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UNIVERSITY OF
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MISSION GREEN:
UNLEASHING A DEFENSE DECARBONIZATION
INNOVATION ECOSYSTEM

Carlos Cantafio Apitz

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INTRODUCTION

Across the world, both public and private sector actors have announced ambitious new decarbonization targets to achieve net-zero emissions by 2050. For example, in North America, both Canada and the United States's (US) governments have announced internal federal greenhouse gas (GHG) emission reduction targets. In both cases, their defense departments appear to be the largest GHG emitters.^{1&2} Given the relative size of defense-to-federal GHG emissions, this paper argues that they could in fact serve as an important “market” for the public sector to capture and generate positive decarbonization innovation externalities. How? Positive innovation externalities have arisen from previous government-led “missions”, such as the advancements in satellite and communication technologies indirectly derived from the National Aeronautics and Space Administration (NASA)’s moon landing efforts.^{3&4} Innovations from “mission”-led public initiatives have enabled governments to become market makers due to their comparative advantage in acting as a centralized procurement, financing, and commercialization agency.⁵ Given this backdrop, this paper has two key research objectives: (A) To explore how reconfiguring the approach of national defense departments to decarbonization, in particular that of the US Department of Defense (DoD), can lead to positive innovation externalities; and (B) To conduct a “market sizing” and diagnostic exercise on the US DoD’s GHG emissions. Defense-led innovations could directly assist in the global trade, transportation, supply chain, and facilities decarbonization.

This report investigates the relationship between two different literatures to provide a fresh perspective on the intersection between defense decarbonization and innovation policy: Mission-oriented innovation policies and “complex established legacy sectors” (CELS).⁶ Additionally, it adds a third lens of analysis by framing the US DoD as a relevant innovation actor. While other researchers have conducted extensive analysis on specific sub-agencies of the DoD as well as the complexities of disrupting the energy sector, there is limited work exploring the convergence of innovation policy, energy decarbonization, and the defense sector. To explore how these interact and answer the two research objectives, this report is structured in five discrete sections:

- (1) The Decarbonization Paradigm: Disrupting CELS via Transformational Missions
- (2) The DoD’s Decarbonization Motives, Enabling Conditions, And Innovation Advantages
- (3) Market Sizing: A Carbon Diagnostic of the DoD’s GHG Emissions
- (4) Assessing the DoD’s Decarbonization Plans
- (5) Synthesis of Contributions and Lessons Learned

¹ Department of National Defence. “Defence: Energy and Environment Strategy,”. 2020

² Office of the Under Secretary of Defense. “DoD Plan to Reduce Greenhouse Gas Emissions”. 2023

³ Mazzucato, Mariana. “Mission economy,”. CH1. 2021

⁴ Weiss, Linda. “America Inc.?”, CH2. 2014

⁵ Mazzucato, M. and Semieniuk, G. “Public financing of innovation: new questions”. 2017

⁶ Bonvillian, W. and Weiss, C. “Complex, Established “Legacy” Sectors,”. 2011

This paper argues that national defense departments' decarbonization policies, if set up as defined missions, can deliver important innovation externalities that could accelerate the path to broader societal decarbonization. There are three interrelated features that underpin this hypothesis:

- (1) Energy can be characterized as a complex established legacy sector (CELS) and exhibits deeply rooted innovation obstacles that need to be targeted via a multi-actor led portfolio of initiatives to unleash transformation in the form of incremental and radical innovations. These transformations have typically been precipitated by public sector action.
- (2) Public sector interventions aimed at fixing directional failures via mission-oriented innovation policies could help “make markets” in support of societal transformations (e.g., decarbonization goals), in particular via transformational missions that target established industries via regime destabilization and generation.
- (3) The US DoD, has a unique set of motives (strategic power competition – climate change paradigm) and enabling conditions (green industrial policies, access to and direction of funding and emissions, and autonomy), that together with its innovation management advantages, can enable it to generate dual-use innovations that can positively affect domestic and international decarbonization efforts.

Upon expanding on the above arguments and providing a data-driven perspective on a potential market segmentation of the DoD's GHG emissions, this paper then proposes a transformational mission evaluation framework and applies this framework to the 2023 US Department of Defense Plan to Reduce Greenhouse Gas Emissions (“the DoD's Plan”). In applying this framework, the objective is to evaluate the extent to which the DoD's plan conforms with transformational mission characteristic as well as identify relevant gaps and opportunities. In a final yet related analysis, this plan is evaluated in relation to the identified DoD GHG emission market segmentation to understand existing progress and future challenges regarding making markets for different types of innovations. This paper finds that the DoD's plan already embeds characteristic features of transformational missions, along with opportunity areas. Similarly, it concludes that the DoD is focusing its market making efforts on relevant GHG emissions market segments with both incremental and radical innovations. Ultimately, this study consolidates knowledge from different literatures and current global affairs to bring attention to the potential role that defense departments can have in affecting innovation ecosystems, and more broadly societal challenges, under specific international and national contexts.

SECTION 1 - THE DECARBONIZATION PARADIGM: DISRUPTING CELS VIA TRANSFORMATIONAL MISSIONS

Ambitious climate change-related policy is placing the energy sector at the core of the sustainability transformation. As such, this section first explores literature related to transition management, regime destabilization, and complex established legacy sectors (CELS), such as energy. CELS are “disruption resistant sectors characterized by stable, well defended paradigms that lock in compatible technologies”.⁷ Given CELS’ high resistance to change, a mission-oriented innovation policy is likely to be the most appropriate response to the energy transition and economic decarbonization as these more closely align to large-scale challenges requiring multi-faceted responses. To this end, this section reviews the rationale for public sector intervention and introduces two different types of mission oriented innovation approaches: linear missions and transformational missions. This novel contribution is summarized in a table that will serve as the basis for an evaluation of existing decarbonization policy approaches in the US defense sector.

The CELS Elements Governing Energy

Existing socio-technological regimes are typically more stable and resistant to change than new ones.⁸ The literature highlights that technology and its related governance prevent rapid change in CELS, encouraging the “lock-in” of the regime.^{9&10} In fact, CELS challenge Schumpeter’s “creative destruction” process in which new technologies replace the obsolete, pressuring incumbents to exit the market.¹¹ Empirical evidence has demonstrated that this process is not necessarily linear, and through creative accumulation, existing actors can “absorb new technologies and integrate them within their existing capabilities”.¹² These dynamics have given rise to a sustainability transitions literature focused on two-pronged policy mixes that consider both the “creation” of new technologies and the “destabilization” of the old.¹³ Table 1 below describes why the energy sector should traditionally be considered a CELS, adapting Weiss and Bonvillian’s conceptual innovation-inhibiting features in legacy sectors, and their energy case study. This paper proposes a distinction among these features, grouping them within *capital* and *embeddedness* factors. Moreover, sample policy interventions needed to disrupt CELS are presented (see Table 2). While research suggests these individual initiatives have slowly made an impact in disrupting CELS, they appear to be fragmented across multiple public and private sector actors, mostly stimulate adoption of existing technology, and are removed from the broader innovation lifecycle (from R&D to commercialization), suggesting that a more comprehensive approach is needed – this paper proposes mission oriented innovation policies as the solution.

⁷ Bonvillian, W. and Weiss, C. “Technological Innovation in Legacy Sectors”. 2015

⁸ Heyen, Dirk. “Governance of exnovation: phasing out non-sustainable structures”. 2017

⁹ Bonvillian, W. and Weiss, C. “Technological Innovation in Legacy Sectors”. 2015

¹⁰ Rogge, K., and Johnstone, P. “Exploring the role of phase-out policies for low carbon energy transitions,”. 2017

¹¹ Soete, L.L.G., ter Weel, B.J. “Innovation, knowledge creation and technology policy,”. 1999

¹² Bergek, A. et al. “Technological discontinuities and the challenge for incumbent firms,”. 2013

¹³ Kivimaa, P., and Kern, F. “Creative destruction or mere niche support?,” 2016

Table 1: Legacy Sector Innovation Inhibiting Features

	CELS FEATURES	UNDERSTANDING ENERGY AS A CELS (examples prior to “green” economic deals of the 2020s)
CAPITAL RELATED FACTORS	1) Cost or price structures favourable to existing technologies ignoring negative externalities / societal goals	Consumer access to fossil fuels is cheap and convenient; excludes cost of negative environmental externalities and is supported (e.g., yearly US and EU subsidies of USD 20B & EUR 55B, respectively). In the US, production subsidies are also embedded in the tax code. Producers can "deduct a fixed % of gross revenue instead of their actual costs as capital expenses, deduct exploration costs", etc. ¹⁴
	2) Financing system oriented towards sustaining mature industries (low risk appetite for new-entrant products)	R&D funds have traditionally not been provided to early stage or disruptive secondary innovations (e.g., hydrogen fuel, off-grid solar, etc.). For example, venture capital funding for clean energy technology was around \$4 billion by 2008 and declined to \$3.3 billion in 2012. More importantly, this funding was directed at commercialization instead of R&D, implying that only mature technologies were supported.
	3) Low R&D capital availability and orientation limiting the rise of alternative technologies ready for scale-wide roll-out	The energy sector is characterized by high capital expenditures; thus, firms need funding to scale inventions. Similarly, there has been low level of private sector R&D on new energy technology (less than 1% on R&D), unless focused on "paradigm compatible" innovations (e.g., fracking). On the public sector side, Federal R&D in new energy technology as of 2007 was about 50% of 1980s (inflation adj.).
EMBEDDEDNESS RELATED FACTORS	4) Established politically powerful vested interests defending the sectoral paradigm & resisting new business models	Energy supply narrative traditionally dominated by politics of fossil fuel scarcity (geopolitical argument) capturing national security interest and support for local oil production and shale gas extraction. Examples of vested interests in action include successful lobbying from oil companies against the Kyoto Protocol and other climate change related measures that could affect price structures.
	5) Institutional frameworks favouring existing technologies, incl. regulations and enabling systems and services	Complex regulatory frameworks impact the deployment of large-scale solar and wind energy projects (e.g., having to obtain multiple approvals from different governing bodies for the establishment of high-voltage transmission lines to link projects to the primary electric power distribution system). Other examples incl. the federal highway construction fund, historically favoring highways over mass transit.
	6) Public support and expectations in line with existing technological regime, incl. price structures and dominant products	Public habits are accustomed to convenient and cheap energy to power day-to-day facilities and mobility (e.g., gas stations vs. electric power stations for vehicles). The energy industry is also highly entrenched in the economy and consumer prices, incl. inflation expectations and management (e.g., CPI indicators).
	7) Knowledge development and human capital structures established around needs of existing technology	University curricula, health and safety protocols, professional standards, and state training services enable career paths in oil and gas technical fields, furthering flow of human capital into the industry. The size of the US industry also places a large economic burden if a transition away from fossil fuels is mismanaged as the industry supported nearly 1M direct and 19M indirect jobs in 2022. ¹⁵

Sources: Adapted from Bonvillian, W. and Weiss, C. (2015) Chapters 2, 5, 6. Augmented with insights from Kivimaa, P., and Kern, F. (2016); and Rogge, K., and Johnstone, P. (2017). Author's analysis - Datapoints not in footnotes sourced directly from Bonvillian, W. and Weiss, C. (2015).

