarly, blending of F-44 with diesel fuel to power ships has been an approved method for some years. Jet-fuel variants are used in tanks, and F-44 is an emergency backup for US Navy submarines.

Notwithstanding that, even when provided for as an essential user under the Australian Government's powers, the ADF would be likely to face greatly constrained liquid-fuel supplies. The nominal capacity of directed domestic production to meet the ADF's needs, on an annual basis, is unlikely to equate to the smooth, assured supply of operational capability in real time. Moreover, it's dubious whether the ADF could function without broad swathes of the civilian economy and transport systems upon which it's habitually reliant, regardless of assured supply for ADF use, and powerful corporate voices are unlikely to quietly agree with broad rationing of their energy needs. Cascading crises, in which international supply is disrupted and limited domestic capacity is strained, be it by accident, equipment failure or malicious activity, would be a worst-case scenario.

Threat: fuel-price volatility

Cost is only one variable that Defence considers, and, indeed, alternative liquid-fuel sources are unlikely to be cost advantageous for years to come. Defence's future approach to liquid-fuel use and alternative-energy sources will therefore be a balance between mitigating cost pressures, guaranteeing supply, and leveraging the tactical advantages that may be present in alternative-energy technologies. Cost is nonetheless clearly an important consideration that's further exacerbated due to its volatility.

The cost to the Defence budget of various liquid fuels and lubricants is likely to rise significantly in the long term, almost regardless of whether they are fossil fuels or alternatives.

Useful models for the price of various fossil-fuel-derived fuels and lubricants don't exist for the long term: such forecasting is too sensitive to a range of uncertain assumptions about global policy settings, production levels and

the progress of innovation in alternate technologies, among other things. It's therefore difficult to meaningfully quantity the size of the long-term budgetary implications for Defence.

Any simple linear projection of growth in fuel spending is likely to be a significant underestimate for three reasons.

First, it doesn't account for the possibility of nonlinear price rises. As has been discussed, as investment in new oil production progressively gives way to investment in alternative sources, already dominant producers are likely to consolidate their hold on the market, with the possibility of significantly higher prices creating trends that are unlikely to be simple and predictable. In scenarios in which Defence is forced to access fuel from extremely limited domestic production capacity, it's highly likely that the cost of those supplies would be well above those on international markets.

Second, it doesn't account for changes in consumption. The relative importance of fuel to each of the armed services has changed over time. Additionally, the ADF's thirst for liquid fuels has grown dramatically over the years and will grow more with some planned acquisitions—such as the large number of heavy armoured vehicles that the Army proposes to acquire in the next phase of LAND 400. For example, during the INTERFET deployment, it was estimated that the entire coalition consumed 30,000 litres of fuel per day.[82] An Australian National Audit Office report estimated that the first five months of Australian operations in East Timor resulted in the consumption of 2.79 million litres of jet fuel and 3.72 million litres of diesel.[83] That equated to 18,600 litres of aviation turbine fuel per day and 24,800 litres of diesel per day, for an operation that wouldn't be considered 'high intensity'.[84]

By comparison, during the air campaign against Iraq in the period between 19 March and 18 April 2003, the air-to-air refuelling effort for the campaign is reported to have transferred 189 million kilograms of jet fuel.[85] Fuel consumed in the 30 days during that campaign equated to approximately 7.9 million litres of fuel per day over that period.

Demand is therefore likely to grow nonlinearly. Indeed, critics of sustainability enthusiasm have noted that, despite periodic efforts in the US military to reduce tactical fuel consumption, demand has inexorably increased.[86]

Defence presumably has the data needed to at least make a more robust forecast of consumption changes, although that data isn't publicly available.

Threat: lack of commercial innovation and sustainment

Platforms reliant on legacy fossil-fuel engines and products will, in the long run, be increasingly bespoke. In the aviation and maritime sectors, this trajectory will depend on the success of efforts to develop 'drop-in' alternative fuels that are also environmentally friendly, as has been noted. Such success would preserve many legacy systems in those sectors.

