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Issue Brief

High Energy Materials: Contemporary Warfare and India's Defence Industrial Policy

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Summary

The effectiveness of advanced weapon systems depends critically on high-energy materials and the intricate sub-systems that constitute the operational core, ensuring their functionality and precision. The thermobaric munitions market is expected to increase significantly, as states pursue futuristic, technology-driven systems.

The high-energy materials ecosystem provides the foundational chemistry of modern explosive systems. Thermobaric weapons, thermonuclear devices, shape-charged munitions, reactive armour systems, high-explosive fragmentation devices (conventional explosives), incendiary munitions, and chemical and biological weapon systems are distinct manifestations of munition applications, each employing unique detonation mechanisms to achieve specific objectives. Given the legal and ethical ramifications associated with the use of nuclear weapons, thermobaric warfare has become the most dangerous yet prevailing form of warfare in contemporary conflicts.[1] This brief examines the use of thermobaric munitions in contemporary warfare, the global growth of high-energy material production and situates India’s policy framework governing their manufacture.

Thermobaric Munitions and Warfare

The deployment of thermobaric weapons has become a recurring feature of 21st-century conflicts. Since the turn of the millennium, these munitions have been used in various operations. In Vietnam, they were used to clear the dense foliage and demolish the deeply covered Viet Cong tunnels. The evolution continued throughout the late 1980s as the US began developing solid thermobaric explosives (TBX) in response to the tactical requirement for blast explosives to pierce through confined and deeply enclosed structures during Operation Desert Storm.[2]

The Russians pioneered the deployment of thermobaric weapons during the Soviet–Afghan War and proceeded to use them extensively in their war with Chechnya. Russia’s large arsenal suggests continued development of third-generation thermobaric munitions, supported by more than 14 distinct delivery systems.[3] During the Chechen conflict of 1999–2000, Russia deployed the RPO-A Shmel thermobaric ‘flamethrower’, the Kornet-E anti-tank guided missile with thermobaric warheads and ODAB-500 fuel-air bombs in Grozny. *Human Rights Watch* reported the use of ‘vacuum bombs’ in the Chechen conflict.[4]

The United States used the 2,000 lb BLU-118/B laser-guided thermobaric bomb against Al-Qaeda and Taliban cave structures in the Gardez region of Afghanistan in March 2002.[5] US sources confirmed the use of this single massive thermobaric bomb

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[1] Arthur van Coller, **“Detonating the Air: The Legality of the Use of Thermobaric Weapons Under International Humanitarian Law”**, International Review of the Red Cross, June 2023.

[2] **“Fuel Air Explosive (FAE) Systems”**, Technical Note 09.30 /04 (1-2), Technical Notes for Mine Action (TNMA), July 2013.

[3] Lester W. Grau and Timothy L. Thomas, **“Russian Lessons Learned from the Battles For Grozny”**, Marine Corps Gazette, April 2000.

[4] **“Backgrounder on Russian Fuel Air Explosives (“Vacuum Bombs”)”**, *Human Rights Watch*, February 2000.

[5] Jonathan Marcus, **“Analysis: How Thermobaric Bombs Work”**, *BBC News*, 4 March 2002.

to neutralise deep subterranean networks that conventional munitions were unable to reach.[6] The urban warfare utility of thermobaric effects was cemented during the First and Second Battles of Fallujah in November 2004, where US Marines expended over 1,000 Shoulder-Launched Multipurpose Assault Weapon - Novel Explosive rounds for the Mk-153 SMAW (bazooka) to clear insurgent-held buildings, highlighting their effectiveness as an 'anti-structure' weapon where collateral damage to the building's integrity was secondary to neutralising occupants.[7]

The technology has further proliferated into regional conflicts, as seen during the Second Nagorno-Karabakh War in 2020, where Azerbaijan deployed the Russian TOS-1A salvos multiple launch rocket system against Armenian Karabakh separatists, rapidly collapsing their defensive lines.[8] Similarly, in the Gaza Strip, in the aftermath of the 9 October 2023 Hamas attacks, Israel used thermobaric or enhanced blast weapons to demolish over 2,900 housing units in one large-scale operation against Operation Al-Aqsa Flood.[9] More recently, on 30 June 2025, the United States approved an estimated US$ 510 million sale of Boeing Joint Direct Attack Munition (JDAM) guidance kits to the Israel Defence Force (IDF), enabling the conversion of conventional 'dumb' bombs into precision-guided munitions (Global Positioning System and Inertial Navigation System equipped) with extended-range capabilities for BLU-109 and Mk 82 weapons, while also allowing for upgrade options to MK-82T thermobaric warheads for the latter.[10]

