The Clean Energy Dividend: Military Investment in Energy Technology and What It Means for Civilian Energy Innovation

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DoD Energy RDT&E and What it Means for Civilian Energy Innovation

- Policy debate over clean energy innovation is DOE-centric
  - Ignores DoD investment in energy technology for military mission
- Our report analyzes DoD's energy RDT&E effort:
  - How much is DoD spending and what is driving the investments?
  - How relevant are the investments for civilian clean energy innovation?
  - How can DOE/civilian agencies better leverage DoD's investments?
- Our report is NOT a critique of DoD's energy RDT&E effort
  - Recommendations are directed at civilian entities (largely DOE)

Context for DoD Investment in Energy RDT&E

- Energy is an essential enabler
  - DoD is largest U.S. energy consumer; FY17 energy bill: $11.7 billion
  - 70:30 split between *operational energy* and *installation energy*
- Energy is a source of vulnerability
  - Fuel convoys were most vulnerable target in Iraq and Afghanistan
  - Fixed installations face own threat: commercial grid vulnerable to disruption
- Technological innovation is DoD's modus operandi
  - Tight link between technology spending and military's mission requirements
  - Importance of procurement

How Much is DoD Investing?

- DoD will spend $1.6 billion in FY19 on energy RDT&E
  - $600M is "upstream" S&T
  - $800+M is "downstream"
    - Aviation propulsion

DOD FY19 Energy RDT&E Funding

Budget Category	Funding
Basic Research (6.1)	$128 M
Applied Research (6.2)	$269 M
Advanced Technology Development (6.3)	$202 M
Science & Technology (S&T) Subtotal	**$600 M**
Demonstration and Validation (6.4)	$824 M
System Development and Demonstration (6.5)	$101 M
Operational System Development (6.7)	$43 M
RDT&E Total	**$1,568 M**

What is Driving DoD Investments in Energy RDT&E?

- DoD's Energy & Power Community of Interest: "Provide technologies to enable intelligent power & energy management and enhance mission effectiveness."
- COI coordinates spending around 5 "warfighter opportunity areas":
  - Soldier Power
  - Base Power (contingency bases; fixed installations)
  - Platform Power
  - Autonomous System Power
  - Weapon Power

Energy & Power Warfighter Opportunity Areas

- Soldier Power: Dismounted soldiers and small tactical units
  - Power more electronic devices, over longer missions, w/o battery resupply
- Base Power—Contingency bases
  - Reduce use of generators while meeting growing demand for electric power
- Base Power—Fixed installations
  - Maintain power to critical loads during extended outages of commercial grid

Energy & Power Warfighter Opportunity Areas

- Platform Power: Manned aircraft, ships and ground vehicles
  - Support increasing amounts of electrical equipment while improving fuel efficiency
- Autonomous System Power: UxVs
  - Support long endurance operations, including propulsion and payloads
- Weapon Power: Directed energy weapons
  - Support use of electric weapon systems

Energy & Power Warfighter Opportunity Areas

- Integrated power & thermal mgt (higher E&P across systems)
- Smart power control & distribution
- Energy storage
- Power generation/energy conversion
- “If you are going to use energy as a weapon, you better have plenty of it.”

Pathways through which Military R&D and Procurement Influence Civilian Innovation

- Investments in foundational science, technology and engineering
  - Advanced composites
- Pursuit of technologies of early interest to the military
  - Wireless power transmission
  - Space-based solar
  - Aviation propulsion (Adaptive engine)
- Military R&D to leverage and advance commercial technology
  - Solar photovoltaics (PV)*
  - Batteries/Energy Storage*

Pathways through which Military R&D and Procurement Influence Civilian Innovation

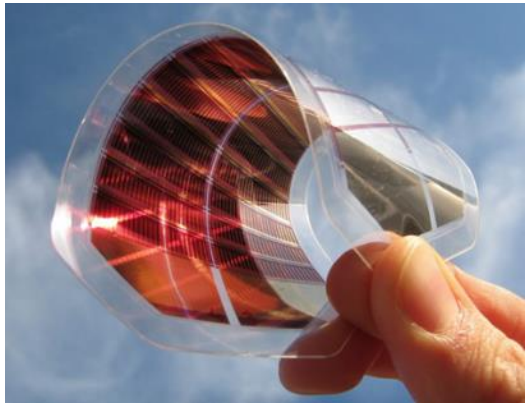
- Shared infrastructure and platforms as test beds for commercial technology
  - Microgrids*
  - Building energy technologies
- Early adoption and procurement of commercial technologies
  - Wide bandgap (WBG) semiconductors for power electronics*
  - Fuel cells
  - Very small modular nuclear reactors (vSMRs)
  - (Advanced biofuels as counter example)