In the context of the rest of Australia transitioning to renewables, without concerted effort it's therefore likely that within the next 20 years the ADF's land vehicles will be considered bespoke, although they constitute a small fraction of Defence's fuel use. Fundamental changes in the national support base for aviation and maritime systems will occur beyond that time horizon but will ultimately be more consequential, given the energy demands of combat aircraft and warships. While government- and military-funded R&D has been associated with many high-technology innovations that have 'spun off' into the wider economy (for instance, computing and space technologies[87]), away from those technical frontiers, militaries are reliant on a whole host of mundane products and services with broad commercial support bases.

It's risky and costly when such mundane but crucial products and services become unsupported. Recall, for example, that the US military and the ADF both remained dependent on legacy software such as Windows 95 for many years after it became commercially unsupported, paying companies such as Microsoft to maintain bespoke support once those systems were well and truly obsolete.[88]

The global fleet of fossil-fuelled systems is so large that it will take many years for commercial support to end. Vehicle technology and the global energy system doesn't move anywhere nearly as quickly as software development. Even with mandates in several jurisdictions directing the end of new internal combustion engine vehicle sales around 2030, for instance, the existing fleet of such vehicles will have some decades of life remaining beyond that point and remain broadly supported.[89] Of course, this process may well be accelerated by more interventionist government action regarding legacy transport systems should governments come to take climate change risks much more seriously.

Nonetheless, the long-term reality is that many legacy fossil-fuel-based systems will become bespoke. For example, countries such as Norway, in which EV take-up is high, are already witnessing the transition of on-road infrastructure from fuel pumps to charging stations.[90] Assured spare-part availability and skilled mechanic support will eventually shrink, too, alongside the incremental technical improvements delivered by the R&D arms of large manufacturers.

Military users will, accordingly, have progressively less choice when it comes to acquiring and supporting such systems, and the systems will be more and more expensive. Accepting more expensive fuel supplies may well be a justified policy choice, particularly if that choice entails much greater supply-chain robustness, or if higher prices are likely to be transitory as technologies mature. But this should be a policy choice, rather than the result of inertia and continued dependence on a transitioning global market.

Threat: reputational risks due to emissions

Community expectations continue to strengthen for all organisations to operate in sustainable and carbon-neutral ways.[91] While Defence's internal sense of exception from such expectations is strong, and is largely mirrored by the Australian community, that exceptionalism will stand on increasingly shaky ground in the long term. Defence anticipated this with environmental management of its training ranges, for example, knowing that being a good steward of those areas of the national estate would assist its long-term access to them. The consumption of large volumes of liquid fossil-fuel products should also be considered in that light.

An increasing number of analyses point to the significant carbon footprint of various militaries.[92] The US military, for example, emits more CO_2 equivalent than the country of Peru each year. It accounts for 80% of US Government emissions; the British military accounts for around 50% of UK Government emissions.[93]

This isn't to suggest that governments are likely to compromise operational capability for carbon neutrality from their militaries anytime soon. Some analysts have pointedly critiqued overenthusiasm for some sustainability initiatives by proponents, perhaps most notably the US Navy's 'Great Green Fleet' initiative during the Obama years.[94] However, the work conducted by the US Defense Logistics Agency to certify and provide seed funding for green-fuel initiatives over that period is one of the major reasons those technologies are now available in the US, enabling an orderly transition in the future.

As mentioned above in the example of environmental management of training areas, the ADF's ability to conduct training activities around Australia is premised on the assumption that it's a 'best practice' steward, allowing it to retain its 'social licence'. For instance, the class action against Defence due to contaminated groundwater in Williamtown, where RAAF Base Williamtown is located, underscores that public expectations of Defence are appropriately high.[95]

In this context, the Australian Government should expect the ADF, like other militaries around the world, to lean forward and require it to decarbonise wherever it's viable to do so without compromising our strategic choices.[96]

Opportunity: reducing demand and going off the grid

As technological maturity and cheaper renewables have started to accelerate the transition of large portions of the market towards renewable fuels, it makes sense for Defence's domestic infrastructure to follow suit and take up all opportunities to reduce fossil-fuel demand in the future. Mitigating the vulnerability of bases to disasters and creating logistics efficiencies both make sense on their own terms.