¹⁴ EESI. “Fact Sheet | Fossil Fuel Subsidies,” 2019; and Urpelainen, J., and George E. “Reforming global fossil fuel subsidies,”. 2021

¹⁵ TIPRO. “TIPRO 2023: State of Energy Report”. 2023

Table 2: Potential Destabilizing Policies and Examples

	SAMPLE CREATIVE AND DESTABILIZING APPROACHES	POLICY EXAMPLES (non-exhaustive and high-level)
CAPITAL RELATED FACTORS	<p>Transition Management literature posits that economic pressure on the regime is needed to drive change and develop a playing field for new entrant technologies to compete in the market.¹⁶ Sample destabilization policies targeting CELS feature 1 include: Reduction or elimination of financial support for selected paradigm-compatible technologies; Structural reforms to tax codes eliminating deduction advantages; Establishment of carbon trading or road pricing to increase economic pressures on current regimes.</p> <p>Conversely, creative policies targeting CELS features 2, 3, 5 and 6 include Low interest loans; Public-private funding matching for R&D; Public procurement and labelling to foster new entrant legitimacy; Targeted funding schemes and tax incentives.</p>	<ul style="list-style-type: none"> • Austria: Public grants and loans (10 - 30% supported by a national program) for solar related installations. • Denmark: Fossil fuel taxation to add economic pressure on energy regime. • Germany: Tax exemptions for individual investors in wind energy, direct financial support for PV roofing, subsidies available to both consumers and industry for transitioning. • Spain: tax benefits received by industry investing in renewable energy projects, stimulating R&D and commercialization.
EMBEDDEDNESS RELATED FACTORS	<p>Legitimacy of regime destabilization is needed for resources to be mobilized across all stakeholders (public, private, consumer, etc.), which implies that there is a need for economy-wide directionality (e.g., ensuring private sector actors that a new regime will be sought and rewarded). Regime destabilization policy targeted at actor-network structures may involve – related to CELS features 1, 4, 5, and 6: Introduction of new actors into existing bodies (e.g., replacing actors in policy advisory councils, formation of new organizations linked to systems change), policies aiming at structural regulatory reforms, reframing narratives to alter consumer behaviour, supporting the upgrading of entrenched enabling systems (e.g., changing electricity grid regulations).</p> <p>Diffusion of new technologies is equally important and should be supported by market formation policies (e.g., feed-in tariffs, public procurement, labelling, green subsidies etc.) to drive consumer adoption, which in turn adds economic pressures to the regime. Other creative policies may include labour-market policy changes, which target CELS features 6 and 7 (e.g., secondment of expertise, funded re-skilling), which are needed to build human capital that supports the commercialization of new technologies.</p>	<ul style="list-style-type: none"> • Austria: Strong political support for creation of jobs and reskilling towards renewable energy industry following national energy strategy targeted at consumption. • Denmark: Agreement between political parties to establish environmental policies by sector to include context specific considerations. In 2012, new regulations changed enabling systems (e.g., utilities) and mandated allowance of access to the grid for renewable energy producers with economically "fair" charging for access. • Finland: National strategies with specific long-term goals (e.g., increase biomass use by 25% in 10 years) supported by strategy refreshments and changing legislation. • Spain: Regional banks becoming shareholders in public-private companies to develop region's renewable energy. Subsidized reskilling programs for unemployed workers for maintenance and installation of green technology.

Sources: Column "Sample Destabilizing Approaches" adapted from Kivimaa, P., and Kern, F. (2016); Column "Policy Examples" adapted from Abdmouleh, Alammari, and Gastli (2015). Author's analysis

¹⁶ Kivimaa, P., and Kern, F. "Creative destruction or mere niche support?," 2016

As can be seen from Table 1, major disruption barriers to the energy sector involve the highly oligopolistic nature of the market, with companies benefitting from a collection of fiscal advantages not shared, until recently, by other low-carbon technologies (e.g., Inflation Reduction Act – IRA). These dynamics have enabled the energy sector to deliver reliable, convenient, and cost-effective energy to users across the US. As such, to drive innovation and transition to sustainable energy, there is a need for the restructuring of financial systems to support early-stage and disruptive innovations, as well as commercialization. Similarly, overcoming the entrenched status quo of the energy sector requires addressing political influences and reorienting policies to support new energy technologies. Per Table 2, transformations to the energy sector towards lower carbon emitting sources have seldom been driven by market demand.¹⁷ Instead, and as supported by the summarized policy making evidence, these transformations are frequently precipitated by public sector intervention.

Public Sector Interventions and Transformational Missions

Robinson and Mazzucato outline three potential public intervention rationales, including Arrow’s market failure theory, innovation system failures, and directional failures.¹⁸ Governments have historically used market failure theory to justify economic interventions, focusing on correcting market inefficiencies. This involves investing in public goods and internalizing external costs and benefits. However, the market failure theory is limited when policy is required to foster entirely new markets and disruptive innovations and it falls short in addressing private sector hesitance.¹⁹ Another rationale for public sector intervention relates to fixing innovation system failures. The rationale behind public sector intervention for fixing innovation system failures concerns the issue of how actors interact (i.e., nature and quality of interactions), including vertical and horizontal links between them.²⁰ That is, public intervention focuses on optimizing the performance of the existing innovation system. However, actors tend to “follow “satisficing” behavior rather than the maximizing behavior assumed in traditional economic models”.²¹ Given the focus on fixing linkages within systems, generating new markets and industries requires a different approach.

This paper is interested in *fixing directional failures*. Fixing directional failures appears to be a growing trend among current innovation policy planners; these aim to tackle societal challenges (e.g., the EU’s Green New Deal or Biden’s IRA).²² Fixing directional failures enables governments to provide a stable direction for public investment and regulations, which ultimately assist in incentivizing private sector involvement. Societal challenges, such as the sustainable development goals or climate change, likely require multi-actor and multi-sector solutions. As such, public sector intervention has to target systemic change that can facilitate both innovation and socio-economic impacts related to a selected challenge. Mazzucato posits that “challenges can be translated into concrete action through an intermediary layer of mission-oriented innovation

¹⁷ Bonvillian, W. and Weiss, C. “Technological Innovation in Legacy Sectors”. 2015.

¹⁸ Robinson, D. and Mazzucato M. “The evolution of mission-oriented policies,”. 2019

¹⁹ Robinson et al. “Waiting games: innovation impasses in situations of high uncertainty”. 2012

²⁰ Robinson, D. and Mazzucato M. “The evolution of mission-oriented policies,”. 2019

²¹ Nelson and Winter. “An Evolutionary Theory of Economic Change”. 1982

²² Hekkert, M et al. “Mission oriented innovation systems”. 2020

policy for creating, shaping and directing markets that otherwise would not occur through fixing market and systems failures”.²³ Mission-oriented innovation policy literature is expanding, and multiple definitions and applications exist. This paper will use the Organization for Economic Cooperation and Development’s (OECD) definition of mission-oriented innovation policy as it encapsulates perspectives from multiple innovation scholars:

*“A mission-oriented innovation policy is a co-ordinated package of policy and regulatory measures tailored specifically to mobilise science, technology and innovation in order to address well-defined objectives related to a societal challenge, in a defined timeframe. These measures possibly span different stages of the innovation cycle from research to demonstration and market deployment, mix supply-push and demand-pull instruments, and cut across various policy fields, sectors and disciplines”.*²⁴

This definition is broad and its use of language such as “possibly” implies that there is flexibility in how it gets applied across countries, regions, and sectors. This is potentially due to the nascent nature of the innovation scholarship on this topic. That is, mission-oriented innovation policy research is a relatively new area, with mentions of “mission oriented R&D” dating to 1967 and an increased interest in fighting societal challenges arising in the early 2000s.²⁵ Freeman, in 1996, is among the first scholars to apply the phrase in the context of enabling a systemic transition related to decarbonizing the economy.²⁶ Mission approaches have changed with time and the OECD’s definition already suggests that the current understanding is different from its past applications. The Manhattan and Apollo projects are widely studied and often are considered as examples of missions that resulted in innovations with significant socio-technological implications (e.g., nuclear power plants and IT developments) stemming from their completion. However, these projects were designed with specific technological solutions as objectives and with the government as the intended customer.²⁷

Most recently, however, missions are becoming interested in transforming systems and have their roots in sustainability transition studies.²⁸ In alignment with the OECD’s definition, missions would require public agencies to engage in “decentralize[d] and dynamic innovation systems that include bottom-up innovation and variation beyond the control of central administrations”.²⁹ And more importantly, they have a distinct focus on invention diffusion and market making. Synthesizing different literatures on missions, this paper advances two distinct types of mission-oriented innovation policy approaches: *linear missions* and *transformational missions*. Table 3 below summarizes the literature review findings and provides defining features of these two types. Transformational missions focus on the entire innovation life cycle, including multi-customer diffusion (i.e., commercialization) as this is transmission mechanism to tackle the defined societal grand challenge. Conversely, linear missions, which resemble the initial

²³ Robinson, D. and Mazzucato M. “The evolution of mission-oriented policies,”. 2019

²⁴ OECD. “The Design and Implementation of Mission-oriented Innovation Policies”. 2021

²⁵ Ibid.

²⁶ Ibid.

²⁷ Ibid.

²⁸ Laatsit, Grillitsch, Funfschilling. “Great expectations: the promises and limits of innovation policy,”. 2022

²⁹ Robinson, D. and Mazzucato M. “The evolution of mission-oriented policies,”. 2019

conceptualization of missions, appear to be primarily focused on single customer inventions.³⁰ That is, they ignore or choose not to prioritize the process of diffusion and commercialization. At a high level, their main differences relate to number of actors involved, centralization vs decentralization of ownership and financing, the focus on radical vis-à-vis both incremental and radical innovation, and their ultimate objectives.³¹

Table 3: Differentiating Linear vs Transformational Driven Missions

	FEATURE	LINEAR MISSIONS	TRANSFORMATIONAL MISSIONS	REFERENCES
1	Strategic Orientation	Clear challenges supported by defined goals and objectives	Broad challenges encompassing a complex mix of goals and objectives	<i>Mazzucato and Penna (2015)</i>
2	Legitimacy	Minimal stakeholder consensus needed on relevance of mission	Consensus among a wide stakeholder group drives mission need and relevance	<i>OECD (2021)</i>
3	Economic Model	Supply-side innovation drivers (e.g., public sector R&D funding)	Supply & demand side innovation drivers (e.g., invention & diffusion are supported)	<i>Laatsit, Grillitsch, Funfschilling (2022); Edquist et al., (2018)</i>
4	Innovation Intensity	One or few new technologies involved as targets	Many new technologies involved as targets	<i>Mendoca, Macedo-Soares, Fonseca (2018); Foray et al. (2012), Mowery (2012)</i>
5	Disruption Level	Efforts are oriented towards radical inventions	Efforts are oriented towards both radical and incremental inventions	<i>Laatsit, Grillitsch, Funfschilling (2022); Mazzucato & Penna (2015)</i>
6	Diffusion Focus	Diffusion of outcomes outside of core group is of minor importance	Diffusion of continuous results is a central goal and is actively encouraged	<i>Laatsit, Grillitsch, Funfschilling (2022); Mazzucato & Penna (2015)</i>
7	Funding	Single source financing administered by a centralized authority	Public & private sources are mobilized for human & capital resources	<i>OECD (2021); Robinson and Mazzucato (2019)</i>
8	Participant Intensity	Participation is limited to a small group of firms given radical invention focus	Necessitates & fosters networks across a large number of actors for system change	<i>OECD (2021); Kuhlmann and Rip, (2014); Kemp et al. (2007)</i>
9	Policy Portfolio Mix	Self-contained projects with limited need for complementary non-funding policies	Encompasses a diverse and consistent set of policy interventions	<i>OECD (2021); Robinson and Mazzucato (2019)</i>
10	Change Environment	Outcomes impact mostly open innovation spaces (regime generation)	Progress affects socio-technical paradigms (regime destabilization and generation)	<i>Haddad and Bergek (2020); Weber and Rohracher (2012); Ghosh et al. (2021)</i>
11	Governance	Linear and centralized	Complex (vertical & horizontal) and distributed	<i>Laatsit, Grillitsch, Funfschilling (2022); Mazzucato & Penna (2015)</i>
12	Evaluability	Summative evaluations (on final results); captures project outcomes	Formative evaluations (on continuous progress); captures systems change	<i>Laatsit, Grillitsch, Funfschilling (2022); OECD (2021)</i>

Source: Author's compilation and analysis

³⁰ Laatsit, Grillitsch, Funfschilling. "Great expectations: the promises and limits of innovation policy,". 2022

³¹ Robinson, D. and Mazzucato M. "The evolution of mission-oriented policies,". 2019

This paper argues that *transformational missions* are the more appropriate innovation policy response to the energy transition and economic decarbonization as these more closely align to societal challenges requiring multi-faceted responses. Transformational missions are characterized by prioritizing the diffusion of results.³² In the case of energy, a CELS, innovations will have to penetrate an existing “technology-economic-political paradigm”, which in turn will need a targeted approach.³³ Missions aiming to address societal challenges will need longer term commitments from multiple stakeholders to ensure success of desired transformations. Innovation in the energy sector has historically been organized through public sector directionality, enabling private sector support. For example, in the 1970s, the mission to enhance national security via reducing dependence on oil imports from OPEC countries led to private investments to expand domestic production and the build-out of the Strategic Petroleum Reserve, with higher prices and public sector demand reinforcing private sector profits and interest.