Four Case Studies

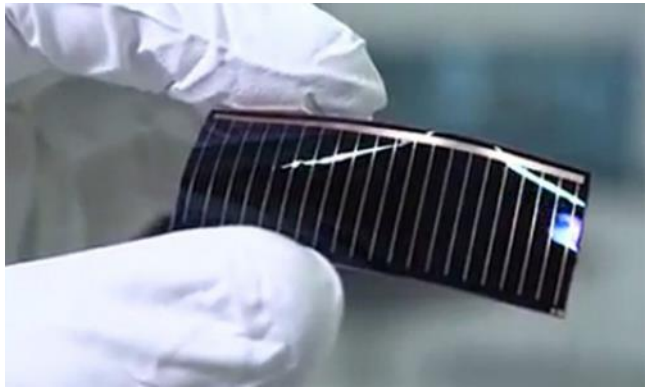
- Four Cases
  - Solar Energy and Photovoltaics (PV)
  - Energy Storage
  - Microgrids
  - Wide Bandgap Semiconductors

Solar Energy and PV
DoD's Potential for Market Disruption

- DOD needs high efficient, light weight, and flexible PV
  - Longer missions for soldiers, increased flight duration, reduced logistics, and space based solar
- The commercial market is dominated by inflexible and heavy crystalline silicon modules
- DoD's R&D support and role as an early adopter can create a large niche market
  - Production volumes could be large enough to drive cost reductions
  - Can lead to disruptive market entrants - competitors to Si



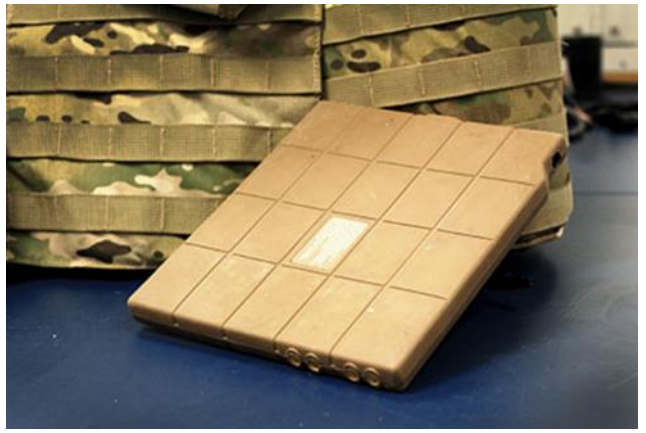
Perovskite Solar Cell



GaAs Solar Cell

Energy Storage
An Urgent Need

- DOD needs advanced energy storage with performance beyond what the commercial Li ion battery market provides
  - High energy density and improved safety for mobility missions and rapid recharge to support OPTEMPO
  - Stationary storage for base security
- DoD's R&D, demonstrations, and role as an early adopter can accelerate innovation
  - DoD is willing to pay a premium for performance that meet its mobility needs
  - DOD is willing to pay more than commercial customers due to the value it places on security



