Army

Power & Energy Paper

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Serving our Nation

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Foreword

As technology proliferates in the modern battlespace, the demand for power and energy is changing. Army is moving towards a period of accelerated warfare characterised by advanced electronic and networked technologies, robotics and autonomous systems, and unprecedented levels of energy dependence. This is occurring in a global context of politicised climate change, strained resources, and changing societal and industrial trends.

This paper is not driven by environmental considerations. Indeed, many of the compelling advantages that emerging power and energy technologies offer are uniquely advantageous for military application, and offer genuine gains in platform, infrastructure and supply chain performance. Environmental preservation is serendipitous of technology that offers the competitive advantage in the hostile, contested and challenging environments Army is required to operate in.

To this end, this paper seeks to consolidate Defence Science and Technology Group research with commercial and military industry opportunities to inform the development of the Objective and Future Force capabilities.

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March 2020

Purpose

1. The purpose of the Power and Energy (P&E) paper is to inform Land capability development with respect to how emerging P&E technology can improve Objective and Future Force capabilities. For the purposes of this document, the term ‘power and energy’ is used to define all types of energy required for military operations. The term is also used for commonality of language with NATO and other strategic entities.

2. The scope of this document does not include non-operational P&E such as National Support Base infrastructure. It also does not address strategic commodity management issues; however, it does seek to focus Army towards a more capable and resilient P&E future in the face of increasing demand and threat.

3. In a national resource context, P&E has strategic roots and it is a vital commodity for any military force. In an operational context, it is highly targetable in physical and non-physical domains and will increasingly become a pivotal resource that can shape operational design. The growing prevalence of highly technical capabilities is further increasing Army’s reliance on P&E.

Increasing Risks to Operational Energy

A2/AD and hybrid threats pose escalating risks to the assured delivery of operational energy and, by extension, the ability to project and sustain power worldwide. While more capable in terms of speed, survivability, stealth, payload, and manoeuvrability, next generation systems often require more energy. The ability of these new systems to meet their performance parameters frequently assumes an assured supply of energy, despite larger operating areas, flat or declining fuel logistics capacity, and increasing threats to energy infrastructure.

US Department of Defense 2016 Operational Energy Strategy

Strategic Guidance

4. Australia's Joint Operating Concept (AJOC) states that the 'Objective Joint Force needs to be capable of conducting sustainable expeditionary operations within a contested environment'[1]. Achieving a level of sustainability in a contested environment requires combat systems that have some level of resilience to supply disruption.

5. VCDF's Future Logistics Concept 2035 aspires to 'adopt and employ a sustainability philosophy so that logistics operations employ best practice of the day to minimise harm to the environment and reduce consumption of non-renewable resources'[2]. The same document promotes:

a. investigation and take-up of alternate fuel and energy sources

[1] Australia's Joint Operating Concept 2016, para 12
[2] VCDF Future Logistics Concept 2035, *Key Theme 4: Enduring and Agile Solutions for Energy and Strategic Commodities*

b. interoperability with strategic partners

c. energy technology that will reduce the logistics burden to store, handle and distribute bulk commodities

d. energy efficient, non-fossil fuel solutions and incorporating them into future capabilities.

6. Ultimately for Army, this represents an opportunity to respond to strategic direction and exploit the intrinsic strengths of emerging P&E technology. Army will use this opportunity to reduce relative demand, increase capability performance, improve capacity to conduct operations across multiple domains, and create tangible improvements in supply chain performance. Where practical, Army intends to do this through adoption of hybrid and electric vehicle propulsion technology, and smart power generation systems that are capable of generating electrical energy at, or near the point of need.

7. Integration of P&E technology into future capability systems will vary depending on the nature of the equipment, and where in the operational spectrum it is required to operate. P&E technology is wide-ranging and will impact most systems including deployable infrastructure, land platforms and soldier combat systems.

8. The increased complexity of combat systems has created unintended consequences of more cumbersome organisations, both at the fighting and logistics echelon levels. This increased demand for energy, including dependence on liquid fuel, has exposed an increasingly targetable vulnerability in the supply chain. Future P&E systems must address these vulnerabilities, whilst

themselves avoiding unwieldy technology and reducing parasitic demand on the supply chain.