Currently, the grand challenge is limiting carbon emissions, which come from multiple sources. As such, different countries, via internal agencies, have launched missions to transform both the sources of energy and their distribution (i.e., expanding public sector directionality and involvement beyond R&D and towards commercialization).³⁴ With the public sector focusing on all aspects of the innovation value chain, it is adopting an “entrepreneurial” behaviour which is resulting in higher risk taking, particularly in the renewable energy sector. This brings formidable coordination and execution challenges characteristic of missions. For example, an OECD study conducted on 20+ missions revealed that these can face several complications, from insufficient actor coordination / integration and “mission capture” by established actors (e.g., strict division of labour rather than collective action, and established incumbents slowing down change to reconfigure their positions of power), to higher-than-estimated costs and limited contributions to societal resistance upon delivering effective solutions (e.g., failing to scale and diffuse solutions due to lack of political and financial resources).³⁵ The study also notes that there are several examples of mission successes, particularly in military, telecommunications, and health due to these missions tackling technological objectives and leveraging the “strong procurement power of public authorities”.³⁶ Given these considerations, this paper proposes that a potential solution to managing the complexities of public sector entrepreneurship relative to disrupting the energy sector is to place defense departments at the center of the decarbonization mission, in particular the US DoD if it activates its “economy” with a transformational mission.

The DoD’s unique position is related to its ability to fund innovation and disrupt networks using domestic industrial policy while directing its military expenditures to create demand for decarbonization technology – this is given by its scope, scale, and autonomy. The below elements underpin this proposal:

- (1) The DoD’s ability to direct military purchases and set standards, coupled with the fact that the size of carbon emissions derived from national defense activities serve as a

³² Robinson, D. and Mazzucato M. “The evolution of mission-oriented policies,”. 2019

³³ Ibid.

³⁴ Mazzucato, M. and Semieniuk, G. “Public financing of innovation: new questions”. 2017

³⁵ OECD. “The Design and Implementation of Mission-oriented Innovation Policies”. 2021

³⁶ Ibid.

direct decarbonization “market”, enables the DoD to surpass the innovation demonstration, “market making”, and diffusion challenges that other public agencies may experience – this “military procurement pathway” is a critical transmission mechanism unique to the DoD that can help scale incremental and radical solutions.

- (2) The size of yearly US federal budget allocations towards national defense as well as the increasing amount of public funds and regulatory benefits geared towards climate change can assist the DoD in addressing financial, legitimacy, and legal barriers associated with missions.
- (3) The current environment may be able to protect DoD innovation work from accountability-agility dilemmas faced by other public agencies, thus protecting DoD efforts from political “capture” and potentially enabling improved coordination. As is demonstrated in subsequent sections, the DoD benefits from being an autonomous organization with intrinsic decarbonization motives and objectives as well as by its embeddedness within the US political-technological arena (i.e., it can be, and has been, used by the government to achieve technological and integration objectives).

The following section tackles this proposal by more comprehensively describing the motives and enabling conditions that give the US DoD a unique position to establish a *transformational mission* approach to deliver the high-technology innovations required to decarbonize defense and kickstart a broader global energy modernization.

SECTION 2 – THE DOD DECARBONIZATION MOTIVES, ENABLING CONDITIONS, AND INNOVATION ADVANTAGES

There are direct and indirect motives behind the defense sector, and in particular the DoD, wanting to pursue defense decarbonization. These motives arise from the current geopolitical context, military advantages associated to energy logistics and efficiencies, and, presently, the global fight against climate change. While some of these motives are not new (i.e., offensive edge arising from lower fuel dependencies), the DoD is presented with certain enabling conditions that can accelerate the path for decarbonization innovations, both incremental and radical, to reach defense and non-defense markets. Following an explanation of motives and enabling conditions, this section describes the DoD’s innovation advantages. Together, these directly address the identified challenges associated to transformational missions in Section 1.

Understanding the DoD’s Decarbonization Motives

In *America Inc.*, Linda Weiss attributes US “primacy” or hegemony to its technology leadership and capacity for innovation.³⁷ Weiss argues that the US acted as a technology enterprise by positioning national security at the core of its innovation policy – a National Security State (NSS). The NSS, a post 1945 creation, aims to mobilize the US’ science and technology resources for military primacy.³⁸ In turn, this focus has resulted in a myriad of dual-use innovations (i.e., positive innovation externalities) that permeate our daily activities (e.g., the internet). A desire for geopolitical primacy in an era of bi-polar great power competition fostered such technology investments and research and development (R&D) efforts.³⁹ After the end of the cold war, once primacy was achieved, strategic power competition was characterized by US unipolarity.⁴⁰ However, a new geopolitical imperative featuring a multipolar world is threatening the US’s achieved primacy, which in turn is fueling a technological arms race once again.⁴¹ Presently, in the US, national security strategy has shifted its focus towards managing strategic power competition, which is also partly characterized by the climate-security-technology nexus (i.e., causes and consequences of climate change, and dependency on carbon emitting energy sources relative to military operational effectiveness).⁴² This nexus represents a national security imperative for decarbonization.

As argued by Crawford, the rationale for defense decarbonization goes beyond reducing emissions and towards ensuring military primacy via improved energy utilization and reduced fossil fuel dependency. These, in turn, affect refueling networks, defense partners, supply choke points, etc.⁴³ For example, historical lessons, including Winston Churchill’s shift from coal to oil for the British fleet in 1911, highlight the substantial advantages that energy-related decisions can confer in military strategies.⁴⁴ This shift enhanced the Royal Navy’s speed, reduced logistical

³⁷ Weiss, Linda. “America Inc.?” . CH9. 2014

³⁸ Weiss, Linda. “America Inc.?” . CH1. 2014

³⁹ Ibid.

⁴⁰ Mazarr, Michael et al. “Understanding a New Era of Strategic Competition”. 2022

⁴¹ Favaro, M., Renic, N., Kuhn, U. “Negative Multiplicity,”. 2022

⁴² US Department of Defense. “2022 National Defense Strategy of The United States of America”. 2022

⁴³ Crawford, Neta. “The Pentagon, Climate Change, and War,”. 2022

⁴⁴ Ibid.

burdens, and offered a distinctive edge over Axis powers during World War I. Energy security and its related competition for oil resources significantly influenced key military decisions and events during World War I and II, such as Nazi Germany's failed Operation Barbarossa and Japanese strategic actions in the Asia-Pacific theater.⁴⁵ These examples highlight that in the realm of military energy decision-making, the fundamental economic, security, and environmental factors guiding energy choices are framed by energy's dual potential to act as a facilitator of military capability and, through its denial, a potential weapon in warfare.⁴⁶ That is, energy has consistently played a critical role in military operations, affecting strategic planning, mobilization, and conflicts.

Borrowing from Crawford's "Pentagon Fuel Use, Climate Change, and the Costs of War" studies, and her expanded book, the DoD's interests in reducing fossil fuel dependency and delivering yet another energy transition derives from four rationales:⁴⁷

1. Lowering GHG emissions can help mitigate climate change and diffuse its "threat multiplier" characteristic (i.e., climate change can amplify the size of other threats such as food / energy insecurity, supply mobility and connectivity challenges). This is relevant insofar the DoD is able to deliver decarbonization products with potential civilian use to affect global decarbonization. A reduction of GHG emissions via declining warfare would result in a momentary pause, yet it may not translate into changes to the energy industry.
2. Decreasing fossil fuel use can result in political and security benefits, such as limiting deployed troop's dependence on oil. Several empirical studies have demonstrated the high military attrition rate related to supplying energy to troops in the field.^{48&49} Similarly, lowering the US's oil dependence could foster a reduction of political and oil resources used to defend its access to foreign oil supplies, particularly in the Middle East. Additional security benefits relate to efficiency and maneuverability (e.g., assets travel faster and longer distances with improved logistic tails) as well as surprise and mass (e.g., electric vehicles increase stealth factor, diminishing heat and sound signatures, and field operations could potentially take less time to assemble without consideration of needed fossil fuels).⁵⁰
3. Lessening US dependence on oil producing states could result in a reassessment of the size of US military presence and diplomatic relations with countries that presently do not abide by the US principles, reducing their strategic relevance in negotiations (e.g., Saudi Arabia).
4. Reducing capital spent on ensuring fossil fuel access and support operations can reorient funding towards other productive activities, including decarbonization R&D, climate change mitigation and adaptation of domestic military capabilities, emerging military technologies, domestic policy issues, supply chain resiliency, etc.

In synthesis, the DoD's motives to reduce fossil fuel dependency derive from associated geopolitical, economic, diplomatic, technological, and energy related benefits that it could obtain

⁴⁵ Ibid.

⁴⁶ Samaras, C., Nuttall, W., and Bazilian, M. "Energy and the military,". 2019

⁴⁷ Crawford, Neta. "Pentagon Fuel Use, Climate Change, and the Costs of War". 2019

⁴⁸ Samaras, C., Nuttall, W., and Bazilian, M. "Energy and the military,". 2019

⁴⁹ Crawford, Neta. "Pentagon Fuel Use, Climate Change, and the Costs of War". 2019

⁵⁰ Hourihan, M. and Stepp, M. "Lean, Mean and Clean: Energy Innovation and the Department of Defense". 2011

in both the short and long term. These benefits, however, have existed in other time periods, which raises the question of “why now?”. There are three present enabling conditions that can allow the DoD to direct a decarbonization transformational mission: (1) Rising domestic economic dirigisme, in the form of industrial policy, targeting CELS innovation barriers; (2) The current size of the DoD’s “economy”, in terms of budget, interconnectedness, and carbon emissions; and (3) The DoD’s ability to overcome accountability-agility dilemmas faced by other public agencies. These three enable the DoD to have the necessary scope, scale, and autonomy to lead a transformational mission.

The DoD’s Decarbonization Enabling Conditions

America Inc., in its final remarks, adds that, compared to the second half of the XX century, there is a geographical “disconnect” between where innovation and manufacturing take place, which may negatively impact the US as a technology enterprise.⁵¹ The current rise of economic dirigisme and green industrial policy in the US directly responds to this disconnect of innovation and production. Globalization and the rise of US unipolarity resulted in a redistribution of supply chains and manufacturing, with the US retaining domestic-led innovation. Green industrial policy, however, can be understood as a direct response to the current multipolarity and is seeking to reactivate the US manufacturing base as a reactionary measure to ensure its technological primacy.

In addition to rebuilding key domestic manufacturing sectors that can be leveraged by the defense-industrial complex, this dirigisme also directly addresses CELS-related innovation inhibiting barriers explained in Section 1, which can facilitate DoD decarbonization efforts. Biden’s IRA and CHIPS Act are a response to a global rise in industrial policy, which is flooding economies with financing and direction to disrupt the energy paradigm (i.e., targeting CELS capital related factors), for example the EU’s Green Deal, South Korea’s support for the hydrogen market, and China’s almost two decade long strategic repositioning in the critical minerals and renewables markets.⁵² These initiatives impact global investment and production networks, with the political economy of domestic renewable energy growth linked to reshoring, job creation, domestic R&D investments, etc.⁵³ The domestic capital influx also affects CELS embeddedness related factors, in particular actor-network organizations as firms focusing on decarbonized or low-carbon emission sources of energy become politically relevant, labour policies shift to prioritize training and reskilling of the labour force of the future, legislation adds economic pressures to the existing regime, and public habits and perceptions begin to change vis-à-vis the impact of fossil fuels to climate change. Domestic green industrial policy also reinforces consumer and corporate demand for low-carbon emission energy as societal co-benefits begin to enter the narrative.⁵⁴ These dynamics may position DoD-led incremental and radical innovations at the forefront of consumer markets, if proven useful.

The current size of the DoD’s “economy” is also a critical enabling condition. Along with a 70+ year history of market making, the DoD manages over two million people and a

⁵¹ Weiss, Linda. “America Inc.?” CH9. 2014

⁵² Allan, B., et al. “Green Industrial Policy and the Global Transformation of Climate Politics”. 2021

⁵³ Ibid.