Conformal Wearable Battery

Stationary Storage at MCAS Miramar

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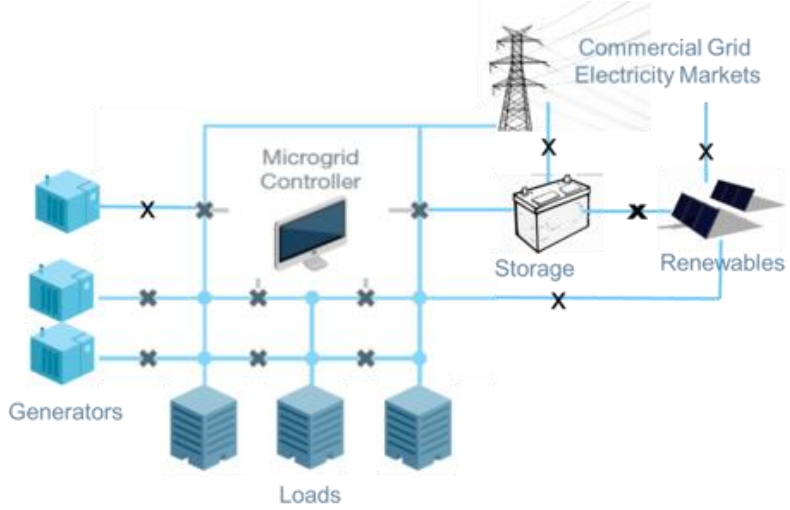
Microgrids
A Must Have for Military Bases

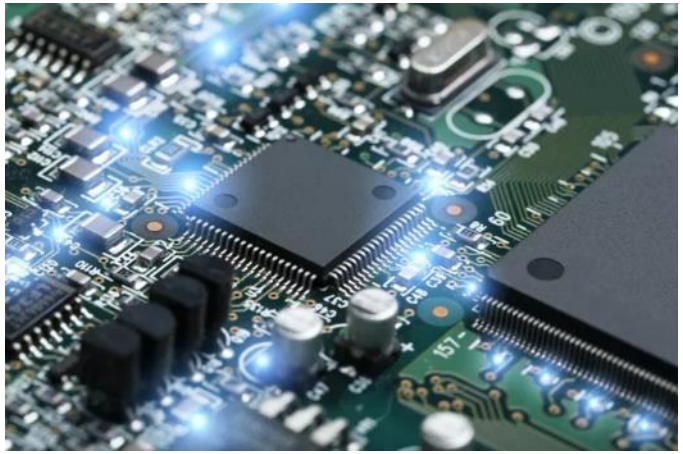
- Microgrids offer a resilient and cost-effective approach to ensuring energy security at military bases
  - At fixed bases stationary microgrids provide power for critical loads during grid outages
  - At contingency bases tactical microgrids can significantly reduce the need for transported fuel
- DoD's R&D, demonstrations, and role as an early adopter can accelerate innovation
  - Advanced commercial stationary microgrids are being demonstrated and procured
  - Tactical microgrids are being developed



Stationary Microgrid

Wide Bandgap (WBG) Semiconductors Power Electronics

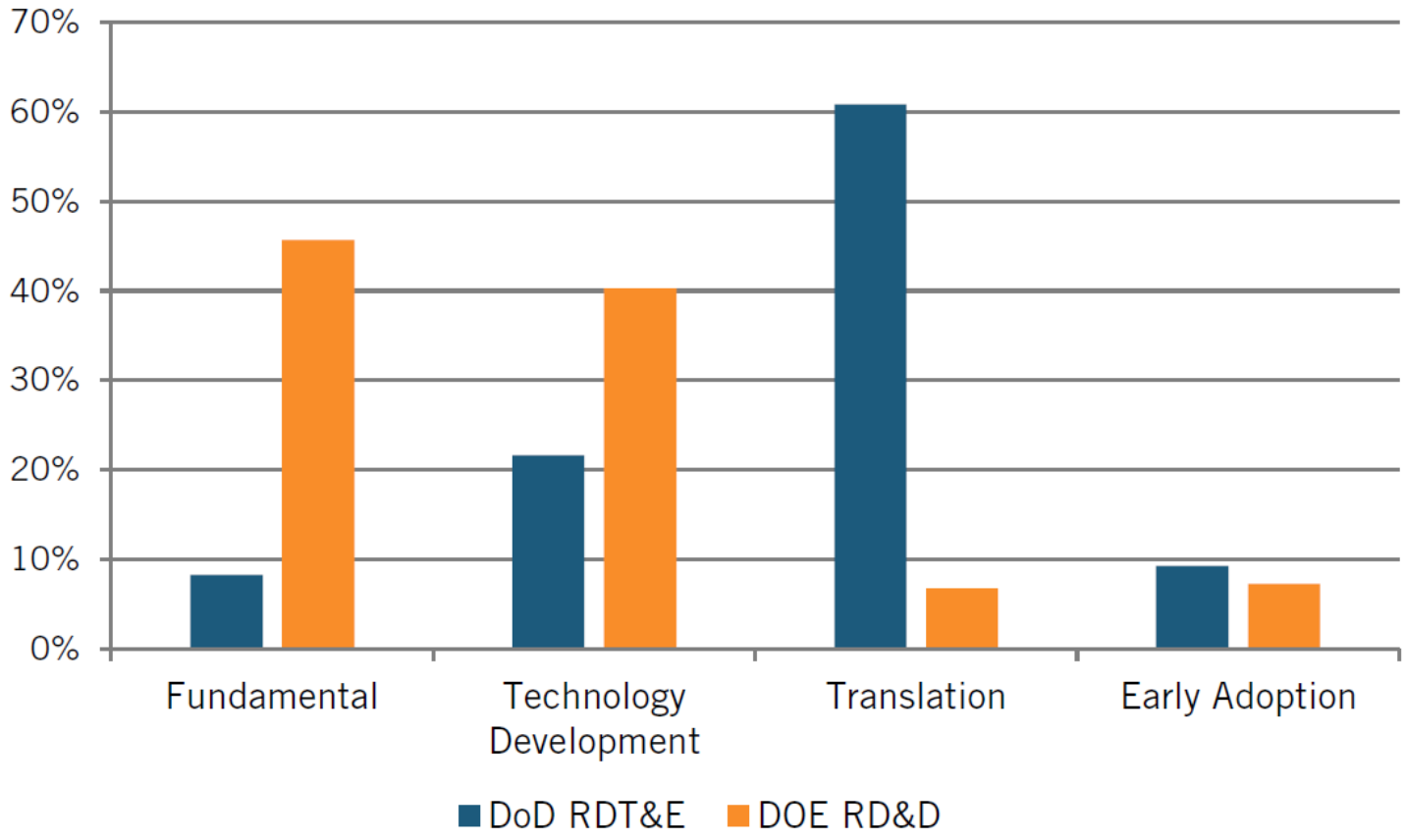
- WBG semiconductors have the potential to revolutionize power electronics while reducing energy losses
- DOE is devoting significant resources to advancing WBG technology (PowerAmerica)
- DOE initiatives are built on past DOD RDT&E
  - ONR and DARPA laid the foundation of WBG semiconductors material science, engineering, and manufacturing
  - WBG devices are currently used in the radar systems of major military platforms and DoD will be an early market for WBG power electronics



WBG Power Electronics

DOE's (RD&D) and DOD's (RDT&E) Energy Investments

- DOD and DOE approaches to innovation are complementary
- DOE's energy R&D budget is devoted heavily to fundamental research
  - Driven by technology push
- DOD's skews heavily to technology development and translation
  - Driven by demand pull



General Recommendations

- DOE and DOD limited interaction on energy innovation needs to increase
  - Collaboration is not unheard of but outside of few efforts it has little support
- Collaboration with DOD would make DOE a stronger innovator
  - DOD through demonstration can provide the opportunity to “learn by using,” which is critical to product development, and though early adoption the opportunity to “learn by doing,” that is critical to drive manufacturing costs down
- DOE should factor DOD’s needs and strengths into both its fundamental and applied RD&D strategies and roadmaps
  - DOE should expand its focus to include DOD needs that are congruent with the civilian market

Specific Recommendations

- DOE should partner with DOD on its stationary-storage programs.
- DOE's battery-technology programs should engage with DOD end users
- DOE's solar technology program should partner with DOD to speed the path to next-generation PV
- DOE's manufacturing initiatives should look to DOD to be an early adopter
- DOE should partner with DOD to advance the deployment of stationary microgrids
- DOE's advanced SMR program should look to DOD to be an early customer
- DOE should lead a government-wide effort to demonstrate and validate energy technologies for the built environment in federal facilities
- The U.S. AID should explore opportunities to exploit DOD's work on tactical microgrids
- The NRC should conduct a study to identify impediments to and opportunities for greater DOE-DOD collaboration on energy RD&D

Summary

- The military relies on energy for everything it does
- Clean energy technologies can benefit from DOD RDT&E and procurement
- DOE should factor DOD's needs and strengths as an innovator into its plans
- Many opportunities exist for DOE to partner with DOD

Thank You!

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