One obvious candidate for transition now is Defence's commercial vehicle fleet of around 6,000 vehicles, ranging from sedans and light utility vehicles to trucks.[97] While Australia is lagging in EV adoption more broadly, that technology is mature and available: Defence should adopt it now to replace its 'white fleet'. This would involve not just a change to the contracted vehicles that constitute the fleet, but also a substantial investment in supporting infrastructure on bases, such as charging stations. It probably makes sense to 'overdo' that infrastructure now: going well beyond the charging requirements of a handful of white-fleet sedan vehicles, for instance, might ease the pain of building more extensive and demanding charging infrastructure for other assets later.

Defence has already made some moves towards taking installations 'off the grid' and should double down on those initial decisions. Headquarters Joint Operations Command is serviced by a 1.9 MW solar farm (it's unclear how much of its demand that meets at different points of time), and a range of other key bases have adopted or are adopting solar and battery capacity.[98] Solar farms, micro-grids and batteries all make sense from an operational point of view now: they make Defence robust to failures in the civilian infrastructure undergirding bases across Australia. This will make more and more sense as uncertainty about the robustness of legacy energy sources grows in the long term, alongside increasingly severe natural disasters and extreme weather than will exacerbate infrastructure vulnerability. Solar farms are at once a sensible sustainability decision and an investment in the long-term viability of our barracks, air bases and ports as mounting bases for domestic and overseas operations, ensuring that Defence is able to operate in the future, even when others can't.

There's a range of other ways to drive down the ADF's routine reliance on fuel supplies. One is simulation, already touted as a cost-saving measure and a way to offset the increasing operating costs of a range of major platforms. Broad-based investment in simulation systems will also be a way of driving down the ADF's fuel demand, both as a matter of routine business and as a means of conducting critical training in the face of supply interruptions.[99] The Air Force has an established reliance on aircraft simulators for a range of training activities, and the Navy has made use of bridge simulators for some time.[100] The Army has been the least mature user of simulation in the past, as the personnel- rather than platform-intensive nature of its activities presents barriers. This is changing, however, and larger investments in more capable simulators are now occurring.[101] The trend towards higher fidelity simulation at greater scale should be cemented across Defence.

Another route to reducing is via innovations in robotics and autonomous systems. Innovative departures from legacy platforms might offer dramatically less fuel (and therefore logistics) intensive alternatives, alongside other tactical benefits. For example, Defence has recently announced the acquisition of Apache attack helicopters to replace the troubled Tiger armed reconnaissance helicopter fleet.[102] This is a more or less 'like-for-like' approach, replacing a poorly performing rotary wing system with a more mature one. We might instead ask whether, for example, smaller drones might not achieve comparable ends with very different means.[103] Driving down fuel consumption will never be the only consideration in such capability decisions, but it should be a significant one.

There's a range of 'no regret' decisions that can mitigate the ADF's fuel demands and that are sensible choices even if we never experience fuel-supply problems.

Opportunity: tactical advantages of alternatives

Alternative energy sources offer a range of existing and prospective tactical advantages for military users.

Noise is a tactical liability. EVs are very quiet, though—indeed, car manufacturers are enlisting audio engineers to redesign EV sounds to make them appealing to the ears of consumers accustomed to the roar of internal combustion engines.[104] The ADF is already leveraging this advantage in modest ways. Electric motorcycles have been trialled as an adjunct to armoured reconnaissance capabilities.[105] Similarly, in conjunction with Defence Science and Technology Group, an Australian company has developed an electric all-terrain vehicle, or eATV, as a replacement for existing vehicles.[106] Quiet vehicles offer huge advantages on the battlefield.