⁵⁴ Allan, B., et al. “Green Industrial Policy and the Global Transformation of Climate Politics”. 2021

comprehensive list of contractors, all of which must abide by DoD-set standards and purchasing requirements. To place in context, the US's DoD, both in budget and emissions, is significantly larger than Canada's and most other countries.. In 2021, the DoD's – rising – budget was USD \$800B, conversely, Canada's Department of National Defense (DND)'s 2021 budget was 3.3% of the DoD.^{55&56} Similarly, the US's federal government emissions are over 30 times higher than that of Canada (Section 3 explains this enabling condition in more detail as it drills into the different sources of emissions and high level trends relevant to chart decarbonization pathways). For added perspective, the US federal government's GHG emissions are higher than the entire country of Peru.⁵⁷ Ultimately, if the DoD is able to significantly decarbonize its assets and activities, its approaches and resulting technologies can help with global decarbonization, particularly as most countries do not engage in maintaining large armies or high emission operations (e.g., overseas missions). As will be discussed in the Section 4, wide adoption of dual-use decarbonization technologies by the DoD can potentially lower production costs of both incremental and radical innovations, create decarbonization capabilities / expertise that can assist in other economic sectors, and transform national electricity production. Similarly, other countries, in particular allies, can serve as technology diffusion partners as well as additional sources of human and financial capital.

Lastly, the current environment may be able to protect DoD innovation work from accountability-agility dilemmas faced by other public agencies. Firstly, there is a resurgence in industrial policy, specifically oriented towards clean energy technology. Distinct, but related, is a broader energy transition away from fossil fuels, which is changing power dynamics between consumers and producers as well as pushing the military to explore other energy sources under a “national security” narrative. Both of these facilitate agility by relaxing the R&D and market launch cost constraint (i.e., via supply of public funds and demand for new energy technologies). Lastly, the accountability factor for the DoD may potentially become masked as projects are framed as “confidential” due to national security implications, which creates a protective space for peripheral smaller experimental work on dual-use decarbonization technology (i.e., enabling peripheral innovation while centralizing the “capture” of external interests). In fact, in the past, this last enabling condition has allowed the DoD to develop exclusive innovation advantages.

The DoD's Innovation Advantage

In addition to the motives and enabling conditions explained that may favour a DoD-led decarbonization intervention, the DoD has significant experience in successfully disrupting CELS and executing linear missions, in particular during similar geopolitical situations as today. The defense sector can be considered a CELS in its own right given that it exhibits powerful vested interests across all stakeholders (e.g., multiple levels of government, private sector, public citizen support). These interests help the industry resist changes to its business model and reinforce human and financial capital support aimed at sustaining the industry's current cost structures.⁵⁸ From

⁵⁵ World Bank-Macrotrends. “U.S. Military Spending/Defense Budget 1960-2023”. Macrotrends. 2023.

⁵⁶ World Bank-Macrotrends. “Canada Military Spending/Defense Budget 1960-2023”. Macrotrends. 2023.

⁵⁷ Bowcott, H. et al. “Decarbonizing Defense: Imperative and Opportunity”. 2021

⁵⁸ Bonvillian, W. and Weiss, C. “Technological Innovation in Legacy Sectors”. CH8. 2015

established national military academies and training systems to yearly long-term budgeting processes and defense technology contracts, the defense industry generally is “locked-in” to established paradigms. However, while these factors exist, the DoD has also demonstrated that it can disrupt technological paradigms and deliver broader changes across the military-civilian arena.

Via the Defense Advanced Research Projects Agency (DARPA) and related meta-change agents (i.e., actors that can manage internal politics hindering change),⁵⁹ the DoD is able to promote innovation outside of its day-to-day military administration (i.e., a set of peripheral yet contained agencies and actors) along the entire innovation lifecycle (i.e., from ideation to diffusion). The meta-change agents, which can include different DoD civilian and military actors as well as newly created peripheral defense bodies (e.g., the secretary of defense, heads of military departments, etc.), work to override legacy pressures related to capital and embeddedness factors (e.g., by conducting internal lobbying, leveraging inter-ministerial personal connections, etc.).⁶⁰ Examples of DoD-led CELS disruption, in particular to barriers 2, 3, 4, and 5 in Table 1, are the stealth aircraft, precision strike, and unmanned aerial vehicles (UAVs). For these innovations, DARPA funded the R&D of the enabling technology and, via meta-change agents, assisted in finding applications that ultimately became mainstreamed in the military. Using sub-contractors in the defense industry as well as internal DoD prototyping processes such as the Advanced Concept Technology Demonstration (ACTD) process, the change agents within the DoD coordinated testing, advanced development, and procurement in alignment to its needs, resulting in markets for these technologies.⁶¹ That is, the DoD has an established process that leverages multiple stakeholders to disrupt capital and embeddedness factors. More concretely, this process can be broken down into four distinct and subsequent value chain steps covering the innovation life cycle:⁶²

1. *Breakthrough R&D Stage*: The DoD leverages DARPA for mission-led technological breakthroughs, supplementing other traditional R&D agencies within both its sub-contracting list and internal venture capital organizations such as the Army Futures Command (AFC), the National Security Technology Accelerator (MD5), among others.⁶³
2. *Prototyping Stage*: Focused on demonstration and testing, the DoD uses internal services and established process (e.g., ACTD), including its service labs (Federally Funded Research and Development Centers - FFRDC's). This is critical as demonstration and validation enables the DoD to prove that new technologies are able to perform at high standards, thus facilitating commercialization of these technologies in non-defense markets (i.e., the DoD acts as a demanding, high-quality customer).⁶⁴
3. *Manufacturing and Engineering Stage*: the DoD uses internal subcontracting programs that align with DoD development and procurement requirements and systems. Presently, this stage could be considered the DoD's weakest link in its innovation process as the US

⁵⁹ Ibid.

⁶⁰ Ibid.

⁶¹ Bonvillian, W. and Weiss, C. “Technological Innovation in Legacy Sectors”. 2015

⁶² Bonvillian, W., and Van Atta, R. “The DARPA Model for Transformative Technologies,”. CH13. 2020

⁶³ Cross, James. “Department of Defense Emerging Technology Strategy,”. 2019.

⁶⁴ Hourihan, M. and Stepp, M. “Lean, Mean and Clean: Energy Innovation and the Department of Defense”. 2011

industrial production base has become fragmented across many countries. However, as stated above, green industrial policy is aiming to shift manufacturing capabilities to domestic organizations.

4. *Market Creation Stage*: The DoD taps into its service-based procurement programs, including different areas of the military, as it can create new standards and direct purchases in alignment to field requirements. In particular, the DoD uses the Defense Innovation Unit (DIU), as it is exclusively focused on “fielding and scaling commercial technology across the U.S. military at commercial speeds”.⁶⁵ The DoD’s size, in terms of budget and personnel, allows it to determine top-down mandates which create demand (“the military procurement pathway”).⁶⁶ This pathway can enable private actors to develop in the space and obtain productive experience, while driving cost reductions and technology enhancements as they explore other applications (e.g., civil).⁶⁷

The above process has assisted the DoD in disrupting the defense CELS (i.e., providing enabling cost structures, creating markets, breaking down political barriers), yet it is important to consider its unique position within the defense ecosystem. In the energy space, the DoD could historically be categorized as one of the parties with vested interests in fossil fuels given that it powers its operations, domestically and abroad. Given current climate change mandates and rising R&D funding levels for alternative energy sources, the DoD is now in a position to explore decarbonization benefits to the military. This paper is arguing that a *transformational mission* is needed, which implies that the DoD has to upgrade its mission innovation approach towards one that focuses on the grand challenge of decarbonization, leverages additional layers of stakeholders along the entire spectrum of actors and networks, emphasizes technological diffusion using both supply and demand side innovation drivers, and accepts public and private sources of human and capital resources. While these changes may appear challenging, the DoD has in fact already started to adapt its process, and this is particularly present in the energy domain whereby it collaborates with the Department of Energy (DoE), its different offices, and its DARPA-inspired innovation organization, the ARPA-E.⁶⁸ Examples of this collaboration include the DoD’s Project Pele, which stems from collaborations with DoE expertise to license, regulate, develop, and integrate nuclear power in DoD assets (e.g., small modular nuclear reactors potentially used in complex battlefields like the Arctic or deserts).⁶⁹ Similarly, the ARPA-E Battery Storage Partnership is a structured collaboration between the DoD and the DoE that linked two distinct mission-oriented projects aimed at cleantech breakthroughs.⁷⁰ This R&D collaboration focuses on developing microgrids, which use DoE funded technology and DoD military applications and testing processes to develop technology that can reduce facilities’ risks to disruptions in local energy supplies.⁷¹ Similar projects with other departments are also in the DoD’s energy innovation pipeline. With the Department of Agriculture and private company Ocean Power Technologies, for example, the Navy is working

⁶⁵ US DoD. “Department of Defense Plan to Reduce Greenhouse Gas Emissions”. 2023

⁶⁶ Bonvillian, W., and Van Atta, R. “The DARPA Model for Transformative Technologies,”. CH13. 2020

⁶⁷ Hourihan, M. and Stepp, M. “Lean, Mean and Clean: Energy Innovation and the Department of Defense”. 2011

⁶⁸ US DoD. “Department of Defense Plan to Reduce Greenhouse Gas Emissions”. 2023

⁶⁹ Waksman, Jeff. “Project Pele Overview: Mobile Nuclear Power for Future DoD Needs”. 2020

⁷⁰ Hourihan, M. and Stepp, M. “Lean, Mean and Clean: Energy Innovation and the Department of Defense”. 2011

⁷¹ Ibid.

on biofuels and renewable energy systems to decarbonize naval fleets.⁷² The above examples demonstrate that the DoD innovation approach is changing for energy related technology and is quickly adapting to the requirements of *transformational missions*. It also points to yet another DoD advantage, its hyper-connectedness across relevant economic sectors, which positions it as a singular hub able to exert power and autonomy to achieve its defense objectives.

When referencing the DoE, it is common to question whether it can apply the DARPA model to energy innovation and serve as the leading agency to set-up an important decarbonization mission. The DoE's ARPA-E was created to disrupt the energy sector by structuring its work similar to DARPA's management principles.⁷³ While both the DoE and the DoD have innovation agencies and related funding, there remains an important gap in experiences, actor-network relations, strategic imperatives, and ability to create markets. As discussed above, the DoD has significant experience funding and launching dual-use innovations. While it had a unique position in the defense industry, also a CELS, the DoD has also experience creating new technological paradigms through IT related innovations. The DoE, however, faces significant challenges in disrupting the energy CELS as it does not have a proven innovation operating model. ARPA-E is a 2007 creation, initially minimally funded through 2009-2011.⁷⁴ Regarding strategic imperatives, the rise of great power competition positions the DoD at the center of policy priorities, and because the climate-security nexus is gaining relevance as a narrative, it is able to capture benefits from green industrial policies. The DoE, similarly, is likely to benefit from Biden's IRA, yet its ability to make markets is far removed from the DoD's direct access to demand making within its space. That is, the DoD's "military procurement pathway" is a unique tool that enables quick commercialization of proven technologies with dual use potential.⁷⁵ Lastly, the DoE, given its central role in energy markets, is likely to experience an agility-accountability dilemma, which may limit its speed to innovate given its potential capture by political interests.⁷⁶ That is, ARPA-E lacks autonomy, scale, and scope. By contrast, DoD benefits from these three, with scale and scope being given by its size as well as relationships with various multi-domain actors.

Ultimately, for the DoD to make a meaningful market for decarbonization innovation externalities, it needs to formalize efforts as a *transformational mission*. The next sections contain two distinct data-driven exercises demonstrating that, in fact, the DoD has recognized elements of this and has started to make progress on this front. Section 3 quantifies and segments the DoD's GHG emissions into relevant market quadrants for decarbonization, an important first step to inform innovation policy formulation as it relates to market making. Lastly, Section 4 maps the DoD's decarbonization plan relative to transformational mission characteristics and highlights areas of alignment and opportunities.

⁷² Ibid.

⁷³ Bonvillian, W., and Van Atta, R. "The DARPA Model for Transformative Technologies," CH13. 2020

⁷⁴ Ibid.