9. P&E investment into the Force-in-Being (FiB), Objective Force, and Future Force will be different for each time window. Time, space and resources available for investment in the FiB and Objective Force will remain contested due to organisational priorities; however, P&E must be recognised as an enduring priority for capability development. To this end and to ensure a degree of future-proofing, Army will benefit from an evolutionary acquisition approach to its P&E. Additionally, a common P&E architecture across land platforms is required in order to accommodate emerging technologies and promote integration between Objective Force capabilities.

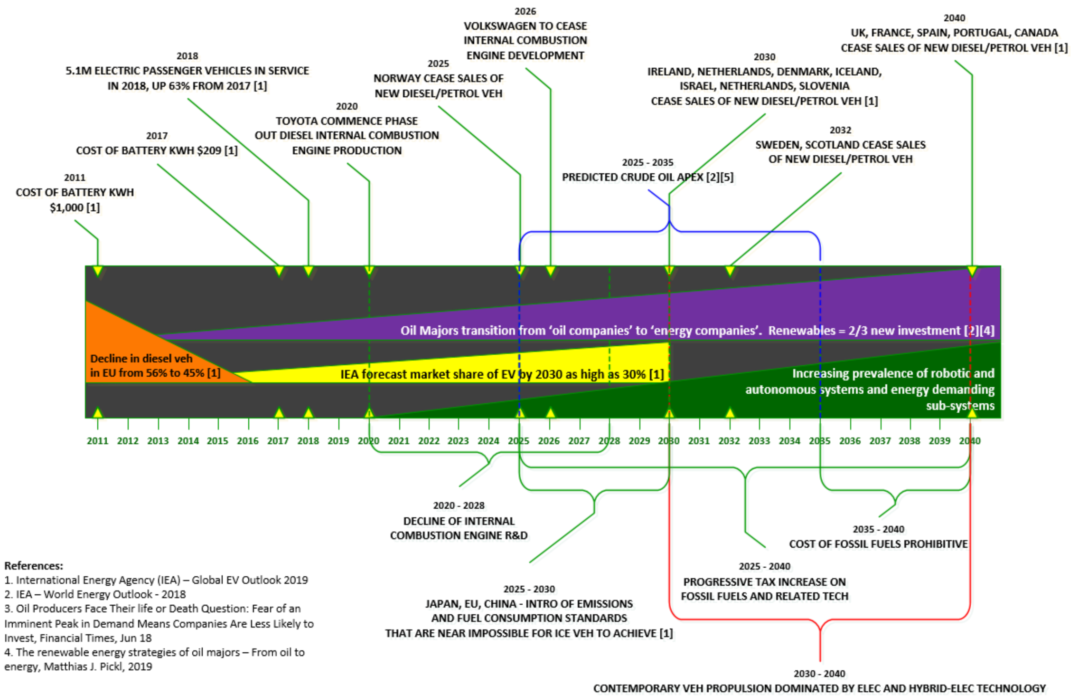

Image 1: Global trends likely to impact on Army vehicle propulsion options. Data gathered from open source media and listed references.

Lines of Effort

10. There are three lines of effort (LOE) that this paper will seek to address. The LOE complement current program modernisation efforts and offer capability improvements through P&E technology.

LOE 1: Deployable Force Infrastructure

11. This LOE seeks to explore how P&E technology can improve the performance of deployable infrastructure. In this context, *Performance* can be defined by ability to generate more electrical power with less resources, be scalable to demand, have greater resilience to supply disruption, lower maintenance, reduced distribution impost, reduced skilled operator labour, simplicity of employment, and ability to operate in diverse environments. *Performance* also implies seamless interoperability within an agreed architecture, and scope for evolutionary development as a whole system.

12. The evolving character of war continues to shape how capabilities such as deployable infrastructure can or cannot be employed. As a consequence of this changing character, the concept of stationary infrastructure within an Area of Operations may not be conducive to high intensity warfare; however, may be suitable in a strategic rear area such as a theatre Agreed Point (AP), in lower intensity operations, or in later phases of conflict where a degree of stability has been secured and signature management is secondary.