During the Syrian Civil War in 2012, the Syrian government air force deployed two ODAB-500PM fuel-air bombs in Azaz, accounting for the highest casualty count, killing over 40 and wounding over 200 civilians in a single airstrike.[11] The 'Dirty Dozen', profiled as the worst dozen explosive systems used in Syria, featured three air-delivered thermobaric munitions and ground-based launchers.[12] Following Russian intervention, the TOS-1A 'Solntsepyok' heavy flamethrower system was extensively used during battles in the governorates of Deir Ezzor and Aleppo during 2015–2016.[13] There were documentations by specialist arms researchers about the

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[6] "**BLU-118/B Thermobaric Weapon**", *GlobalSecurity.org.*

[7] Kevin Gessner, **"Shoulder-Launched Munitions: R&D Transformation and Infantry Fighting Again"**, Marine Corps Gazette, US Naval Sea Systems Command (NAVSEA), September 2013.

[8] Mark Episkopos, **"One Scary Photo: Russia's Thermobaric Weapons Should Be in a Horror Movie"**, *The National Interest*, 2 June 2021.

[9] **"Israel Takes Revenge on Palestinian Armed Factions by Mass Killing Civilians in Gaza"**, *Euro-Med Human Rights Monitor*, 9 October 2023.

[10] Gareth Jennings, **"US Approves JDAM Kits as Israel Replenishes Munitions Stocks"**, *Janes*, 1 July 2025.

[11] **"Azaz, Syria"**, Action on Armed Violence (AOAV), 1 August 2014.

[12] Robert Perkins, **"Investigation: Syria's Dirty Dozen"**, Action on Armed Violence (AOAV), 23 September 2013.

[13] Alex Hopkins, **"Reported Civilian Casualties from Russian Airstrikes in Syria: January 2016"**, *Airwars Research*, September 2016.

use of, inter alia, RPO-A Shmel and MRO-A thermobaric rocket launchers by Syrian forces on front lines.[14]

Most significantly, the full-scale Russian invasion of Ukraine (2022–present) has seen the most extensive use of thermobaric weaponry in history. The first recorded use of RPO-A rockets was in the Donbas region (2014–2017).[15] The full-scale invasion ushered in a widespread deployment of TOS-1 and TOS-1A systems, along with MRO and RPO series weapons against Eastern Ukrainian fortifications.[16]

A defining feature of this technology-driven conflict was the deployment of unmanned aerial vehicles (UAVs), with around 1889 drones deployed in October 2024, particularly after the deal with Iran to acquire Shaheds.[17] Shahed-adapted thermobaric-armed drones are exponentially more expensive and constitute about 5 per cent of the total drones deployed alongside decoy drones to saturate Ukrainian air defences as a façade, while penetrating fortified structures and causing disproportionate damage through enhanced blast effects.[18] UAVs and tactical drones are being integrated with thermobaric warheads to maximise destruction.[19] PLA scientists have also tested a non-nuclear, thermally decomposing hydrogen explosive and integrated thermobaric warheads into robots, alongside a variety of platforms that use these payloads.[20]

Such global usage is projected to significantly increase the thermobaric munitions market as states pursue futuristic, technology-driven systems capable of delivering the highest possible impact. Market growth is projected to achieve a Compound Annual Growth Rate (CAGR) of 4.8 per cent, with valuation increasing from US$ 1.74 billion in 2024 to US$ 2 billion in 2025 and further to US$ 2.78 billion by 2032.[21]

Given the exponential increase in global defence expenditure and investment, the substantial cost per unit of TBX procurement relative to conventional systems is being regarded as a rational premium for niche, high-lethality applications. This

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[14] N.R. Jenzen-Jones, **"Russian MRO-A Thermobaric Rocket Launchers in Syria"**, Armament Research Services (ARES), 30 October 2015.

[15] **"Seperatist Commander 'Givi' Killed in Eastern Ukraine"**, RFE/RL, 8 February 2017.

[16] Thomas Haydock and Jack Meeker, **"Lessons in Reconstitution from the Russia-Ukraine War: Gaining Asymmetric Advantage through Transformative Reconstitution"**, *Military Review*, January–February 2025.

[17] Emma Burrows, Hanna Arhirova and Lori Hinnant, **"Investigation Reveal a Russian Factory's Plan to Mix Decoys with a New Deadly Weapon in Ukraine"**, Associated Press (AP), 16 November 2024.

[18] Ibid.

[19] Ibid.

[20] Ngo Di Lan, **"China's Hydrogen Test and the Future of Non-Nuclear Deterrence"**, *The Diplomat*, 29 April 2025; Stephen Chen, **"China Arms Combat Robots with Controversial Thermobaric Weapon in Urban Warfare Drill"**, *SCMP*, 25 February 2025.

[21] **"Thermobaric Munitions Market"**, *Fortune Business Insights*, 5 January 2026.

increasing deployment on the battlefield underscores a critical dependency on the production and procurement mechanisms used by nation-states.