⁷⁵ Bonvillian, W., and Van Atta, R. "The DARPA Model for Transformative Technologies," CH13. 2020

⁷⁶ Schwaag-Serger, S. "S&T Policymaking in Times of Uncertainty and Crisis," 2020

SECTION 3 – MARKET SIZING: A CARBON DIAGNOSTIC OF THE DOD’s GHG EMISSIONS

To understand how the DoD’s GHG emissions contribute to climate change, both as a driver and as a potential “market” for decarbonization products and services, it is critical to differentiate the sources of emissions. As such, this section will detail the outcomes of a carbon emissions diagnostic and segmentation exercise conducted on the US’s DoD GHG emissions for the year 2021.

GHG Emissions “Market Sizing” Methodology

This data exercise primarily leverages the World Resources Institute GHG Protocol for Corporate Accounting and Reporting Standards. This carbon footprint accounting protocol has been used by the US federal government to publicly report their respective GHG emissions in terms of CO₂ equivalent (CO₂-e) emissions emitted.⁷⁷ This protocol segments carbon footprint across three “scopes”:⁷⁸

- *Scope 1 – Direct GHG Emissions:* Emissions occurring from sources owned by an entity. In the case of defense departments, these typically refer to energy usage for vehicles and other types of transportation for people and equipment.
- *Scope 2 – Electricity Indirect GHG Emissions:* Emissions generated from purchased electricity consumed by the entity (i.e., emissions occur at the facility where electricity is generated, not where it is utilized). For the DoD, these emissions generally encompass purchased electricity for facilities.
- *Scope 3 – Other Indirect GHG Emissions:* Emissions resulting from activities of an entity, yet occurring from other sources not owned / controlled by such entity. The US reports Scope 1 and 2 emissions, as such Scope 3 is not taken into consideration in the analysis.

US federal GHG emission data from Comprehensive Annual Energy Data and Sustainability Performance reports further subdivide Scope 1 and 2 across the following categories: end-sector use and type of operations. End-sector use refers to emissions arising from, for example, buildings, facilities, vehicles, equipment, etc. Conversely, type of operations subcategorizes emissions by standard (related to the day-to-day administrative management of defense departments) vis-à-vis non-standard (related to military or national security operations) emissions.^{79&80}

⁷⁷ WRI and WBCSD. “The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard”. 2004

⁷⁸ Ibid.

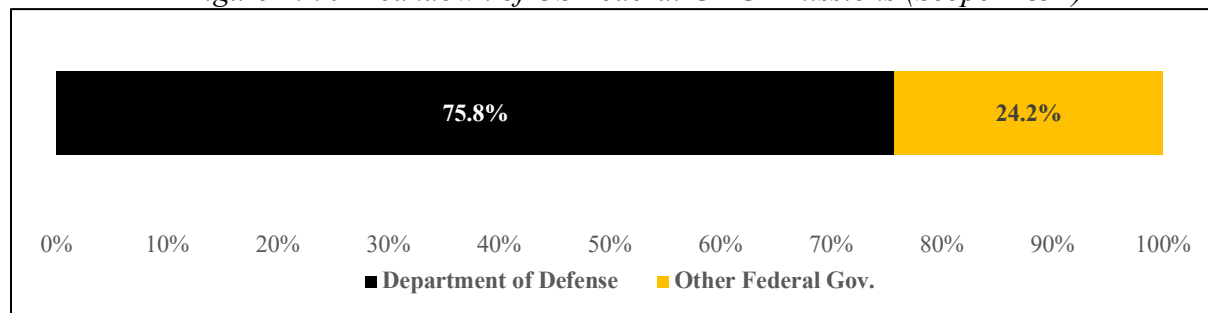
⁷⁹ Centre for Greening Government. “Government of Canada’s Greenhouse Gas Emissions Inventory” 2022

⁸⁰ US Department of Energy. “Comprehensive Annual Energy Data and Sustainability Performance”. 2023

Understanding the DoD's GHG Emissions "Market"

Figure 1 disaggregates total US federal government emissions. In 2021, the US federal government released 66,756 kilotonnes (kt) of CO₂-e, with national security agencies accounting for 70%+ of total emissions.

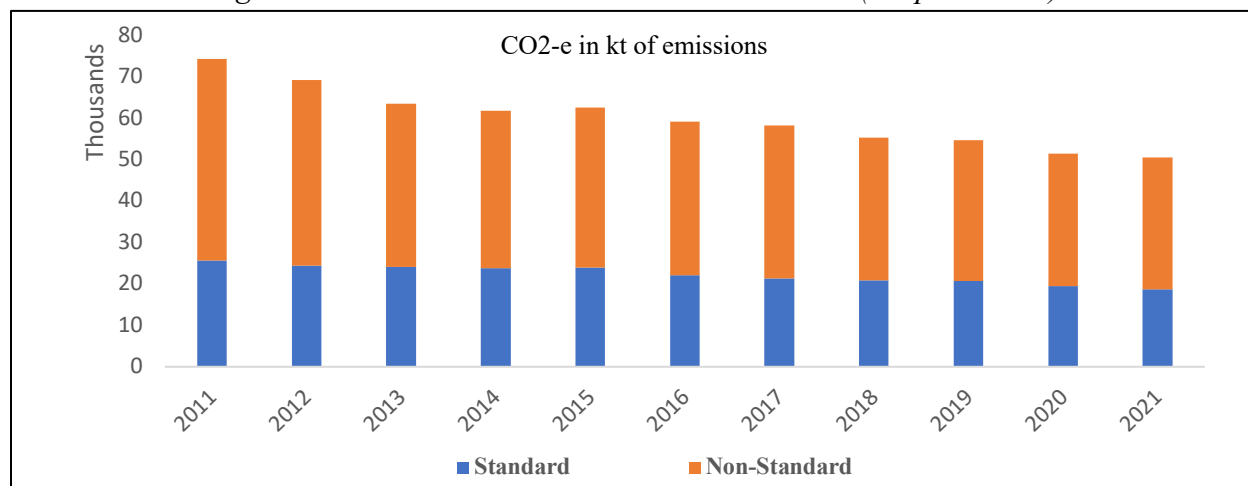
Figure 1: % Breakdown of US Federal GHG Emissions (Scope 1 & 2)



Source: Author's calculations. Data - US Annual Energy Data & Sustainability Performance, 2023

Overall, there appears to be a downward trend in standard emissions in the last decade (see Figure 2 below). In 2021, DoD's standard emissions stood at 73% of its 2011 total. These reductions are a result of projects that have had a larger time span. For example, in the US, the private sector has invested USD\$5.5B over the last ten years on upgrading energy efficiency in DoD installations alone, showcasing high level estimates of the potential size of the defense decarbonization market.⁸¹

Figure 2: US DoD 2011 to 2021 CO₂-e Emissions (Scope 1 and 2)



Source: Author's calculations. Data: US Annual Energy Data & Sustainability Performance, 2023.

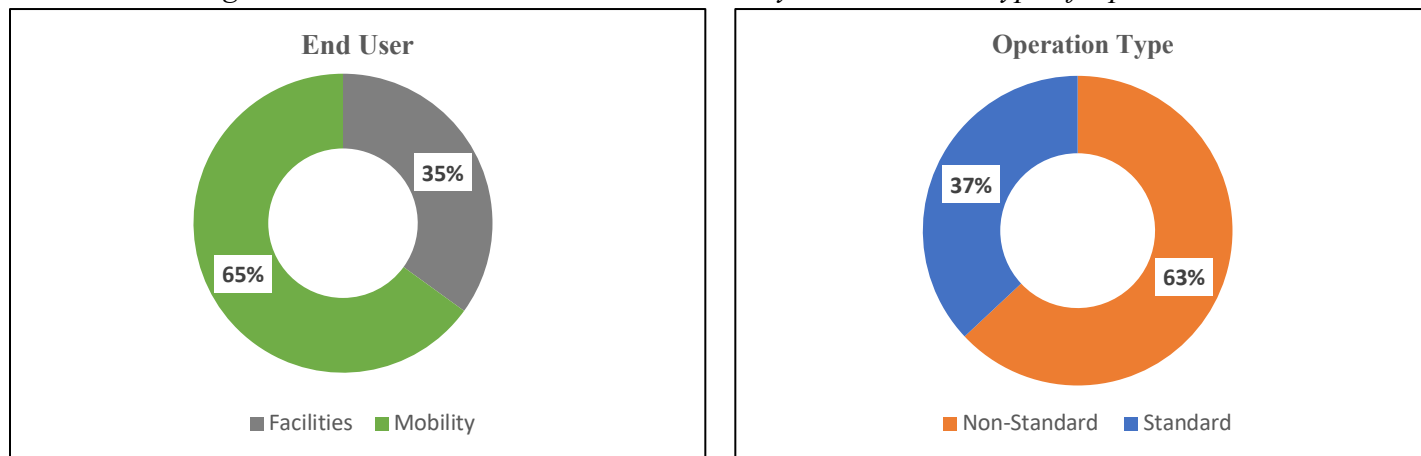
It is evident, however, that the DoD's non-standard emissions (i.e., military operations) are the largest source of CO₂-e. The downward trend is associated largely to a reduction in combat operations in Iraq and Afghanistan, in addition to changes in overall personnel and equipment mobility due to the Covid pandemic.⁸² For example, US personnel in overseas operations

⁸¹ US DoD. "Department of Defense Plan to Reduce Greenhouse Gas Emissions". 2023

⁸² US DoD. "Department of Defense Plan to Reduce Greenhouse Gas Emissions". 2023

decreased by 50% in the last 10 years (450K in 2010 to 221K in 2020).⁸³ Given the rise of strategic power competition, the potential need to enhance power projection, and the current dynamics of the Russian war of aggression in Ukraine, emissions from non-standard operations may rise again in the next decade unless military mobility experiences an accelerated rate of decarbonization.

Figure 3: US's DoD 2021 CO₂-e Emissions by End User and Type of Operations



Source: Author's calculations. Data - US Annual Energy Data & Sustainability Performance. 2023

Figure 3 provides a snapshot of current state breakdown of the DoD's emissions by end user and operation type. Facilities represent less than 40% of total emissions, yet the opportunity for decarbonization could still be significant. For example, the DoD's portfolio includes 284,000 buildings, requiring USD \$3.3B in expenditures to provide power, heating, and cooling.⁸⁴ This amount is spent on purchased electricity and stationary combustion of fossil fuels, which comprise 95% of scope 1 and 2 emissions for DoD's facilities. Conversely, mobility (60%+ of the DoD's emissions) is the critical enabler of military and defense operations, and refers to the use of aircrafts, ships, tactical vehicles, contingency bases, etc. In 2021, the US Airforce drove 56% of emissions, followed by the Navy (31%). When disaggregating by fleet type, however, aircrafts represent 76% of emissions, followed by ships (17%).⁸⁵ If air operations are to be maintained in similar numbers, jet fuel decarbonization is likely to become an area where both incremental and radical innovation will be needed.

A Market Segmentation Proposal for Defense Departments

The above analysis demonstrates that while the market for decarbonizing defense is vast in terms of total size of emissions, different subsectors of defense have different decarbonization requirements. This paper proposes a market segmentation that jointly considers types of operations and end-users. Each market quadrant is characterized by types of assets to decarbonize, which in turn result in several different decarbonization considerations that can affect future positive innovation externalities (see Table 4):

⁸³ IMCCS. "Decarbonized Defense:,". 2022

⁸⁴ US DoD. "Department of Defense Plan to Reduce Greenhouse Gas Emissions". 2023

⁸⁵ Ibid.

- Quadrant 1 – Facilities / Std. Ops.: Administrative buildings, within-national-border bases
- Quadrant 2 – Mobility / Std. Ops.: Administrative department vehicle fleets (e.g., cars)
- Quadrant 3 – Facilities / Non Std. Ops.: Infrastructure in foreign countries (e.g., camps)
- Quadrant 4 – Mobility / Non Std. Ops.: Aircraft, ships / vessels, tanks, other land vehicles

Table 4: US DoD 2021 GHG Emissions – Proposed Market Quadrants

<i>End-User / Type of Operation</i>	Facilities	Mobility	TOTAL
Standard Ops	<i>Quadrant 1</i> 17,399 kt (34.4%)	<i>Quadrant 2</i> 1,297 kt (2.6%)	37%
Non-Standard Ops.	<i>Quadrant 3</i> 287 kt (0.5%)	<i>Quadrant 4</i> 31,586 kt (62.5%)	63%
TOTAL	35%	65%	100%

Source: Author’s calculations and analysis

Given their relative sizes, Quadrants 1 and 4 are likely to represent the critical R&D areas of focus for both incremental and radical decarbonization innovations. These are explored more in-depth in the next section, where the DoD’s decarbonization plan is evaluated relative to transformational mission features and a perspective on innovation externalities is provided.