13. P&E technology is currently emerging from industry that presents opportunities for Army to modernise its Deployable Force Infrastructure. This technology specifically offers more efficient energy generation, management and storage, and introduces emergent technologies such as smart grids, micro-island or nano-grids, hybrid load-following generators, militarised solar systems, containerised alternate power generation plants and various energy storage technologies. Central to these individual technologies are the *micro-grid energy management systems* which combine the strengths of these individual systems into intelligent, resilient, versatile and efficient systems.

Image 2: Example of commercial-off-the-shelf deployable containerised renewable power by Ecosphere Technologies.

14. Smart micro-grid systems are able to autonomously manage whole of system supply and demand, integrate with platforms[3], store power for known peak draw periods, and retain a level of resilience when supply interruptions occur – all the while consuming reduced quantities of fossil fuel. Whilst this technology is

[3] US Marines use Ground Renewable Expeditionary Energy Network System (GREENS) to power HIMARS and M777 howitzers, eliminating the need to tow a 3kW generator and reducing vehicle idle time

yet to be exploited by the ADF it is commercially available.[4]

15. Commercial-off-the-shelf (COTS) and military-off-the-shelf (MOTS) micro-grid capabilities are already in service or in trials with other militaries around the world. Defence Science and Technology Group has conducted modelling and analysis of technologically similar equipment and has demonstrated net savings of 33% to 50% reduction in fuel consumption and 25% to 40% reduction in generator run times with corresponding maintenance reduction[5]. These figures are consistent with US Marine Corps Expeditionary Energy Office research where multi-source hybrid electric generator systems are demonstrating up to 50% fuel savings and up to 80% reduced generator run time.[6]

16. In the longer term, it is likely that the emergence of other energy generation, management, storage, and distribution technologies will open new opportunities for deployable force infrastructure. Of particular interest is the ability to produce and store energy at the point of need in an operational environment. This includes technologies such as hydrogen generators, fuel cells, wind turbines and advanced photovoltaic systems, if conducive to militarisation. The technical readiness level (TRL) of many of these technologies is steadily progressing with a number of COTS and some militarised hydrogen based

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[4] Defence Science and Technology Group Report – *Hybrid Field Power Systems for Relocatable Installations* May 2015

[5] Defence Science and Technology Group Report - Reducing Fossil Fuel Consumption of Deployable Installations – March 2016

[6] US Marine Corps Expeditionary Energy Office: Mobile Electric Hybrid Power Sources (MEHPS) power generation—combining batteries, solar, and smart controls with traditional diesel generators—has demonstrated up to 50% fuel savings and up to 80% reduced generator run time

systems emerging as noteworthy energy storage options for deployed forces.

17. By its nature, deployable P&E infrastructure is compatible with a number of procurement models, including government ownership, medium-term lease, short-term hire or a hybrid of these options. These models are also conducive to raise, train and sustain (RTS) use and most operational models, albeit in a strategic rear area or during lower intensity operations. In addition, the prevalence of commercial vendors supports the use of leasing or hiring models for P&E capabilities.

Image 3: Deployable energy by Ecosphere Technologies using containerised photovoltaic solar systems with integral fuel cells as an energy storage method.

Use of distributed headquarters

18. Employment of virtual capabilities could provide a means of realising energy savings in austere environments. US studies into energy consumption in Afghanistan from the decade beginning in 2003 suggest more fuel is consumed by power generation infrastructure in forward operating bases than ground combat vehicles conducting missions.[7] Power generation was attributed to consuming up to a third of fuel shipped into theatre with further analysis showing climate control systems consuming almost two-thirds of that energy.[8]

19. Employment of virtual command and control (C2) would significantly reduce energy consumption in forward operating areas. While various command appointments would be required to lead by being physically present with their soldiers, a number of C2 and C2 enabler outputs could be delivered remotely in order to reduce energy consuming infrastructure in forward operating areas. For example, a headquarters Force Element (FE) operating within Australia, a staging area, or at a theatre gateway could provide C2 via virtual means into theatre. Virtual reality systems could also be exploited by some logistics functions such as warehousing and maintenance, particularly as logistics intelligence capabilities develop and sensors such as Health and Usage Monitoring Systems (HUMS) become common place. Whilst essential infrastructure remains, the number and diversity of specialists could be reduced. In this context, it is less

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[7] State of Solar Photovoltaic Technologies in Department of Defense Forward Operations, 2011 Fall White Paper Series, prepared by Mark Steven Apfelbacher, LEED AP. A Marine Expeditionary Brigade was used as the sample to source these statistics.

[8] US Marine Corps Expeditionary Energy Strategy and Implementation Plan (2011)

important *how much* energy is being consumed and more important *where* it is being consumed.

LOE 2: Land Platforms

20. The primary P&E aspiration for land platforms is to improve the performance of vehicle propulsion systems via alternate energy technologies. Whist the focus is on propulsion systems, it also seeks to exploit other benefits inherent with electric and hybrid electric systems, many of which outweigh commonly known advantages such as economical use of fuel. This LOE recognises that a vehicle platform could well be a sub-system itself within a broader military system such as a command, control and communications (C3) node, or an air-defence system.

21. The take-up of P&E technology must be nested under other capability programs by design. It is important to recognise that the amalgamation of hybrid or electric propulsion with an existing platform, as an engineering afterthought, will not enable many of the advantages to be fully realised. The development of a Generic Vehicle Architecture (GVA) to support hybrid and electric systems will be essential to enable all the benefits of electrification to be realised, including its interoperability with power grids within Generic Base Architecture.

22. The TRL of hybrid electric propulsion systems is sufficiently advanced to be introduced into Army platforms in the Objective Force timeframe.[9] Potential platforms include armoured vehicles, heavy logistics transporters, anti-access and area denial (A2AD) systems, amphibious platforms, heavy plant, and material handling equipment[10].

[9] TARDEC Powertrain Electrification Efforts, US Army RDECOM, June 2018
[10] Defining the Future, Kalmar Global, 11 Jun 19

Hybrid and/or electric propulsion is highly desirable for robotic and autonomous system (RAS) enabled platforms due to the inherent electronic control and connectivity advantages of this technology.

23. A good example of emerging capabilities that are demanding unprecedented levels of electrical power, are air-defence capabilities. Combat and combat support platforms require weapons that are capable of defeating drones, rockets, artillery and mortars. Solutions currently being developed by the US Department of Defense include directed energy weapons that put significant demands on a host platform's power generation system. The key challenge that is currently limiting this technological development is not the laser systems themselves, but generating the electrical power to satisfy them.[11] Hybrid or electric based propulsion systems offer a solution that is capable of providing the levels of electrical power being demanded.

24. As future platforms evolve they will increasingly resemble a 'combat system of systems', with the vehicle component being one of the many enabling sub-systems. The way these platforms interact with each other and distribute P&E is likely to require a vehicle-to-grid and vehicle-to-vehicle nano-grid system that can meet the escalating demand for P&E. Platforms will effectively operate like a *local area network of things*, coordinating the operations of numerous sub-systems such as Human-Machine Teams, support platforms, soldier combat systems, a range of un-crewed vehicles (UXV) and various force protection systems. These systems will

[11] Breaking Defense – 'Army wants Hypersonic Missile Unit by 2023: LTGEN Thurgood' – by Sydney J Freedberg, 4 June 2019

be capable of interacting with their parent platform in order to replenish ammunition and energy systems.

25. Similarly, Combat Service Support (CSS) elements may employ mobile nodes that are enabled by un-crewed aerial system (UAS) or un-crewed ground vehicle (UGV) sub-systems that dock on the parent platform for replenishment and connect tactical lines of communication to forward dependents.

Image 4: The US Army is developing Manoeuvre Short-Range Air defence capabilities based on the Stryker Anti-aircraft variant. Future evolutions of this capability will demand in excess of 100 KW of electrical power which is currently not achievable with conventional propulsion systems.