High-Energy Materials and India: Regulatory Framework and Key Issues

The paradigm shift in India’s defence production landscape towards the overarching philosophy of ‘Atmanirbharta’ has reached significant milestones, with defence production value reaching Rs 1.51 lakh crore in 2024–25.[22] The Munitions India Limited (MIL) recorded 95 per cent indigenisation of established platforms and sub-systems. The Defence Research and Development Organisation (DRDO), through its High Energy Materials Research Laboratory (HEMRL), is at the forefront of developing these indigenous compositions, including thermobaric explosives, explosive inks and advanced solid propellants.[23] The indigenous development of the thermobaric composition PBTE 201 by HEMRL has completed user-associated trials. It has institutionalised production processes for all raw materials and machinery required to fill these warheads.[24]

The Explosives Act of 1884 remains the foundational legislation governing the civilian and military explosives sector in India.[25] Although updated through the Explosives Rules of 2008 and subsequent amendments, the fundamental architecture reflects concerns about controlling dangerous materials to prevent insurrection, rather than about bifurcating the regulatory framework or fostering a competitive, industrial-scale defence industry.

Furthermore, high-energy materials fall under Category A of defence production licences, which mandate the highest level of security clearance and impose stringent production restrictions.[26] Historically, Category A production has been restricted to Defence Public Sector Undertakings (DPSUs) due to concerns regarding national security and technology proliferation. However, while DPSUs demonstrate competence, rapid demand surges during conflicts or export opportunities necessitate a joint public–private sector effort.

In the aftermath of Operation Sindoor, the Indian government passed a landmark amendment in October 2025 to open missile and ammunition manufacturing to the

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[22] “**Ministry of Defence; Year End Review – 2025**”, Press Information Bureau, Ministry of Defence, Government of India, 31 December 2025.

[23] “**Annual Return 2023-24**”, Munitions India Limited, 2024.

[24] “**Thermobaric Explosive Composition PBTE 201 for Bombs**”, HEMRL, DRDO, Government of India, 5 October 2022.

[25] “**The Explosives Act 1884**”, Petroleum and Explosives Safety Organization (PESO), Government of India.

[26] “**Security Manual for Licensed Defence Industries (SMLDI)**”, Department of Defence Production, Ministry of Defence, Government of India, June 2025.

private sector.[27] This policy shift eliminates the bureaucratic hurdle posed by the requirement of a no-objection certificate. Yet, challenges lie in strategic execution, capital intensity, and the transfer of technology for sensitive energetic formulations.

India's dilemmas relate to liberalising the production of high-grade military explosives to boost industrial capacity without compromising internal security. The need to limit civilian access is underscored by the threat of high explosives falling into the hands of non-state actors and terrorist groups. Recent history provides grim reminders, such as the 2025 Red Fort blast and the 2011 Mumbai bombings, where improvised explosive devices (IEDs) utilising ammonium nitrate and Research Development Explosive (RDX) were employed.[28] The potential for non-state actors to use more complex thermobaric-like devices using commercially available fuels and oxidisers is a significant security concern that necessitates strict oversight.

However, the current procedural and financial asymmetries of a public-sector monopoly create capacity constraints in an essentially buyer's market, where the government must prioritise domestic capabilities. Reports indicated that US annual artillery production would last only 10 days to two weeks of combat at Ukraine-level intensity, while UK forces exhausted their national ammunition stockpiles in just eight days during a recent war game simulation involving US, UK and French forces.[29]

In India, the private sector could bring technological dynamism to the production of high-energy materials through risk capital and agile management. The deterioration of compounds in storage, which has led to accidental explosions in past incidents, highlights the need for modern infrastructure and inventory management that private capital could help upgrade.[30]

Way Forward

Operational Readiness

India needs to focus more on producing and acquiring chemical sub-systems with a longer shelf-life. This is primarily due to the unforeseen nature of war, which does not guarantee the availability of stored sub-systems. The nation's strategic reserves

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[27] **"India's Defence Leap: Private Sector Enters Missile and Ammunition Manufacturing Amid Push for Self-Reliance"**, Indian Defence Research Wing, 6 October 2025.

[28] S.L. Narasimhan, **"Understanding the Red Fort Attach in New Delhi"**, Center for Strategic & International Studies, 25 November 2025; Animesh Roul, **"Mumbai Outraged Once Again: India Blinks, Blames Homegrown Terror"**, *Jamestown*, 8 March 2011.

[29] Oleksandr V. Danylyuk and Jack Watling, **"Winning the Industrial War: Comparing Russia, Europe and Ukraine, 2022-24"**, Royal United Services Institute for Defence and Security Studies, April 2025.