Logistics tails are also a classic vulnerability that preoccupy militaries. In certain niches, alternative-energy technologies might alleviate dependence on logistics systems. Direct air-capture technologies, which use carbon dioxide as a feedstock for synthetic oil production, are an immature but potentially significant advance.[107] Solar cells that continue to improve in efficiency and small, deployable hydrogen-fuel cells offer potential small-scale energy sources independent of liquid-fuel resupply.[108] The potential alternatives offered by robotics and autonomous systems for certain legacy systems, such as attack helicopters, should also be seen as tactically advantageous because of their greater sustainability in the field. Fundamentally, anything that creates the ability to reduce the need for large numbers of vulnerable fuel tankers can ease the problems that were experienced in conflict areas, such as in Afghanistan.

Military applications of these technologies remain immature and modest. Clearly, small-scale use of electric bikes isn't going to ameliorate the dependence of key platforms such as warships and jet aircraft on fuel supplies. As these technologies mature, however, the opportunities they offer in a tactical setting will grow.

Opportunity: relationships and partnerships

There's an opportunity to partner with the commercial aviation sector. Following the fuel crisis of the 1970s, large military operators, along with civilian operators, transitioned in response to the same concerns. In 1979, the US Air Force moved from its main operating fuel jet propellant number 4 (JP4), which is a blend of kerosene and gasoline, to JP8, which is a commercial aviation fuel containing military additives for protection against corrosion, static build-up and icing. Due to the same concerns, NATO forces followed suit shortly after.[109] Given that the establishment of industrial-scale alternative-fuel production facilities has traditionally been deemed uncompetitive and hasn't been widely pursued, there's an opportunity, indeed a need, for Defence and the aviation sector to work together to provide seed funding and ongoing support by requiring a certain percentage of their liquid-fuel demand to be from alternative sources. This will provide certainty to the market and grow an alternative-fuel industry in Australia. Qantas Airways recently announced a 10% target for the airline's fuel mix to be from sustainable aviation fuels by 2035,[110] but the absence of Australian providers has meant that it continues to provide secure funding for overseas sustainable aviation fuel providers.[111] Defence can ensure that funding is also allocated within Australia by creating a partnership with large operators to shape the aviation-fuel market in Australia.

There's also the opportunity to partner with other militaries. For instance, the Royal Air Force has laid out its path to net zero by 2040.[112] It has reported that three-quarters of its emissions footprint is made by jet-fuel usage.[113] Accordingly, it aims to achieve its 2040 goal using sustainable aviation fuels. Similarly, I've noted, the US military has been on this path for some years. This presents the ADF with an opportunity to also partner with other like-minded militaries either under the AUKUS partnership or through broader technology exchanges in developing a sustainable aviation-fuel industry in Australia.

Similarly, the ADF jet fuel procurement standard DEF(AUST)5240E was recently updated to include the approval of alternative fuels as blend components, bringing it into line with commercial and other military operators. This also demonstrates the ADF's willingness to transition to sustainable fuels. It would then make sense to put this approval

into use by providing a similar target for fuel mixes along with other operators, such Qantas, in support of an alternative-fuels industry in Australia. Certainly, this isn't a new concept, given that in 2009 the US Navy established a target to obtain 50% of its total needs from nonconventional sources by 2020.[114] As part of those efforts, the ADF's first exploration of alternative fuels occurred in 2012 during the Rim of the Pacific Exercise, in which an RAN Sikorsky Seahawk helicopter refuelled with alternative fuel produced from biomass on board USS *Nimitz*.[115] After that event, although those efforts were no longer pursued within the ADF, 65% of all energy on naval bases in the US now comes from alternative fuels, while nuclear and alternative-fuel sources provide approximately 35% of energy requirements at sea. Considering the US Navy's efforts, there's an opportunity for the ADF to rely on such proven methods.

In summary:

- Over the long term, Defence will face greater threats to its liquid-fuel supply chains than it has hitherto expected.
- Over the same time frame, Defence should expect the cost of meeting liquid-fuel demands to rise substantially.
- As investment in the wider economy shifts away from traditional forms of transport propulsion, less 'spin-off' investment will be available from commercial applications for military systems.
- Alternative forms of energy generation and vehicle propulsion will offer advantages for the ADF. Those advantages are niche at this stage but can be expected to expand as the energy transition increasingly drives disruptive innovations.

Conclusion

The rapid and long-term shifts of the global energy system are due to technological advances and the availability of cheaper renewable fuels. Technologies such as the electrification of vehicles and the use of alternative fuels will continue to accelerate at scale within the civilian sector. It's acknowledged that the ADF will continue to operate materiel that relies on fossil fuels for some years. However, Australia's dependence on imports for liquid-fuel security places the ADF at risk. The risk isn't whether the ADF can get to an area of operations and perform poorly but whether it can get there at all.

To avoid such grim possibilities and maintain its ability to operate, the ADF will need to form partnerships with the commercial sector to shape the alternative-fuels market in Australia by providing a secure source of the investment for alternative-fuel providers. Those fuels can then supplement traditional fuel sources until a complete transition away from fossil fuels can occur. In this context, the golden thread for the ADF is its need for rapid transition towards renewable energy sources as a means to operationalise its strategy among its many and varied plans and contracts.

The commercial sector and Defence can work in partnership to shape the aviation-fuel market in Australia by providing a secure source of investment for alternative-fuel producers. The alternative fuels can then supplement traditional fuel sources until a complete transition away from fossil fuels can occur. Without the appropriate investment and energy security, stable fuel costs and low emissions will remain elusive.

More importantly, in the absence of proactive change, Defence may ultimately have to own the entire fuel supply chain which would be a bad outcome from all perspectives. The Australian Government and Defence must recognise this long-term risk to a fundamental input to our military capability and start acting to mitigate it for the future.

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Acronyms and abbreviations

ADF	Australian Defence Force
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EU	European Union
EV	electric vehicle
F-T	Fischer–Tropsch
IEA	International Energy Agency
INTERFET	International Force in East Timor
ML	megalitre
PtL	power to liquid
R&D	research and development
RAAF	Royal Australian Air Force
RAN	Royal Australian Navy

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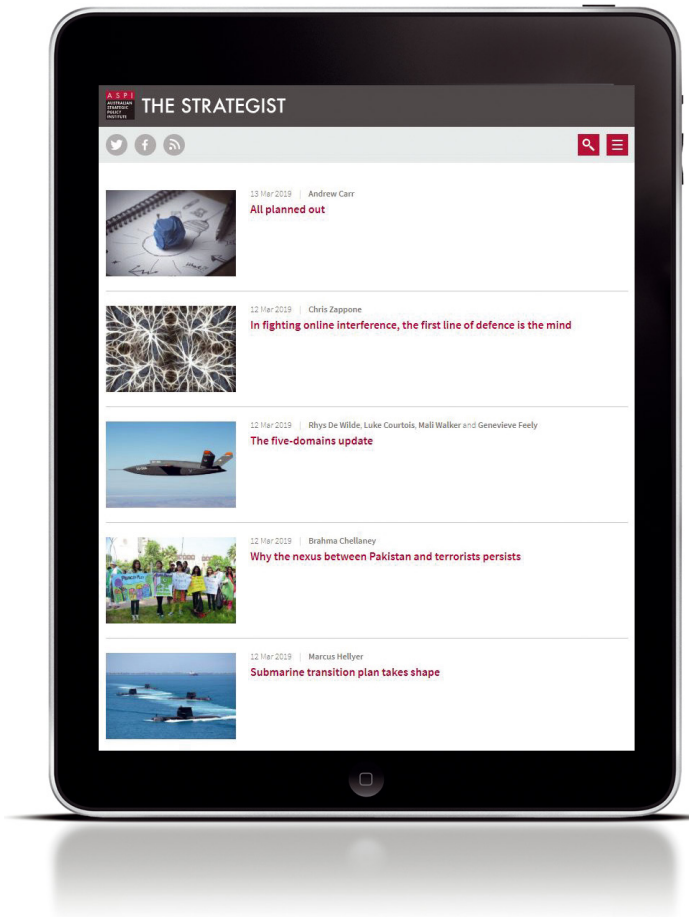

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