26. There are a number of compelling reasons why future force platforms should employ hybrid electric propulsion systems. This configuration is inherently more adaptable for supporting platforms with increasing

numbers of energy demanding sub-systems. Conversely, platforms with internal combustion engines paired with conventional transmissions do not make sufficient electrical energy for sub-systems, and are not as reconfigurable for evolutionary upgrade – being akin to mechanical control systems versus drive-by-wire control systems.

27. A vehicle chassis that is engineered from the outset to run electric drive systems, be it via separate hub motors or modular on-board motors, facilitates a degree of future-proofing that can exploit step-changing technology as it becomes available. For example, within a GVA, a diesel generator can be exchanged with a fuel cell or other emerging technology energy source; however, a conventional diesel propulsion system cannot be as easily substituted. Some advantages of electric and hybrid platforms include[12]:

a. Increased fighting compartment volume and flexibility in design;

b. Resilience to battle damage (no transmission, no drive-shafts, and each wheel station has its own motor);

c. Signature management (extended silent watch, silent operation, low heat, reduced exhaust gas, lower profile vehicle design possible);

[12] The cancelled US Army Ground Combat Vehicle (GCV) Program provides significant insights into the potential advantages of hybrid electric drive systems for armoured vehicles. TARDEC (see Powertrain Electrification Efforts, dated June 2018), has carried on research into alternate propulsion systems with numerous advantages being explored in hybrid-electric, hydrogen-electric and fully electric armoured vehicle platforms.

d. Superior torque / acceleration (instant acceleration to support active protection system);

e. Superior connectivity to future autonomic or autonomous control systems and HUMS;

f. Ease of evolutionary upgrade without a chassis / hull upgrade (motor and energy storage technology);

g. Availability of electrical energy for sub-systems such as directed energy weapons;

h. Exportable power for command posts or other external demands;

i. Deep water fording without need to retrofit snorkel or risk water ingress through exhaust;

j. Reduced demand on the supply chain (fuel and repair parts[13]);

k. Simplicity of on-site maintenance (modular design); and

l. Parts commonality and simplicity more conducive to additive manufacture.

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[13] BAE Systems hybrid Ground Combat Vehicle trials in 2014 claimed up to 20% reduction in fuel usage and a drive system with 40% fewer parts.

LOE 3: Soldier Combat Systems

28. The primary goal of P&E development within the soldier combat system LOE is to increase the operational viability period of dismounted force elements and reduce the physical load on the soldier.

29. The individual soldier and small team are increasingly enabled with equipment to fight and win the tactical battle. This has resulted in an increased dependency on electronic devices that currently require consumable batteries to run.[14] A number of benefits could be realised by a breakthrough in battery technology and lightweight recharge systems. Advantages sought are;

Image 5: In field battery charging solution for squad UAV by Aeryon Labs Inc.

carried weight reductions, less demand on supply chain, greater endurance of isolated tactical FE, less consumed waste for enemy exploitation and reduced cost.

30. The most accessible technologies in this space are COTS and MOTS lightweight flexible solar systems. Development of these systems has largely been driven by commercial demand and US military tender, and has

[14] Soldiers and small teams are historically issued with rechargeable batteries, however they are rarely able to recharge the batteries / devices themselves and often have to return to a larger CP to exchange batteries. Additionally, the battery technology is often obsolete or has limited serviceability.

enabled electrical charging of UAV, soldier-portable command, control, communications, computers and information (C4I) equipment, electronic countermeasure (ECM) and other small devices. This equipment is currently in-service in some US Army and Marine units[15] and is exploiting the low cost and tactical versatility of the technology.

31. At a soldier combat system level, small force elements could be optionally enabled with squad UGV platforms with hybrid propulsion. While the platform may principally provide a lightweight direct or indirect fire

Image 6: Milrem Robotics Tracked Hybrid Modular Infantry System (THeMIS) supports dismounted troops through various sub-system configurations and is a potential energy source for dismounted combatants. Photo courtesy of Milrem Robotics

[15] The US Marine Corps Expeditionary Energy Office has developed a number of systems such as Solar Portable Alternative Communications Energy System (SPACES) to increase the operational viability periods of small isolated FE.

support effect, it could also be configured to enable other systems such as command, control, communications, computers, intelligence, reconnaissance and electronic warfare (C4ISREW) or provide a mobile energy source for other systems. Such capabilities could therefore be used to extend the operational viability period of dismounted or specialist force elements.

32. Other technologies are being developed to harvest kinetic and thermal energy from the human body. These include kinetic knee energy harvesting devices, and footwear and body armour based devices. The practicality of such systems in physically challenging environments is unknown. Additionally, the ergonomic impracticalities of devices such as exoskeletons could quickly outweigh any potential benefit, particularly in the context of dismounted combat in arduous conditions where dexterity, simplicity, reliability and practicality are most important. Rather than increasing supply through complexity, a better way to address these issues may be by reducing demand and looking for upstream solutions.

Development timeline

Force-in-Being

33. As at 2019, Army's investment into P&E innovation has varied across infrastructure, vehicle platforms and soldier combat systems. Army's current power generation infrastructure is basic, essentially relying on diesel generators running 100% of the time, regardless of demand.[16] Relative to the civilian energy sector, Army's capabilities are very underdeveloped, so much so that numerous commercial non-innovative solutions exist that could see fossil fuel consumption savings of greater than 50%.[17]

34. Considering the cost of upgrading in-service systems, and the timeframes required to deliver new systems within the Capability Life Cycle, Army's ability to invest in wholesale change in this time window is limited. However, opportunistic 'bolt-on' development for the FiB may be possible for isolated capabilities. In this phase small capability gaps or opportunities can be addressed with COTS or MOTS systems or even leased systems which, in some cases, are decades more advanced than in-service platforms.

[16] HQ 17 CSS BDE Preliminary Trial Report – Power and Energy Survey HAMEL 18, provides typical examples where large generators are being employed at as little as 10% capacity with the surplus power being consumed by load banks (heaters)
[17] Defence Science and Technology Group Report – Hybrid Field Power Systems for Relocatable Installations May 2015

Image 8: Example of MOTS rapid deployable renewable power by Remules

35. For some tracked vehicle platforms, fitting composite rubber tracks will generate immediate performance enhancements. This has been demonstrated by the UK Ministry of Defence where rubber tracks were fitted to Warrior Infantry Fighting Vehicle (IFV) and results showed up to 30% reduced fuel consumption, 80% reduced track maintenance and significant reductions in noise signature.[18]

Objective Force

36. Army's P&E development plan for the Objective Force is to deliver technically mature P&E systems through projects in the Integrated Investment Program (IIP). For example, the Deployed Force Infrastructure project (Land 8140) will introduce into service an operational infrastructure system that will utilise some of the emerging P&E technology mentioned in this document. The project will seek to incorporate smart micro-grid technology and load following generators to improve P&E capabilities. It is expected to improve the resilience of energy generating systems and net reductions in fossil fuel consumption. The project does not include platform propulsion, energy transportation systems or capabilities to support soldier combat systems.

[18] Soucy Defence Group composite rubber track systems as tested on UK Warrior IFV (as promoted at Land Forces 2018)

Joint Project 8190 is currently considering bulk liquid energy storage for the supply chain.

37. During this window, Army will be positioned to commence program level development of alternate / hybrid electric vehicle propulsion for land platforms, for both UGV and conventional vehicle platforms. This is likely to be by serendipity as much as by design due to the prevalent emergence of these technologies in vehicles. The TRL of these systems is sufficiently mature for military use and will become financially viable towards the mid-2020s. Introduction of platform chassis and/or hulls that are conducive to evolutionary upgrade of propulsion systems will also be investigated in order to exploit technology while minimising duplicative costs.