[30] **"Bhandara Ordnance Factory Blast: 4 Officials Booked; FIR Says Negligence in Repairing Machines"**, *Deccan Herald*, 14 March 2025.

must be prioritised if a war-like scenario arises. The Atmanirbhar project intends to achieve this objective by raising ammunition reserves to required levels, ensuring at least two supply sources for every ammunition type, and reducing reliance on imports.[31]

Immense importance should be placed on the availability of indigenised high-energy compounds and their unprocessed materials to ensure military readiness when exporting countries experience delivery failures or deliberately impose sanctions and supply cut-offs during crises. Prioritising core sub-system over manufacturing assembly-led or low-value localisation provides a strong impetus towards Atmanirbharta. Unless procurement policy is anchored around control over technology rather than capital inflows, further liberalisation risks deepening dependence rather than advancing towards genuine self-reliance.

Tiered Licensing Framework

The government should establish a tiered licensing framework that retains strategic explosives (such as HMX or CL-20 used in nuclear triggers or strategic missiles) under strict DPSU or joint-venture control, while fully opening the production of tactical systems (such as standard artillery propellants and TBX compositions for infantry weapons) to licensed private firms. This distinction between strategic and tactical energetics would enable MSMEs to handle high-volume, low-sensitivity production, freeing DPSUs/DRDO to focus on next-generation strategic compounds.

Updating the Explosives Act

With the rapid development of high explosives and thermobaric systems, the Explosives Act could impede research, development and production. There is often no clear legislative divide between civilian and military explosives usage in the pre-manufacturing stage, which leads to blanket restrictions. A compound like RDX, while having enormous military capacity, is distinct from civilian blasting agents like ANFO (Ammonium Nitrate/Fuel Oil). The Act could be revised to introduce specific schedules for 'Dual-Use Energetics' versus 'Military-Grade Energetics', allowing differential compliance burdens similar to those in the Australia Group's control lists.[32]

International Benchmarks

India should draw lessons from international models, such as those of South Korea and China. In South Korea, the defence industry boom is supported by a strong interplay between government research institutes and private giants such as

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[31] **"Ministry of Defence; Year End Review – 2025"**, no. 22.

[32] ***Australia Group Common Control List Handbook, Volume I: Chemical Weapons-Related Common Control Lists***, Government of Australia, 8 January 2024.

Hanwha Defence, which manages large-scale explosives production.[33] The Korean model utilises institutions such as Korea Trade Insurance Corporation to provide export credit, thereby aggressively supporting the industry's global expansion.[34] Similarly, China employs a strategy where the Institute of Chemical Materials (ICM) focuses on design and development of energetic materials, but production is often scaled through ‘civil-military fusion’ enterprises.[35]

China has invested significantly in the R&D of high-energy materials, with numerous Chinese research institutes, such as Nanjing University of Science and Technology, driving innovation in revolutionary materials, including RDX@FOX-7 composites. This composition raises the melting temperature of RDX, shifts the thermal decomposition peak of RDX to a double peak, and shortens the ignition delay compared to that of RDX or FOX-7.[36] India needs a transparent metric to assess the extent to which export ambition can be supported before drawing on strategic reserves, similar to South Korea's managed export credit and production quotas.

Single-window Clearance and Infrastructure

A single-window clearance authority should be established to streamline the currently cumbersome multi-agency approval process for the production of energetic materials. Additionally, specialised academic programmes are needed to develop a skilled workforce capable of safely handling advanced energetics. Upgrading storage infrastructure to modern standards is a pathway to Industry 4.0 and is critical to preventing compounded deterioration and accidental explosions, ensuring the stockpile remains combat-ready.

Conclusion

In conclusion, mastery of high-energy materials is the quiet engine of military supremacy. For India to secure its strategic autonomy and realise its export potential, it must modernise not only its factories but also the laws that govern them. Balancing the lethality of thermobaric capabilities with the safety of its citizenry requires a regulatory evolution as potent as the explosives it seeks to control.

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[33] Wooyeal Paik, **“South Korean Defense Industry Goes Global, and Local Too: An Econo-Tech Approach”**, ISPI, 8 April 2024.

[34] Gabrielle Godard, **“South Korea as the New International Defence Industrial Powerhouse: Implications for Europe”**, Briefing Paper, European Institute for Asian Studies (EIAS), February 2024.

[35] Chao Chen and Genserik Reniers, **“Chemical Industry in China: The Current Status, Safety Problems, and Pathways for Future Sustainable Development”**, Safety and Security Science Group, August 2020.

[36] Jin Yu, Hanyu Jiang, Siyu Xu, Heng Li, Yiping Wang, Ergang Yao, Qing Pei, Meng Li, Yang Zhang and Fengqi Zhao, **“Preparation and Properties of RDX@FOX-7 Composites by Microfluidic Technology”**, Science and Technology on Combustion and Explosion Laboratory, Xi’an Modern Chemistry Research Institute, 18 January 2023.

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