SECTION 4 – ASSESSING THE DOD’S DECARBONIZATION PLAN

The DoD launched its inaugural decarbonization plan in 2023 as mandated by the National Defense Authorization Act and Executive Order 14057 to engage in GHG reductions.⁸⁶ In line with this, the DoD submits a report to Congress, and its Secretary is due to provide annual briefings on progress to the Committee on Armed Services of the House of Representatives and the Senate. Using the transformational mission definition and features outlined in Section 1, this section aims to build an evaluation framework and apply this framework to the 2023 Department of Defense Plan to Reduce Greenhouse Gas Emissions (hereon “the DoD’s Plan” or “the Plan”). In applying this framework, the objective is to evaluate the extent to which the DoD’s Plan conforms with transformational mission characteristics and identify relevant gaps / opportunities. In a subsequent related analysis, the Plan will be evaluated in relation to the identified DoD GHG emission quadrants, specifically quadrants 1 and 4, to understand DoD progress to date and future challenges that may be faced regarding making markets for different types of innovations.

Methodological Considerations

Both the transformational mission mapping exercise and quadrant progress assessment are conducted using publicly available information from the DoD’s Tackling the Climate Crisis centralized website. Sources analyzed include only published reports since the release of Biden’s Executive Order (EO) 14008 “Tackling the Climate Crisis at Home and Abroad”, which comprise of the DoD’s Plan, Climate Adaptation Plan, Climate Risk Analysis, as well as the Army, Navy, and Air Force’s independent climate action plans and strategies released in 2022. That is, future research should consider testing such findings against other sources of data, including stakeholder consultations within different sectors (e.g., public, private, academia). The mapping exercise is summarized in Table 5, which includes high-level evidence per transformational mission feature analyzed. The ensuing analysis section highlights broader patterns and vulnerabilities that, while at the very least meriting further investigation, demonstrate areas for reformative action.

⁸⁶ US DoD. “Department of Defense Plan to Reduce Greenhouse Gas Emissions”. 2023

Table 5: Mapping the DoD's 2023 Decarbonization Plan vis-à-vis Transformational Mission Characteristics

TM FEATURE	CRITERIA	COMMENTARY ON EVIDENCE
Strategic Orientation	Broad challenge definition	The DoD's latest broad decarbonization challenge definition exists as a result of (1) President Biden's Executive Order (EO) 14008, establishing that addressing the climate crisis will be "at the center" of US foreign policy and national security and (2) Section 323(a) of the National Defense Authorization Act requiring the DoD to submit a decarbonization plan. However, there is a long history of statutory requirements and executive orders since 1995 that have guided DoD decarbonization activities in the past. Presently, the broad challenge is defined by EO 14057, which sets the goal of a net-zero economy by mid-century, with different US federal departments setting evolving targets as more data and technology becomes available. As of the DoD's latest plan, the department has not set out a specific internal target and highlights that it anticipates receiving target-setting guidance in the calendar year 2023.
Legitimacy	Multi-stakeholder buy-in	As evidenced by decarbonization plans and rise of green industrial policies both in the US and abroad, coupled with civil society pressure (e.g., see NGO presence in UNFCCC COPs), there appears to be multistakeholder buy in to tackle the reduction of GHG emissions, thus providing legitimacy for action to different actors. In the case of the US, there are at least three different federal working groups involving multiple stakeholders, incl. White House Office of Domestic Climate Policy, National Climate Task Force, and the White House Environmental Justice interagency Council, all of which involve the DoD as a key contributor. Per the plan, the DoD has its own Climate Working Group with different defense and energy public sector bodies participating.
Economic Model	Presence of supply and demand side support factors	In addition to the DoD's budget size and appropriations from US green industrial policy supporting the funding of inventions, the DoD's plan specifically makes reference to "leveraging all sources of funding, including third-party financing and appropriated funds, to rapidly deploy proven technologies". This suggests that diffusion is widely supported, at least within the Defense sector. Similarly, for several decarbonization initiatives, the plan highlights that the DoD intends to test and demonstrate decarbonization offerings as they develop, which helps foster diffusion feedback loops as these tests garner interest from different defense related private and public parties. For example, on zero-emission vehicles (ZEVs), the plan stipulates that the DoD will "continue to provide a demand signal to the industry to develop medium- and heavy-duty ZEV", enabling market creation.
Participant Intensity	Work is centered around multi-domain stakeholders	Participant intensity appears to be high, with multiple public sector departments outlined, including internal DoD agencies, as well as references to "private industry" along specific innovation initiatives.
Change Environment	Efforts target regime destabilization and generation	The outlined Federal and DoD-wide challenge is one that targets a new socio-technical frontier (i.e., shift from fossil fuels may change power dynamics, industry structures, transmission and distribution of electricity, new industries, changes to incumbents' business models, etc.). The DoD's decarbonization plan is linked to Federal emission targets, as such the plan targets regime generation and destabilization, although to different extents and directionality.

TM FEATURE	CRITERIA	COMMENTARY ON EVIDENCE
Innovation Intensity	Efforts target one / few vs many technologies	The plan focuses on the development of many different technologies covering a wide range of assets, including innovations for reducing installation energy demand (e.g., improving GHG data availability and upgrading efficiencies), scaling clean energy solutions for installation energy (e.g., pursuing ZEV vehicles and charging infrastructure), reducing operational energy demand (e.g., improving propulsion fuel usage on water and air mobility assets), and extending operational energy substitutes (e.g., alter assets and infrastructure to enable use of low-carbon fuels).
Disruption Level	Efforts target radical and incremental inventions	
Diffusion Focus	Diffusion / commercialization goals are outlined	The plan has both explicit and implicit goals of innovation diffusion, from standard setting (e.g., aligning assets to commercially approved sustainable aviation fuels to ensure these technologies enter global supply chains, setting interagency partnerships for electric vehicle support equipment and energy storage, etc.) to commercialization (e.g., engaging the Defense Innovation Unit to field and scale technology across the US military at commercial speeds, sponsoring R&D for dual-use commercial technologies in the energy domain).
Funding	Public & private sources are mobilized	A detailed list of policy instruments, including sources of funding, procurement, commercialization agencies, regulations, grants, etc., is not explicitly provided within the Plan. However, since Biden's EO, the DoD has developed and published 8+ climate crises, decarbonization, and adaptation documents highlighting areas of policy focus, expenditures and funding of different sizes, procurement efforts, climate monitoring technology deployment, etc. In fact, three out of six branches of the US Armed Forces, specifically the Army, the Navy, and the Air Force, have published independent Climate Action reports with 2030 targets accompanied by policy measures and mechanisms. While not all of these target decarbonization, there are a large number of initiatives linked to GHG emissions reduction, with subsequent market making implications for decarbonization technologies. Similarly, regulatory changes and mandates have been imposed on the DoD for decarbonization since 1995, with and over 25 laws, statutes, and EOs issued in the last 20 years. However, it was not until 2021 that climate change was linked to foreign and national defense policy, which has driven change momentum.
Policy Portfolio Mix	Encompasses a diverse set of policy instruments	
Governance	Complex (vertical & horizontal) and distributed	These features are complex to measure given a lack of supporting publicly available information on internal governance and evaluation processes. However, it appears that key performance indicators, where available, and reporting roll-up vertically with limited mention of horizontal prioritization or decision making. Given the top-down nature of military organizations, even when enabled by working groups and joint task forces, the governance of the decarbonization plan is likely primarily vertical and centralized. The evaluability of the Army, Navy, and Air Force plans appears to be summative instead of formative, that is, focused on specific targets and outcomes. The larger DoD Decarbonization Plan, however, does mention that global targets are likely to evolve as better data is captured and as technology evolves.
Evaluability	Existence of feedback loops / continuous progress orientation	

Sources: Author's compilation and analysis from: (1) US DoD "Department of Defense Plan to Reduce Greenhouse Gas Emissions", 2023; (2) Department of the Air Force "Climate Action Plan", 2022; (3) Department of the Army "US Army Climate Strategy", 2022; (4) Department of the Navy "Climate Action 2030", 2022.

Analysis – Is the DoD’s Plan Structured as a Transformational Mission?

Alignment Areas

The DoD’s Plan, at a high level, appears to exhibit most transformational mission features, either fully or with some variations. This demonstrates a shift in thinking from the past three decades. While multiple laws, statuses, and EOs have been enacted discussing the relevance of energy efficiency, climate change adaptability, and decarbonization, policy frameworks and direction from the last two years have broadened the rationale for change and introduced an imperative to tackle decarbonization via a multi-stakeholder and multi-technology approach. From a *Strategic Direction* perspective, a Federal-wide directional challenge exists, even if the DoD has not set specific targets since the EO was signed. The broad direction provided by the DoD in its plan and to the different branches of the US Armed Forces has resulted in branch-specific actions and related key performance indicators.

The *Economic Model* feature can be ranked as the most advanced aspect of the DoD’s plan relative to transformational missions, which may be due to the “military procurement pathway” explained in Section 2. Throughout the document, the DoD highlights the areas where it could both enable market making and take advantage of supply side measures. The plan also differentiates between energy end-users (i.e., facilities and installations vs. mobility and operational energy use). The two end-users identified within the plan generally align with the decarbonization quadrants identified in Section 3. Along these two, the plan alludes to market making efforts by articulating a high-level list of DoD innovations which signals to other stakeholders about demand for both innovation and consumption. More importantly, the plan has a discrete section on "Technology Innovation and Adaptation", directly discussing the DoD’s innovation ecosystem. This section covers the DoD's different internal innovation enablers, including coordinating and funding work with external public and private sector stakeholders, setting standards for environmental security certifications, explaining its internal innovation units and their decarbonization research, and describing its interactions with the DoE's ARPA-E and other organizations. Given this supporting economic model, the DoD’s Plan also has a stated *Diffusion Focus*, albeit primarily within the defense sector. Its diffusion focus is structured such that it aims to commercialize new technologies while at the same time adopting commercial inventions and standards, which enhance existing markets for incremental innovations. While categorized as an aligned feature, its defense sector focus potentially represents an opportunity area as well, particularly if the DoD spends taxpayer capital on R&D that leads to limited dual-use technology.

The plan’s *Innovation Intensity, Disruption Levels, and Change Environment* are interrelated. By targeting multiple incremental and radical innovations, the DoD’s plan is both destabilizing the energy sector and potentially generating new paradigms. The implications, however, are likely to be long-term, as diffusion of these technologies need to penetrate civilian applications in order to fully affect all innovation inhibiting barriers characteristic of CELS.

Opportunity Areas

Legitimacy appears to exist, particularly across public sector stakeholders. However, limited reference is made to specific private industry actors, academia, or civil society within the DoD's Plan, which may affect legitimacy of focus areas (e.g., certain innovations may not be applicable to civilian domains or diffusion of results could be delayed if other stakeholders' input is not appropriately considered). This can be contemplated as an area for improvement if the DoD wants to realign its plan towards a defined transformational mission. However, it is clear the department's focus is national security and, as such, other network enhancing measures could be put in place to improve ecosystem linkages (e.g., adding late stage actor involvement for dual-use considerations). Separate yet relatedly, while the *Participant Intensity* of the DoD's Plan is high, there is not an explicit nor high-level section outlining actor-network clusters or work packages which may limit external collaboration interest. Nonetheless, this may assist with the outlined accountability-agility dilemma as it enables the capture of political interests by the DoD. Stakeholder validation sessions could corroborate if an internal comprehensive network document or process exists to fill this gap.