38. In this window of time there will be significant global changes in legislation, technological and industrial trends, and consumer acceptance of carbon based fuel technologies. Globally, pressure is mounting on government entities to acknowledge and act on what is being popularised as a resource and climate change crisis. Numerous leading economies are responding to the mounting pressure to act, and legislating points in time from when fossil fuel dependant technologies are to be actively restrained.[19] Of note are the number of states ceasing sales of new petrol/diesel vehicles in the next 15 years (see Image 1). Current trends towards vehicle electrification are gathering momentum globally faster than what Australia is experiencing. Australia's modest uptake of electric vehicles has the potential to create sudden discombobulation in the domestic automotive and energy sectors as industry and government authorities are later

[19] Survey of Global Activity to Phase Out Internal Combustion Engine Vehicles, Isabella Burch and Jock Gilchrist, Sep 18; ABC News – NRMA calls for ban on sale of petrol and diesel cars by 2030, S March, L McGregor, N Selvaratnam, Apr 19

forced to catch up with foreign technology. Change is not always desirable; however, forced change in times not of our choosing is not only undesirable, but potentially chaotic and expensive.

Future Force

39. P&E development for the Future Force, will focus efforts on addressing the ever increasing demand for energy required by technologically advanced capabilities. It will also investigate energy autonomy for deployed forces (through energy scavenging/harvesting and in-situ generation) in order to reduce the fuel resupply burden.

40. Developments in RAS, uninhabited platforms, novel methods for harvesting and storing energy, and smarter ways of managing and distributing energy will also have a defining impact on how the future force will operate. Army's dilemma is knowing when and how to transition to alternate energy systems, be it for infrastructure or platforms, in order to avoid finding itself propping up obsolete and unsustainable platforms and in the process risk in-operability with partner organisations and the national support base.

41. How future land forces operate will also shape how P&E systems will be integrated into warfighting organisations and capabilities. For example, Combat Brigade FEs (including C2 and logistics nodes) need to be highly agile and therefore cannot rely on P&E systems that are stationary. In addition, Combat Brigade platforms will increasingly operate energy dependant sub-systems, be required to integrate with RAS, and approach signature management in new ways. Therefore P&E systems need to be sufficiently versatile to accommodate these requirements whilst enabling growth of demand.

42. Within the Future Force P&E domain, the conditions for step-change may include:

a. Energy storage density improvements > 10 fold[20]

b. Local energy harvesting with substantial improvements in efficiency (such as with solar photovoltaic cells or paint)

c. Sudden breakthrough in alternate power generation opening the way for usable small-scale power generation.

Key Milestones

43. IIP approved projects that will deliver new P&E capabilities to Army include:

a. Land 8140 *Operational Infrastructure* is scheduled reach initial operating capability (IOC) in 2022-23.

b. JP 8190 *Bulk Liquid Distribution System* is scheduled reach IOC in 2024-25.

44. The following projects should look to exploit hybrid and electric propulsion technology and take advantage of the benefits listed above under *Land Platforms*:

[20] Diesel fuel has an energy density of 100 times greater than current lithium Ion batteries; however an internal combustion engine can only convert approximately 20% of the fuel energy into rotational torque. Therefore a 20 fold increase in battery energy density would exceed the performance of fossil fuel energy density. However, given other efficiencies inherent to electric drive systems, a 10 fold increase in battery energy density would be sufficient to make it genuinely competitive with ICE powered platforms.

Objective Force 2020-30	**Future Force 2030-40**
Infantry Fighting Vehicle (L400 PH 3)	Main Battle Tank replacement (L907 PH3)
PMV replacement (L4107)	Artillery Replacement (L8112)
Long Range Fires (L8113)	Rheinmetall MAN Truck Replacement (L8701)
Engineer Support Platform (L8120)	Mercedes G-Wagon Replacement (L8700)
Enhanced Gap Crossing Capability (L8160 PH 1)[21]	
Army Water Transport (L8710)	

45. It is acknowledged that there may be perceived or real risks associated with transitioning capabilities to new and fundamentally different energy technologies. In the context of vehicle platforms, the appetite for performance risk with mission essential capabilities is rightfully low. While caution is warranted, the TRL of hybrid electric vehicle propulsion technology is sufficiently ready to employ in the next Protected Mobility Vehicle fleet (L4107), Medium Heavy Capability fleet replacement (L8701), Light Vehicle fleet replacement (L8700), and potentially the Long Range Fires capability (L8113) if the vehicle platform permits.

46. Projects should also consider global trends, such as those identified in Image 1, in order to facilitate a degree of future proofing of prospective capabilities.

[21] As this platform will likely be based on a legacy platform, hybrid-electric upgrade may not be feasible

Specifically, in the future force window, vehicle platforms should expect to:

a. Operate in an environment where conventional fossil fuels may not be a guaranteed operational commodity;

b. Be compatible with RAS enabled sub-systems that use advanced P&E propulsion systems;

c. Be capable of replenishing energy storage of those sub-systems; and

d. Be capable of coupling with uninhabited CSS sub-systems in order to conduct automated replenishment.

47. Soldier Combat Systems supports a number of soldier C4ISREW systems that require lightweight and rechargeable power sources. Evolutions of Land 125 *Integrated Soldier System* will increasingly demand man portable systems that depend on small electronic devices. These devices can be supported by readily available COTS and MOTS rechargeable batteries and ultra-lightweight recharging systems as soon as practical for the program.

48. These projects, and all future land capability development involving reliance on operational P&E, will be subject to rigorous assessment on how it is to be supported and sustained. Analysis of system or platform sustainability after critical design decisions have been made, or independent of the direction P&E technology is proceeding, is counterproductive to platform performance, interoperability, evolutionary development and sustainability.

Conclusion

49. P&E, from a global technological perspective, is in demand. For Defence, at some point P&E change will become less negotiable, and options taken for granted in the first quarter of the century may cease to be options in the future. Global investment in new renewables is now roughly double that of fossil fuel investment[22] implying the sector will continue to advance whilst technologies that are reliant on fossil fuel are likely to fall behind.

50. When and how this point will occur is uncertain, however given current global trends fundamental change could reasonably be expected within the 2030 - 40 window. For Army, this coincides with the life-of-type for a number of combat and logistics platform fleets and is likely to be the decisive point for major P&E change.

51. This P&E paper offers three LOE where Army can address P&E opportunities. Embracing the P&E technology deliberated on by this paper will put Army in a good place to exploit emerging technology in an Accelerated Warfare future.

[22] Defence Science and Technology Group - Horizon Scan of Emerging Technologies and Trends for ADF Combat Service Support 2018

Abbreviations

AJOC	Australia's Joint Operating Concept
AI	Artificial Intelligence
AP	Agreed Point
AR	Augmented Reality
BDE	Brigade
COTS	Commercial off-the-shelf
C4ISREW	Command, control, communication, computers, intelligence, surveillance, reconnaissance and electronic warfare
COP	Common Operating Picture
CSS	Combat Service Support
DCAP	Defence Capability Acquisition Program
DPG	Defence Planning Guidance
DSTG	Defence Science and Technology Group
EMS	Electro-magnetic spectrum
ECM	Electronic counter-measures
FE	Force element
FORCOMD	Forces Command

FiB	Force-in-Being
GBA	Generic Base Architecture
GVA	Generic Vehicle Architecture
HUMS	Health and Usage Monitoring
ICE	Internal combustion engine
IFV	Infantry Fighting Vehicle
IIP	Integrated Investment Plan
IOC	Initial operating capability
ISR	Intelligence, Surveillance, Reconnaissance
JCNS	Joint Capability Needs Statement
JP	Joint project
LCMP	Land Capability Modernisation Plan
LFD	Land Force Design
LOE	Line of Effort
LOT	Life of Type
LOTS	Logistics over the shore
MOTS	Military off-the-shelf
NGTF	Next Generation Technology Fund
OS	Offensive Support (Fires)
P&E	Power and energy

PH	Phase
PMV	Protected Mobility Vehicle
PV	Photovoltaic
RAS	Robotic & Autonomous Systems
RTS	Raise, train and sustain
TRL	Technology Readiness Level
UAV	Un-crewed Aerial Vehicle
UGV	Un-crewed Ground Vehicle
UxV	Un-crewed Vehicle (nonspecific)
VCDF	Vice Chief of the Defence Force
VR	Virtual Reality