The complexity in identifying and validating the extent of the *Funding and Policy Portfolio Mix* features within the DoD's Plan raises strategic communication and demand signaling concerns. This paper is not assessing whether or not the sources of funding or policy instruments available are sufficient and adequate, but rather argues that the plan exhibits weaknesses with regards to ensuring that public, private, academia, and civil society actors are aware of market opportunities. Without explicit annexes covering the list of instruments, it can be complex for prospective participants to understand the incentives available to assist in the financing, R&D testing, procurement, and commercialization of innovations. However, in alignment with the previous accountability-agility argument, it is possible that other communication mechanisms exist that enable the DoD to overcome bureaucratic reporting that may otherwise slow progress.

Lastly, the analysis suggests that the Plan's *Governance* and *Evaluability* features represent the most critical alignment opportunity areas. Transformative missions require multi-stakeholder participation, which in turn places challenges on governance. It is clear that, while the plan is owned by the DoD, its delivery relies on multiple public and private sector participants. As such, leading actors, in this case the DoD, need to design appropriate management frameworks to evaluate outcomes. Similarly, in addition to managing the challenges of distributive governance, the DoD needs to consider building the necessary capabilities to evaluate progress towards such outcomes (e.g., providing directionality, coordination, etc.). While the DoD's Plan appears to be lacking specific targets relative to the plans from its individual Armed Forces, it presents goals in a more formative rather than summative manner as exemplified by having moving-intermediate targets depending on data availability - although this could be political instead of purposefully formative. The objective of formative evaluations is to capture systems change as they progress and the DoD's Plan fails to mention any methodological approach, particularly on diffusion, on how incremental and radical innovations are altering energy paradigms. Ultimately, for the DoD to enact a working transformational mission, it would require internal experimentation with novel governance and evaluation models.

Analysis – DoD progress to date relative to its GHG Emissions’ “Market”

In addition to the above analysis, the DoD’s plan provides details of its portfolio of initiatives to target emissions from facilities to mobility sources. The below briefs on the DoD’s decarbonization initiatives focus on quadrants 1 and 4 due to the size of their associated emissions (97% of total 2021 DoD GHG emissions). Progress along these quadrants suggest areas where potential incremental and radical innovation externalities may arise, which in turn signal to incumbents about opportunities for involvement within the innovation value chain (i.e., from R&D funding to commercialization and market opportunities).

Quadrant 1 (Facilities in Standard Operations)

Reducing standard facilities emissions generally do not constrain the operational capabilities of militaries, contributing to the currently high defense decarbonization focus on this area. For Quadrant 1, standard facilities’ emissions are being targeted by a combination of footprint optimization / reduction projects, efficiency upgrading efforts, and cleaner electricity purchases. Presently, contracts totalling to USD \$1.3B are being reviewed for 2023 deployment focusing on energy efficiency of buildings and infrastructure.⁸⁷ Moreover, purchasing plans and methods are being drafted and analyzed to ensure DoD transitions its electricity use to 100% carbon free electricity (CFE) by 2030 (approx. 60% of standard facilities emissions are derived from purchased electricity).⁸⁸ This suggests that the DoD is already engaging in market making for CFE and is delivering this via centralized financing and procurement mechanisms.

This quadrant’s challenge, however, is that for these decarbonization initiatives to fully affect the defense system, all electricity sources will have to come from “cleaner” utility providers, thus leaving the responsibility to decarbonize outside of defense departments’ scope of control. The market opportunities are then clear: defense departments should (1) incentivize electricity providers to decarbonize their energy supplies, for example by using public tenders to purchase green electricity;⁸⁹ (2) invest in improving energy efficiency or carbon neutral / negative technologies for on-site decarbonization; and (3) develop climate change adaptation and mitigation infrastructure upgrades (e.g., higher resiliency, carbon data tracking and monitoring, etc.). These dual-use technologies, in turn, can have broader civilian impacts, by potentially lowering the costs of production of technologies, creating decarbonization capabilities / expertise that can assist in other economic sectors, and transforming national electricity production.

Quadrant 4 (Mobility in Non-Standard Operations)

The preliminary diagnostic demonstrated that non-standard mobility emissions represent 60%+ of the DoD’s yearly emissions, and these are mostly driven by fuel usage for aircraft and, to a lesser extent, power vessels and land-based vehicles. Decarbonizing this quadrant will likely require radical innovations in fuel and fuel efficiency, as transportation is inherently linked to military operational success and vulnerabilities management. The US has started to target energy efficiency and operational practices as an initial way to reduce emissions. These include improving

⁸⁷ US DoD. “Department of Defense Plan to Reduce Greenhouse Gas Emissions”. 2023

⁸⁸ Ibid.

⁸⁹ IMCCS. “Decarbonized Defense;”. 2022

approaches to airlifts, refueling, and engine upgrades to decrease fuel burn, among others. For example, the Air Force’s automated planning tool has helped advance the efficiency of aerial refueling to meet mission requirements, reducing aviation fuel use by approximately 180,000 gallons per week.⁹⁰ Additional areas of research are highlighted, particularly with identifying and scaling operational energy substitutes. Currently, liquid fuels (e.g., gasoline), still present the best energy density. This is incentivizing DoD’s R&D efforts to focus on other battery and hydrogen technologies as well as other alternative fuels (e.g., bio or synthetic fuels). In efforts to ensure dual-use market functionality, this research is also testing for the compatibility of alternative fuels with DoD equipment, enabling local purchases through current supply chain partners and amplifying the size of markets.⁹¹ Other decarbonization areas include electrification of tactical vehicles, sea systems, and air systems (e.g., unmanned aerial vehicles – UAVs). Lastly, DoD is aiming to test the results of its Project Pele initiative by the end of 2024, which was directed at testing, building, and commercializing small modular nuclear reactors to support DoD operations.

Decarbonization efforts in this market quadrant remain at a nascent stage, with the DoD enabling a wide portfolio of research initiatives to ensure that energy efficiency, fuel substitution, financial viability, and operational effectiveness requirements are considered. Quadrant 4 represents the largest “market” for decarbonization, where both incremental and radical innovations will be needed. The goal of reaching net-zero by 2050 for the US federal government, in conjunction with a global power race for dominating emerging technology markets, could spur the necessary dual-use innovations.

Ultimately, from a technology standpoint, the potential path to decarbonizing standard facilities emissions appears to be feasible and attainable in a shorter period of time. The more complex challenge will be the decarbonization of mobility related assets and equipment. These efforts will need cross-domain R&D collaboration, multi-sector diffusion, and effective use of established and nascent public-private partnerships, all of which are core initiatives associated with broader transformational missions.

⁹⁰ US DoD. “Department of Defense Plan to Reduce Greenhouse Gas Emissions”. 2023

⁹¹ Ibid.

SECTION 5 – SYNTHESIS OF CONTRIBUTIONS AND LESSONS LEARNED

To mitigate the severe impacts of climate change, there must be heightened efforts in the research, development, demonstration, commercialization, deployment, and adoption of clean energy technologies. This paper argued that disrupting the energy sector, where particular capital and embeddedness factors act as innovation barriers, sits at the core of the global decarbonization challenge. To tackle this, transformational missions are proposed, with the public sector adopting a more significant role in planning and execution of missions. This, however, brings formidable execution challenges. As such, this paper suggests that a potential solution to managing the complexities of public sector entrepreneurship is to place defense departments at the center of the decarbonization mission, in particular the US DoD. These dynamics are synthesized below as four core research contributions:

1. Findings on CELS and missions are consistent with research on mobilizing innovation for sustainability transitions. Problems associated with transformational change should not be attributed to lack of talent and resources, but rather how these assets are mobilized.⁹² Policy makers have an opportunity to set clear direction and shape the sustainability transition as an opportunity (i.e., non zero-sum). This could help foster multi-actor long-term commitment to mobilizing and engaging in the transition.⁹³ To effectively disrupt CELS, numerous different levers are likely to be required in policy responses, including knowledge, finance, institutions, and consumer demand. As such, holistic policy making needs to consider the end-to-end innovation value chain. Lastly, to match the scale of the challenge related to decarbonizing and transforming energy, appropriate governance and innovation in governance should be taken into account. These considerations give rise to the main theoretical contribution of this paper: mission-oriented innovation policies can be segmented into two distinct types, linear vs transformational, with sustainability related transitions matching the policy requirements of transformational missions.
2. Supporting the need for public sector intervention in the form of a transformational mission and, more specifically, to unlock the public sector's market making abilities for decarbonization, this report proposes that defense departments can be the engine and first movers in organizing such missions. That is, the second contribution of this paper is the synthesis and contextualization of the DoD's unique motives and present enabling conditions which, coupled with its innovation management advantages, serve as a business case for the US DoD to be central in tackling the climate crisis. The current strategic power competition places the *climate – energy security – technology* nexus at the center. By focusing firstly on military technologies related to decarbonization, the US can manage internal and external audiences while continuing to defend its technological primacy in this multipolar world. This approach could help foster dual-use innovations with the potential to transform global decarbonization efforts.

⁹² Fagerberg, Jan. "Mobilizing innovation for sustainability transitions,". 2018

⁹³ Ibid.

3. The third contribution is the build-out and application of a transformational mission evaluation framework, which can be further refined and leveraged for similar research in the future. Using the evaluation framework, the DoD's Plan was assessed for its level of alignment to transformational mission features. The analysis demonstrated that the plan's economic model aspect is notably advanced, emphasizing market facilitation and supply-side measures while focusing on the diffusion of both incremental and radical innovations. Conversely, three opportunity areas are worth highlighting. While legitimacy exists among public sector stakeholders, limited reference to private industry, academia, and civil society may impact dual-use relevance. Enhancing ecosystem linkages and late-stage actor involvement could address this, if adverse impacts to the DoD's autonomy and flexibility are minimized. More importantly, the Governance and Evaluability features potentially require re-design. The plan failed to make reference to specific targets, approaches to monitor multi-stakeholder participation, and a methodological approach for evaluating incremental and radical innovations' impact on energy paradigms.
4. The analysis of the DoD's Plan, augmented with the GHG emissions market quantification and segmentation, enables a high-level externalities foresight exercise. Decarbonization efforts along two quadrants could result in civilian-use innovations. The DoD focuses on reducing standard facilities emissions through the application of incremental innovations. The DoD is already enabling the diffusion of these innovations by opening its internal market and also by assisting in creating economies of scales for producers of these technologies. In the case of non-standard mobility emissions, radical innovations will be needed which in turn will require the DoD to engage different networks and actors across earlier stages of the innovation lifecycle. Successful mobility decarbonization may result in low-carbon or no-carbon fuels, advancements in nuclear energy, and market making for electric vehicle and related infrastructure.

Given the above, several future areas of research emerge that are worth exploring. Firstly, research should delve into the nuances of innovation in governance and the politization of innovation to understand the extent to which these missions can pragmatically match the scale of the decarbonization challenge as well as disrupt other CELS (i.e., how does the theory work in practice). Additionally, refinements to mission evaluation frameworks, in particular transformational missions, offer a fertile ground for ongoing research. Lastly, comparative studies (e.g., US, China, and EU defense decarbonization approaches) and stakeholder consultations could add depth to the data presented herein and assist in better defining the potential role defense departments can play in innovation ecosystems, particularly within diffusion. Given the world's collective journey towards a sustainable future, these research avenues could be instrumental in shaping effective policies and strategies for global decarbonization.

WORKS CITED

- Abdmouleh, Alammari, and Gastli. “Review of policies encouraging renewable energy integration & best practices”. *Renewable and Sustainable Energy Reviews* Volume 45. February 2015. <http://dx.doi.org/10.1016/j.rser.2015.01.035>
- Allan, B., Lewis, J., and Oatley, T. “Green Industrial Policy and the Global Transformation of Climate Politics”. *Global Environmental Politics - MIT*. November 2021. https://doi.org/10.1162/glep_a_00640
- Bergek, A., Berggren, C., Magnusson, T., Hobday, M. “Technological discontinuities and the challenge for incumbent firms: destruction, disruption or creative accumulation?” *Res. Policy* 42, 1210–1224. 2013.
- Breznitz, D. and Ornston, D. “The politics of partial success: fostering innovation in innovation policy in an era of heightened public scrutiny”. *Socio-Economic Review* Volume 16. September 2018. <https://doi.org/10.1093/ser/mww018>
- Bonvillian, W., and Van Atta, R. “The DARPA Model for Transformative Technologies: Perspectives on the US Defense Advanced Research Projects Agency – Ch13 Arpa-E and DARPA”. *Open Book Publishers*. 2020. <https://doi.org/10.11647/OBP.0184.13>
- Bonvillian, W. and Weiss, C. “Complex, Established “Legacy” Sectors – The Technology Revolutions That Do Not Happen”. *Innovations: Technology, Governance, Globalization*. 6 (2): 157–187. 2011. doi: https://doi.org/10.1162/INOV_a_00075
- Bonvillian, W. and Weiss, C. “Technological Innovation in Legacy Sectors”. *New York; online edn, Oxford Academic*. August 2015. <https://doi.org/10.1093/acprof:oso/9780199374519.001.000>
- Bowcott, H., Gatto, G., Hamilton, A. and Sullivan, E. “Decarbonizing Defense: Imperative and Opportunity”. *McKinsey*. 2021. <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/decarbonizing-defense-imperative-and-opportunity>.
- Centre for Greening Government. “Government of Canada’s Greenhouse Gas Emissions Inventory.” Treasury Board of Canada Secretariat. Nov 2022. <https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/government-canada-greenhouse-gas-emissions-inventory.html>
- Crawford, Neta. “Pentagon Fuel Use, Climate Change, and the Costs of War”. *Watson Institute & Costs of War Project*. June 2019.
- Crawford, Neta. “The Pentagon, Climate Change, and War. Charting the Rise and Fall of U.S. Military Emissions”. *Penguin Random House*. 2022.
- Cross, James. “Department of Defense Emerging Technology Strategy: A Venture Capital Perspective”. *Acquisition Research Program – Naval Post-Graduate School*. 2019. www.acquisitionresearch.net

Department of National Defence. “Defence: Energy and Environment Strategy – Harnessing energy efficiency and sustainability: Defence and the road to the future 2020-2023”. *Government of Canada – National Defence Reports and Publications*. 2020.

https://www.canada.ca/content/dam/dnd-mdn/images/dees2020/2020-23%20Defence%20Energy%20and%20Environment%20Strategy_EN%20-%20Signed.pdf

Department of the Air Force. “Climate Action Plan”. *US Department of Defense*. October 2022.

Department of the Army. “US Army Climate Strategy”. *US Department of Defense*. February 2022.

Department of Defense. “Executive Order 14008 – Tackling the Climate Crisis at Home and Abroad”. *US Department of Defense*. 2020.

Department of the Navy. “Climate Action 2030”. *US Department of Defense*. May 2022.

Edquist, C., Zabala-Iturriagagoitia, J.M., Barbero, J., Zofio, J.L. “On the meaning of innovation performance: Is the synthetic indicator of the Innovation Union Scoreboard flawed?” *Res. Eval.* 27, 196–211. 2018. <https://doi.org/10.1093/reseval/rvy011>

EESI. “Fact Sheet | Fossil Fuel Subsidies: A closer Look at Tax Breaks and Societal Costs”. *Environmental and Energy Study Institute*. July 2019. <https://www.eesi.org/papers/view/fact-sheet-fossil-fuel-subsidies-a-closer-look-at-tax-breaks-and-societal-costs>

European Parliament. “EU’s response to the US Inflation Reduction Act (IRA)”. *EU Parliament Briefing – ECON Committee*. June 2023.

[https://europarl.europa.eu/RegData/etudes/IDAN/2023/740087/IPOL_IDA\(2023\)740087_EN.pdf](https://europarl.europa.eu/RegData/etudes/IDAN/2023/740087/IPOL_IDA(2023)740087_EN.pdf)

Fagerberg, Jan. “Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy”. *Research Policy* Volume 47. August 2018.

<https://doi.org/10.1016/j.respol.2018.08.012>

Favaro, M., Renic, N., Kuhn, U. “Negative Multiplicity: Forecasting the Future Impact of Emerging Technologies on International Stability and Human Security”. *Institute for Peace Research and Security Policy*. September 2022.

Foray, D., Mowery, D.C., Nelson, R.R. “Public R&D and Social Challenges: what lessons from mission R&D programs?”. *Res. Policy* Volume 41, 1697-1702. 2012.

Freeman, C. “The economics of technical change”. *Camb. J. Econ.* 463–514. 1994.

Hekkert, M., Matthus, J., Wesseling J., Negro, S. “Mission oriented innovation systems”. *Environmental Innovation and Societal Transitions* Volume 34: 76-79. May 2020.

<https://doi.org/10.1016/j.eist.2019.11.011>

Heyen, Dirk. “Governance of exnovation: phasing out non-sustainable structures”. *Oeko-Institut Working Paper – Institute for Applied Ecology*. 2017. www.oeko.de/fileadmin/oekodoc/WP-Exnovation-EN.pdf

Hourihan, M. and Stepp, M. “Lean, Mean and Clean: Energy Innovation and the Department of Defense”. *The Information Technology and Innovation Foundation*. March 2011.

IMCCS – International Military Council on Climate and Security. “Decarbonized Defense: The need for clean military power in the age of climate change”. *The World Climate Security Report* 2022. June 2022. https://www.clingendael.org/sites/default/files/2022-06/Decarbonized_Defense_World_Climate_and_Security_Report_2022_Vol._I.pdf

Kemp, R., Loorbach, D., Rotmans, J. “Transition management as a model for managing processes of co-evolution towards sustainable development”. *Int. J. Sustain. Dev. World Ecol.* 14, 78–91. 2007.

Kivimaa, P., and Kern, F. “Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions”. *Research Policy* Volume 45. October 2016. <http://dx.doi.org/10.1016/j.respol.2015.09.008>

Kuhlmann, S., Rip, A. “The challenge of addressing Grand Challenges”. *EU Commission*. September 2014.

Laatsit, M., Grillitsch, M., Funfschilling, L. “Great expectations: the promises and limits of innovation policy in addressing societal challenges”. *Centre for Innovation Research – Lund University – Papers in Innovation Studies no. 2022/09*. September 2022. <http://www.circle.lu.se/publications/>

Mazarr Michael; Frederick, Bryan; Crane, Yvonne. “Understanding a New Era of Strategic Competition”. *RAND Corporation*. 2022. https://www.rand.org/content/dam/rand/pubs/research_reports/RRA200/RRA290-4/RAND_RRA290-4.pdf

Mazzucato, Mariana. “From market fixing to market-creating: a new framework for innovation policy”. *Industry and Innovation*, Volume 23 (2): 140-156. May 2016. <https://doi.org/10.1080/13662716.2016.1146124>

Mazzucato, Mariana. “Mission economy. a moonshot guide to changing capitalism.” *London: Allen Lane*. 2021

Mazzucato, M. and Penna, C. “Mission-Oriented Finance for Innovation: New Ideas for Investment-Led Growth”. *Rowman & Littlefield*, London. 2015.

Mazzucato, M. and Semieniuk, G. “Public financing of innovation: new questions”. *Oxford Review of Economic Policy*, Volume 33 (1): 24–48. 2017 <https://academic.oup.com/oxrep/article/33/1/24/2972707/Publicfinancing-of-innovation-new-questions>

Mendoca, Van Aduard de Macedo-Soares, and Vinicius de A. Fonseca. “Working towards a framework based on mission-oriented practices for assessing renewable energy innovation policies”. *Journal of Cleaner Production* Volume 193. May 2018. <https://doi.org/10.1016/j.jclepro.2018.05.064>

Mowery, D.C. “Defense-related R&D as a model for “grand challenges” technology policies”. *Res. Policy* Volume 41, 1703-1715. 2012.

NATO Press. “Signing Ceremony of Climate change Centre of Excellence”. NATO. July 2013. https://www.nato.int/cps/fr/natohq/photos_217003.htm

Nelson, R.R., Winter, S.G. “An Evolutionary Theory of Economic Change”. *Harvard Business School Press*, Cambridge, MA. 1982.

OECD Science, Technology, and Industry. “The Design and Implementation of Mission-oriented Innovation Policies: A new systemic policy approach to address societal challenges”. *OECD Policy Papers* No. 100. February 2021. <https://stip.oecd.org/stip/moip>

Office of the Under Secretary for Policy. “Department of Defense Climate Risk Analysis”. *US Department of Defense*. October 2021.

Office of the Under Secretary of Defense for Acquisition and Sustainment. “Department of Defense Climate Adaptation Plan 2022 Progress Report”. *US Department of Defense*. October 2022.

Office of the Under Secretary of Defense for Acquisition and Sustainment. “Department of Defense Plan to Reduce Greenhouse Gas Emissions”. *US Department of Defense*. April 2023. <https://media.defense.gov/2023/Jun/16/2003243454/-1/-1/1/2023-DOD-PLAN-TO-REDUCE-GREENHOUSE-GAS-EMISSIONS.PDF>

Robinson, D. and Mazzucato M. “The evolution of mission-oriented policies: Exploring changing market creating policies in the US and European space sector”. *Research Policy* Volume 44 (4): 936-948. May 2019. <https://doi.org/10.1016/j.respol.2018.10.005>

Robinson, D.K.R., Le Masson, P., Weil, B. “Waiting games: innovation impasses in situations of high uncertainty”. *Technol. Anal. Strateg. Manag.* 24 (6). 2012

Rogge, K., and Johnstone, P. “Exploring the role of phase-out policies for low carbon energy transitions: The case of the German Energiewende”. *Energy Research & Social Science* Volume 33. November 2017. <http://dx.doi.org/10.1016/j.erss.2017.10.004>

Samaras, C., Nuttall, W., and Bazilian, M. “Energy and the military: Convergence of security, economic, and environmental decision-making”. *Energy Strategy Reviews* Volume 26. September 2019. <https://doi.org/10.1016/j.esr.2019.100409>

Schwaag-Serger, S. “S&T Policymaking in Times of Uncertainty and Crisis: Opportunity for Transformative Change?” *Presentation to the OECD workshop ‘STI Policy in Times of Uncertainty’ Paris, October 5. 2020*

Soete, L.L.G. and ter Weel, B.J. “Innovation, knowledge creation and technology policy: the case of the Netherlands”. *EconPapers* 147, 293–310. 1999.

TIPRO. “TIPRO 2023: State of Energy Report”. *Texas Independent Producers and Royalty Owners Association*. 2023. <https://tipro.org/tipro-energy-report-2023/>

Urpelainen, J., and George E. “Reforming global fossil fuel subsidies: How the United States can restart International Cooperation”. Brookings Institution. July 2021. <https://www.brookings.edu/articles/reforming-global-fossil-fuel-subsidies-how-the-united-states-can-restart-international-cooperation/>

US Department of Defense. “2022 National Defense Strategy of The United States of America”. *US Department of Defense*. 2022. <https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF>

US Department of Energy. “Comprehensive Annual Energy Data and Sustainability Performance”. Federal Facility Reporting and Data – Annual Data. July 2023. <https://ctsedwebweb.ee.doe.gov/Annual/Report/ComprehensiveGreenhouseGasGHGInventoriesByAgencyAndFiscalYear.aspx>

Waksman, Jeff. “Project Pele Overview: Mobile Nuclear Power for Future DoD Needs”. *Office of the Secretary of Defence – Strategic Capabilities Office Distribution Statement*. March 2020. https://gain.inl.gov/GAINEPRINEI_MicroreactorProgramVirtualWorkshopPres/Day-2%20Presentations/Day-2-am.02-Nichols_PeleProgOverviewPublicMarch2020%2C19Aug2020.pdf

Weiss, Linda. “America Inc.?: Innovation and Enterprise in the National Security State”. *Cornell University Press*. 2014. <http://www.jstor.org/stable/10.7591/j.ctt5hh1c9>.

World Bank-Macrotrends. “Canada Military Spending/Defense Budget 1960-2023”. *Macrotrends*. 2023. <https://www.macrotrends.net/countries/CAN/canada/military-spending-defense-budget>

World Bank-Macrotrends. “U.S. Military Spending/Defense Budget 1960-2023”. *Macrotrends*. 2023. <https://www.macrotrends.net/countries/USA/united-states/military-spending-defense-budget>

WRI and WBCSD. “The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard”. Revised Version – Greenhouse Gas Protocol, World Resources Institute. 2004. <https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf>