Cleantech for Defence, Security and Resilience

White Paper

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Authors:

Kädi Ristkok, Cleantech for Baltics

Laima Balciune, Cleantech for Baltics

Contributors:

Brooke Latham, NATO Innovation Fund

Jules Besnainou, Cleantech for Europe

Julia Reinaud

Victor Van Hoorn, Cleantech for Europe

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Thank you for your commitment and expertise in advancing this vital discussion!

EXECUTIVE SUMMARY

The next battlefield might not be a border but a power grid - cleantech is Europe's first line of defence.

Cleantech: Europe's First Line of Defence and Strategic Advantage

As cyberattacks, energy dependencies, and climate-driven instability reshape global security, Europe must harness clean technologies not just for sustainability but as a cornerstone of strategic autonomy, resilience and defence. The war in Ukraine, attacks on critical infrastructure, and the accelerating weaponization of energy demonstrate the urgent need to integrate cleantech into security, resilience and defence strategies.

Strengthening Strategic Autonomy and Defence Readiness with Cleantech

Europe's overreliance on imported fossil fuels and critical materials is a vulnerability that adversaries can exploit. Cleantech – through decentralized energy systems, advanced batteries, and synthetic fuels – can reduce these dependencies while securing military and civilian infrastructure. Resilient microgrids, green ammonia for fertilizer and energy, and AI-driven precision agriculture can reinforce Europe's energy, food, and raw materials autonomy.

Bolstering Defence Capabilities with Cleantech

Warfare demands operational endurance, stealth, and secure supply lines. Clean energy solutions – such as hydrogen-powered drones, hybrid military vehicles, and self-sustaining forward bases – enhance military effectiveness while reducing logistical vulnerabilities. Silent power generation and infrared-absorbing materials lower detection risks, while modular and repairable technologies extend the lifecycle of critical assets. Cleantech is not just an environmental strategy – it's a force multiplier.

Post-War Recovery: Cleaning Up and Building Up with Cleantech

War leaves behind toxic landscapes, crippled infrastructure, and economic devastation. Cleantech solutions – such as drone-assisted reforestation, bioremediation, and circular construction – are essential for rapid, resilient recovery. In Ukraine, clean energy microgrids and sustainable building materials will be key to rebuilding a secure and autonomous future.

A Call to Action: A European Clean Technologies and Defence Task Force Needs to Be Established

Integrating cleantech into defence, security and resilience strategies is no longer just an option but a necessity. Yet, they often operate in isolation, slowing progress. Europe must establish a Task Force on Clean Technologies and Defence to accelerate this critical integration. This initiative would drive strategic cooperation, align investments, and remove barriers to scaling dual-use innovations.

By uniting policymakers, industry leaders, and security experts, this task force will ensure that cleantech is embedded in Europe's defence, resilience, and recovery efforts – strengthening security while positioning Europe as a leader in sustainable innovation.

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INTRODUCTION

In a world where fuel convoys can cripple a battlefield and carbon emissions threaten our future, the same hydrogen engines powering European cargo ships may soon propel naval vessels in silence and zero emissions. As the line between security and sustainability blurs, cleantech is emerging as Europe's most strategic defence and security asset.

The world is facing an era of converging crises – a "polycrisis" – where geopolitical tensions, environmental degradation, technological shifts, and societal divides threaten global stability. The World Economic Forum's Global Risks Report 2025 highlights an increasingly fractured landscape, where climate-driven disasters coincide with growing conflicts, and trade and energy are weaponized. Climate change poses long-term risks to Europe and has profound implications for security and resilience, acting as a threat multiplier that exacerbates existing vulnerabilities, accelerates resource conflicts, and heightens geopolitical tensions. Political and societal polarization further strain governance, making this one of the most volatile periods since the Cold War.

Historically, climate risks, security, resilience, and defence have operated in separate silos. However, today's challenges demand a more integrated approach. The European Union and its Member States must leverage cross-sector expertise to address shared risks and seize emerging opportunities. Recognizing this urgency, key EU policy reports from Mario Draghi, Enrico Letta, and Sauli Niinistö (2024) identify three core imperatives for Europe: (1) closing the innovation gap with the US and China in advanced technologies, (2) integrating decarbonization with industrial competitiveness, and (3) strengthening security and reducing dependencies. Europe must innovate, build a sustainable autonomous economy, and enhance its defence capabilities.

The EU has launched ambitious strategies bridging climate action, industrial policy, and security to meet these goals. The European Green Deal (2019) sets a path toward climate neutrality by 2050, while the Fit for 55 package aims to cut greenhouse gas

emissions by 55% by 2030. Beyond environmental benefits, the green transition enhances energy security, reduces reliance on fossil fuel imports, and fosters domestic cleantech industries. On the defence side, the Strategic Compass for Security and Defence (2022) lays out concrete actions to strengthen Europe's ability to anticipate and respond to threats, emphasizing infrastructure resilience, technological innovation, and strategic autonomy. Most recently, the Clean Industrial Deal (2025) positions cleantech as a driver of European competitiveness, supporting energy-intensive industries in transitioning to clean energy and securing critical raw materials through circular economy practices. The Concept for an Integrated Approach to Climate Change and Security (2021) is the European Union's strategic framework to address the multifaceted risks that climate change poses to global security. Recognizing that climate change acts as a "threat multiplier," exacerbating existing vulnerabilities and potentially leading to conflicts over resources, forced migrations, and geopolitical tensions, this concept underscores the necessity for a cohesive and comprehensive response.

While these initiatives acknowledge the links between climate action, industrial strength, and security, clean technologies[1] remain largely underutilized in Europe's defence and security strategies. Failing to integrate sustainable technologies into security and resilience planning is a missed opportunity. Cleantech can play a pivotal role in three key areas: (1) strengthening strategic autonomy through resilient, decentralized energy systems, resilient food, agriculture and land use, and raw materials; (2) dual-use military applications such as decentralized clean energy technologies, sustainable materials and production methods, and (3) contributing to post-conflict recovery and environmental restoration, using bioremediation, drone-assisted reforestation, and circular construction techniques. For example, cleantech innovations such as offshore wind energy, green hydrogen, heat pumps, decentralized

[1] **Clean technologies**, often referred to as **cleantech**, encompass products, services, or processes that enhance operational performance, productivity, or efficiency while simultaneously reducing costs, resource consumption, energy usage, waste, or environmental pollution. These technologies aim to provide superior performance compared to traditional methods, with a focus on sustainability and minimal ecological impact.

solar power and aviation fuels produced from electricity and hydrogen can reduce Europe's reliance on imported natural gas while ensuring energy resilience.

These technologies, alongside advancements in sustainable materials and circular economy practices, can create a more autonomous, secure, and decarbonized Europe.

This white paper aims to break down silos and align investments, policies, and innovations across cleantech, security, and defence. By integrating clean technologies into these domains, Europe can meet its climate commitments and enhance its strategic resilience and long-term security. The defence sector could also serve as a critical demand-pull, driving the scale-up of cleantech production in Europe and creating the necessary momentum to achieve both sustainability and security objectives. Without this integration, Europe risks losing the global cleantech race and failing to secure the technologies required for its strategic autonomy, resilience, and security. As the geopolitical landscape evolves, it is increasingly crucial for Europe to strengthen its technological sovereignty through a unified approach that links cleantech innovation with defence and security priorities.

EUROPEAN INNOVATORS AT THE CLEANTECH – SECURITY NEXUS

Europe is home to numerous companies – from agile startups to industrial giants – developing cleantech solutions relevant to security and defence. The European cleantech ecosystem is supported by various EU initiatives (e.g. Horizon Europe funding for dual-use technologies, Incubation Forum for Circular Economy in European Defence[2]) and a growing venture capital interest in security- and defence-related tech. A year ago, the European Commission and the European Investment Fund joined forces to boost investment in defence innovation through the Defence Equity Facility and launched a €175 million fund that aims to support venture capital and private equity funds that are investing in European companies developing innovative defence technologies with a 'dual-use' potential. A recent surge in European defence tech startup funding (over 500% increase from 2021 to 2024)[3] suggested strong momentum for innovation at this nexus. Many cleantech startups unintentionally develop dual-use capabilities – for instance, a startup making robust energy storage for remote villages can find its technology equally valued by the military for remote outposts; drones to detect wildfires are also widely used in warfare.

By identifying and supporting these companies, the EU can accelerate the adoption of cleantech in defence and for security and autonomy purposes. Startups and SMEs often supply the innovative components (novel batteries, fuel cells, sensors), while large integrators like Airbus, Leonardo, Thales incorporate them into systems at scale. It's vital for policymakers and investors to create an environment where such collaborations flourish – ensuring Europe's security community has access to home-grown sustainable solutions.

In the following sections key clean technology domains contributing to defence, security and resilience are identified. Some prominent examples are provided of European companies across different scales, each contributing to these domains.

[2] European Defence Agency, https://eda.europa.eu/what-we-do/eu-policies/if-ceed
[3] European Defence Tech Comes Into Its Own - Megaproject

1. STRENGTHENING STRATEGIC AUTONOMY AND DEFENCE READINESS WITH CLEANTECH

In the context of tensions and threats, the role of clean technologies is expanding beyond environmental and climate considerations to encompass critical aspects of security and resilience. Integrating security and resilience into all policies and activities is essential to prepare for and adapt to evolving risk conditions. This proactive approach ensures that nations can withstand and recover rapidly from significant disruptions, maintaining business continuity and operational stability. Furthermore, it increases European industrial competitiveness by creating strong lead markets for the globally demanded clean technologies.

Recent geopolitical developments have highlighted Europe's urgent need to enhance its strategic autonomy, protect critical infrastructure, and strengthen civil defence preparedness. Integrating clean technologies into security strategies goes beyond addressing environmental concerns – it offers a cost-effective approach to bolstering resilience, reinforcing defence capabilities, reducing vulnerabilities and advancing Europe's clean industrial competitiveness. This quadruple advantage underscores the necessity of embedding cleantech, security, and resilience considerations across all policy areas and implementation frameworks.

Energy security and resilience

The full-scale Russian war against Ukraine and the resulting energy crisis highlighted the security threats linked to Europe's energy dependencies. Energy dependencies can and are weaponized, emphasizing the need for locally produced decentralized energy. Depending on fossil fuel imports from third countries may create short-term economic advantage, but we have experienced that it also deepens long-term resilience and security challenges. In parallel, European countries are experiencing increasingly frequent attacks on their critical energy infrastructure, such as the recent attacks on under-sea power cables in the Baltic Sea.

Clean energy technologies collectively contribute to a more resilient energy system capable of adapting to various challenges. Decarbonizing Europe's energy sector by developing and adopting locally manufactured clean technologies is crucial for lowering energy dependency on third countries and reducing energy-related costs while positioning the region as a leader in clean energy innovation.

For example, deploying renewable energy sources such as solar, wind, and geothermal, combined with advancements in energy storage and hydrogen technologies, ensures a more stable and independent energy supply. By accelerating the transition to clean energy, Europe can minimize its exposure to geopolitical energy pressures while reinforcing economic stability and industrial competitiveness. In parallel, radar surveillance technologies must be further developed to guarantee their compatibility with wind parks. While Europe transitions to clean energy, it must ensure that there are supply chains for CE in Europe, i.e., critical minerals. It's not only about clean energy sources but securing the entire clean energy supply chain.

Distributed renewable energy systems, including microgrids and smart grids, offer a robust solution to the growing threats against critical energy infrastructure. Unlike centralized fossil fuel-based energy networks, decentralized clean energy infrastructure reduces single points of failure and enhances the ability to withstand disruptions from cyberattacks, physical sabotage, or geopolitical conflicts. Integrating digital monitoring, artificial intelligence, and predictive maintenance in clean energy networks further strengthens resilience by enabling real-time responses to emerging threats. The development and deployment of European-manufactured renewable energy technologies like PV inverters and wind turbines needs to be accelerated to avoid excessive dependencies on technologies imported from third countries, which additionally increase cybersecurity risks.

Synthetic fuels, particularly e-SAF (electrofuels for Sustainable Aviation Fuel), present an innovative solution to mitigate import dependencies on conventional oil, particularly during supply shortages. These fuels are produced using renewable energy sources to synthesize liquid fuels from CO2 and water, effectively creating a closed carbon cycle that diminishes the reliance on fossil fuels. Modular e-SAF

production facilities, which can be scaled according to demand and local energy availability, enhance this benefit by enabling decentralized production close to the point of use, such as airports or industrial sites. This not only supports energy security but also reduces transportation costs and emissions. Adopting synthetic fuels could significantly bolster national energy resilience, drive down greenhouse gas emissions, and catalyze local economic development.

As attacks on critical infrastructure become more frequent, it is essential to integrate cleantech solutions into security and defence strategies. Offshore wind farms, energy islands, and localized power generation hubs provide alternative pathways to mitigate the risks associated with targeted strikes on major energy assets. Additionally, investing in the protection and hardening of renewable energy infrastructure through reinforced grid connectivity, enhanced surveillance, and cybersecurity measures ensures that Europe's transition to clean energy also enhances its strategic security and resilience.

Key technology domains:

- **Renewable Energy Generation**: Solar photovoltaics, wind turbines, geothermal systems, hydropower
- **Energy Storage Solutions**: Lithium-ion batteries, solid-state batteries, flow batteries, pumped hydro storage, hydrogen storage
- **Smart Grid Technologies**: Microgrids, smart meters, grid automation systems, demand response technologies
- **Clean Transportation**: Electric vehicles, hydrogen fuel cell vehicles, sustainable aviation fuels, electric public transit systems
- **Energy Efficiency**: High-efficiency HVAC systems, smart building management systems, advanced insulation materials
- **Carbon Capture and Utilization**: Direct air capture, bioenergy with carbon capture and storage (BECCS), carbon mineralization, CO_2-to-fuels technologies

Industry examples:

Skeleton Technologies (Estonia): A leading manufacturer of graphene-based ultracapacitors and energy-storage systems for transportation, grid, and defence applications. Skeleton's high-power ultracapacitors can deliver bursts of energy and recharge rapidly, useful for applications like engine start modules in tanks, regenerative braking in military vehicles, or stabilizing base microgrids. This European unicorn's innovation in advanced materials (curved graphene) exemplifies how cutting-edge cleantech can serve defence needs with faster and lighter energy storage.

NACO Technologies (Latvia) specializes in advanced nano-coating solutions designed to enhance the performance, reliability, and durability of critical industrial components. Founded in 2020, NACO develops cutting-edge nano-coatings that significantly reduce friction, corrosion, and wear, directly benefiting sectors like automotive, aerospace, renewable energy, and defence. Their proprietary vacuum-based coating technology improves component resilience under extreme conditions, making it especially valuable for military and security applications. NACO's technology is used to enhance the operational readiness and lifespan of equipment, vehicles, and weapon systems, supporting strategic defence capabilities, improving energy efficiency, and lowering maintenance burdens - essential aspects in modern security and defence contexts.

Food, agriculture, and land use

The recent disruptions in global food supply chains have underscored the vulnerability of Europe's agricultural sector. Heavy reliance on food and wood imports, fertilizers, and agricultural inputs from third countries - particularly ammonia from Russia - exposes Europe to significant geopolitical risks, price volatility, and supply chain disruptions.

Despite diversifying efforts, Europe still imports a substantial portion of its ammonia for fertilizer production, making it susceptible to supply cuts and price shocks. This dependency not only threatens agricultural productivity but also compromises broader food security and strategic autonomy.

Climate change further exacerbates these challenges, with increasing droughts, floods, and biodiversity loss threatening food production and rural economies. At the same time, attacks on critical agricultural infrastructure, including cyber threats targeting supply chains and disruptions to food logistics, highlight the need for greater resilience in food systems. Investing in green ammonia production - using renewable energy sources to synthesize ammonia - offers a dual solution: reducing dependency on imports while decreasing the carbon footprint of Europe's agricultural sector. Green ammonia can serve as a sustainable fertilizer input and a clean energy carrier, reinforcing both agricultural resilience and broader energy security objectives.

Sustainable and innovative agricultural technologies can significantly enhance food security and land-use resilience. Transitioning to regenerative and precision farming, adopting alternative proteins, and integrating climate-smart agricultural practices reduce dependency on external inputs, lower emissions, and enhance food sovereignty. Europe can mitigate geopolitical risks by fostering local, circular food systems and strengthening supply chain diversification while reinforcing economic stability and global leadership in sustainable agriculture.

Decentralized and climate-resilient agricultural systems, including controlled-environment farming and agroforestry, solve emerging threats. Smart agriculture, enabled by AI-driven monitoring, robotics, and soil health sensors, enhances efficiency and minimizes resource waste.

Strengthening Europe's agricultural resilience requires integrating food security into broader security and defence strategies. Investing in digital monitoring, supply chain traceability, and sustainable land management protects food production and supports climate adaptation and national security.

Key technology domains:

- **Regenerative and Precision Agriculture**: AI-powered soil health monitoring, precision irrigation, autonomous farming machinery
- **Alternative Proteins and Sustainable Food Production**: Plant-based proteins, cultivated meat, fermentation-based food production
- **Controlled-Environment Agriculture**: Vertical farming, greenhouse technologies, aquaponics, hydroponics
- **Climate-Smart Agricultural Practices**: Agroforestry, carbon farming, nature-based soil regeneration
- **Green Ammonia and Sustainable Fertilizers**: Production of ammonia using renewable energy sources for fertilizers, reducing dependency on imported natural gas-based ammonia. Applications in both agriculture as a low-carbon fertilizer input and in energy systems as a hydrogen carrier.
- **Supply Chain Resilience** and Digital Agriculture; Blockchain traceability, AI-driven logistics, cold-chain optimization
- **Sustainable Land Use and Biodiversity Protection**: Reforestation, soil carbon sequestration, ecosystem restoration

Industry examples:

Agrobiomics (Denmark) specializes in microbiome-based solutions aimed at enhancing crop resilience, yield, and sustainability through biological innovations. Founded in 2018, Agrobiomics leverages beneficial microorganisms to naturally strengthen plant immunity, reduce chemical dependency, and promote sustainable agricultural practices. Their technologies help ensure food security by enabling crops to better withstand diseases, climate stress, and environmental disruptions – factors increasingly relevant in national security scenarios. By securing stable food production and decreasing vulnerabilities in agricultural supply chains, Agrobiomics indirectly contributes to national defence preparedness, enhancing resilience against biosecurity threats and environmental crises.

Solar Foods (Finland) specializes in producing sustainable, protein-rich food through an innovative fermentation technology that converts air, electricity, and microbes into a nutritional powder called Solein. Founded in 2017, Solar Foods offers a revolutionary food solution independent of traditional agricultural practices and unaffected by climate or geopolitical disruptions. Their technology enhances national food security and resilience, significantly benefiting the security and defence sectors by ensuring stable, portable, and reliable nutrition for military operations, emergency preparedness, and disaster relief missions.

Raw materials

The European economy depends on a steady supply of key raw materials, such as rare earth elements, lithium, and cobalt, which are essential for industrial production, clean energy technologies, and digital transformation. However, the concentration of raw material supply chains in a few third countries creates strategic risks, including supply chain disruptions, price volatility, and potential economic coercion.

Diversifying and securing the supply of raw materials is crucial for strengthening Europe's economic and industrial resilience. Increasing domestic extraction, refining, and recycling capacities reduce reliance on external sources while fostering local economic growth, and job creation and meeting the growing resource needs of the European defence industry. Additionally, investing in sustainable mining practices and circular economy models ensures that Europe's raw material needs are met with minimal environmental and social impact.

Innovation in material science and resource efficiency is key in reducing demand pressures and mitigating supply risks. For example, novel synthetic graphite production technology: (1) could supply ~40% of EU graphite demand by 2035, (2) reduce emissions by >90% vs incumbent processes (imports from China), (3) despite higher cost than competition in China, has limited impact on final battery costs (<5%).[4] Another example – domestically produced lithium. Direct lithium extraction: (1) could supply ~7% of EU lithium demand by 2035, (2) reduce emissions by >90% vs incumbent processes (imports from China), (3) with initial estimates suggesting similar costs vs existing production.

Europe can lower its dependence on critical raw material imports while maintaining technological leadership by developing alternative materials, improving material recovery from end-of-life products, and optimizing industrial processes.

[4] Systemiq, EU CRM Innovation Roadmap, https://www.systemiq.earth/wp-content/uploads/2024/12/2024-12-10-EU-CRM-Innovation-Roadmap-vFinal-1.0-1.pdf

The EU Critical Raw Materials Act (2023) seeks to mitigate risks relating to raw materials by promoting domestic extraction, refining, recycling, and supply diversification. It sets ambitious benchmarks for 2030, such as extracting at least 10% processing 40% of the EU's annual need for critical raw materials domestically, and recycling at least 15% of consumption. Achieving these will require innovation and investment. Mechanisms like contracts-for-difference are being considered to de-risk markets and spur private investment in mining and refining. Alongside, fostering substitution and a circular economy is key – using alternatives where possible and recycling materials to reduce fresh import needs.

Key technology domains:

- **Domestic Extraction and Processing:** Expanding sustainable mining operations and refining capacity within Europe
- **Recycling and Circular Economy:** Enhancing material recovery from e-waste, batteries, and industrial byproducts
- **Material Innovation, Substitution and Efficiency:** Developing synthetic minerals, alternatives to critical raw materials and improving resource efficiency in manufacturing
- **Supply Chain Diversification and Trade Strategies:** Establishing strategic partnerships and securing ethical and diversified supply routes
- **Advanced Material Innovation:** Investing in next-generation materials with lower environmental impact and enhanced performance

Industry example:

Uplift360 (UK, Luxembourg) is a cleantech company focused on recycling and reusing advanced materials for the defence sector. They have an eco-friendly method to recycle para-aramid fibres (like Kevlar) from expired body armour, preserving material strength and reducing waste. They collaborate with Babcock Intl. to recycle and repurpose composite materials from defence equipment, enhancing supply chain resilience and sustainability.

2. BOLSTERING DEFENCE CAPABILITIES WITH CLEANTECH

Operational effectiveness is critical due to escalating geopolitical tensions and the necessity for strategic autonomy, which can be supported by adopting clean energy solutions and other clean technologies. The European Union actively seeks to enhance its defence capabilities, as evidenced by the proposed €800 billion ReArm Europe initiative, which aims to modernize military assets and reduce reliance on external powers.

Integrating clean technologies into the defence sector presents opportunities to improve various aspects of military operations. For instance, diversifying energy supplies through renewable sources can enhance energy security and operational efficiency, reducing the defence sector's vulnerability to fossil fuel market fluctuations. Modular production techniques for eSAF enable flexible, scalable, and localized fuel production, enhancing energy security and reducing logistic vulnerabilities in military operations. Moreover, the transition to cleantech can drive technological innovation within the defence industry, leading to the development of advanced systems that are both effective and environmentally responsible. Therefore, integrating cleantech solutions is pivotal in enhancing Europe's defence effectiveness while promoting sustainability and resilience.

Circularity, including modular and repairable technologies, is essential for enhancing both cost-efficiency and operational effectiveness in defence. Modular systems enable faster repairs and upgrades, minimizing downtime and ensuring that equipment can remain operational for longer periods. Prioritizing circular practices, such as component reuse, remanufacturing, and efficient maintenance, reduces waste and lowers lifecycle costs, directly supporting military readiness and sustainability goals. To maximize impact, the primary focus must be on achieving superior operational effectiveness, with sustainability serving as a force multiplier - ensuring that resources are managed strategically, supply chains are more resilient, and operational capabilities are maintained under diverse conditions.

Reducing supply chain vulnerabilities and reduced fuel dependence

Military supply lines are a critical vulnerability in modern warfare – fuel convoys and logistics hubs are often prime targets. As global tensions rise and operations extend, the ability to sustain forces without constant resupply becomes a strategic imperative. Reducing fuel demand means fewer convoys on dangerous routes and less exposure to disruption. Producing fuel onsite also strengthens supply lines by eliminating reliance on extended and vulnerable fuel logistics, ensuring consistent energy availability and reducing dependence on external sources.

Cleantech offers pathways to strengthen supply lines by cutting dependence on fossil fuels. Deploying renewable energy sources (e.g. portable solar panels and wind turbines) with advanced energy storage allows military units to generate power in the field rather than rely on vulnerable fuel deliveries. For example, forward operating bases can use solar microgrids and battery banks to run communications and sensors. Hybrid and electric propulsion in vehicles, ships, and aircraft further decreases fuel needs, extending operational reach and simplifying logistics. An electric or hybrid vehicle fleet can operate longer before refuelling and might be replenished via mobile generators or local grids rather than tanker trucks. These technologies improve battlefield sustainability and enable forces to operate with greater autonomy and stealth (an off-grid unit is harder to detect or isolate).

Importantly, many of these technologies have dual-use benefits: the same portable solar array or battery that powers a military camp can be deployed to disaster-struck communities to restore electricity. Thus, investing in them bolsters civilian resilience as well.

Key technology domains:

- **Renewable energy generation**: Portable solar panels, wind turbines, solar microgrids
- **Advanced energy storage**: Battery banks, mobile energy storage units, solid-state batteries
- **Hybrid and electric propulsion**: Hybrid-electric military vehicles, electric aircraft, electric naval vessels
- **Microgrid and decentralized power systems**: Deployable microgrids, mobile power stations, energy management systems
- **Alternative fuel technologies**: Hydrogen fuel cells, synthetic fuels, biofuels for military transport
- **Waste-to-energy systems**: Biomass gasification, waste-derived biofuels, field-deployable waste-to-energy units
- **Circularity and Modular Technologies**: Modular and repairable equipment to extend service life, standardized components for easier upgrades and maintenance, remanufacturing, and recycling of critical materials to reduce dependency on imports.

Industry examples:

SoliTek (Lithuania): A prominent manufacturer of lithium-ion battery systems and solar solutions for residential, commercial and industrial applications. Solitek's high-performance batteries provide reliable energy storage and efficient power management, making them ideal for integrating solar systems, mobile command centres, and uninterruptible power supplies for critical infrastructure, including security and defence. The company's advanced battery management systems ensure rapid response and durability in demanding environments, supporting applications like portable power units for military outposts and backup systems for secure communications. This Lithuanian company's innovation in sustainable energy technologies showcases how cleantech can enhance energy resilience and operational efficiency in the defence and security sectors.

Ineratec (Germany): A leading manufacturer of modular chemical plants for the production of eSAF (electro-sustainable aviation fuels) and other e-fuels. Ineratec's compact and scalable modules leverage power-to-liquid (PtL) technology, converting renewable electricity and water and capturing CO2 into synthetic hydrocarbons. These fuels can directly replace conventional jet fuels, significantly reducing carbon emissions in the aviation sector. This German company's innovation in modular reactor design and synthetic fuel production exemplifies how cleantech can drive the transition to sustainable aviation and support the decarbonization of hard-to-abate industries.

MAN Energy Solutions (Germany) specializes in advanced engineering solutions for sustainable energy production, propulsion systems, and industrial applications. Founded in 1840, the company provides innovative power generation technologies, including high-efficiency engines, hybrid propulsion systems, and energy storage solutions. Their technology directly contributes to the defence and security sectors by enabling reliable, efficient, and sustainable propulsion systems for naval vessels and submarines, enhancing operational readiness and reducing logistical vulnerabilities. Additionally, MAN's energy systems strengthen strategic autonomy by ensuring secure and resilient power supplies critical for military infrastructure and national defence operations.

Reduced thermal and acoustic signatures

Being harder to detect on the battlefield can mean the difference between survival and destruction. Advanced sensors like infrared cameras, radar, and acoustic detectors make it easier to find assets based on heat, noise, or electromagnetic radiation.

Tanks, generators, and aircraft with large thermal or acoustic signatures become obvious targets for precision-guided munitions and drones. Reducing these signatures is critical for stealth operations, especially for special forces, submarines, and unmanned systems operating in contested areas.

Reduction of the thermal and noise outputs. Hybrid-electric propulsion systems in submarines and armored vehicles generate far less heat and noise than conventional diesel engines. Some European diesel-electric submarines already use air-independent propulsion with fuel cells, allowing them to cruise silently for extended periods. Likewise, an electric vehicle has no engine noise and a much lower heat profile than a diesel vehicle. Fuel cells are a game-changer: they produce electricity electrochemically (e.g. from hydrogen or methanol) with almost no noise and minimal thermal footprint. Unlike a noisy petrol generator, a small fuel cell generator can power a forward unit's electronics silently. Additionally, low-altitude drones and autonomous unmanned systems can be operated with electricity and without emitting radio signals.

Additionally, materials science contributes through infrared-absorbing coatings, advanced insulation that can dampen heat emissions, and acoustic damping materials that can quiet mechanical noises. Cleantech advancements in materials (like graphene-based composites) yield lighter, stronger, and adaptive camouflage materials that help blend military assets into the environment.

Key technology domains:

- **Hybrid and electric propulsion**: Drones, hybrid-electric armored vehicles, electric submarines, electric unmanned ground vehicles
- **Fuel cell technology**: Hydrogen fuel cells, methanol fuel cells, air-independent propulsion for submarines
- **Infrared and acoustic signature reduction**: Infrared-absorbing coatings, thermally insulating materials, acoustic damping technologies
- **Advanced camouflage and adaptive materials**: Graphene-based composites, metamaterial coatings, adaptive thermal camouflage
- **Silent power generation**: Solid-state batteries, portable fuel cell generators, thermoelectric energy systems

Industry example:

Instagrid (Germany): Developer of portable battery power stations that replace gas/diesel generators. Instagrid's compact, high-output battery units provide reliable off-grid electricity for construction sites, events and first responders, eliminating noise and emissions from traditional generators.[5] Such technology can be invaluable for military field operations or disaster response, enabling silent, fume-free power anywhere.

Enhancing operational endurance and mobility

Operational endurance refers to how long forces can sustain their activities – whether a drone loitering in the sky or a unit deployed in the field – before needing to refuel, resupply, or rest. Traditional fuel-dependent vehicles (fighter jets, diesel trucks, etc.) have finite ranges and require frequent resupply, limiting how far and long they can operate. In an era where long-range, long-duration missions (like persistent UAV surveillance or rapid response across large threats) are critical, extending endurance is a decisive advantage. Mobility – the ability to manoeuvre quickly to where needed – is similarly crucial.

Boost endurance by making platforms more energy-efficient and increasing onboard energy availability. For example, high-density batteries or hydrogen fuel cells can enable UAVs or ground robots to operate for many hours longer than current technology allows. Lightweight composite materials reduce the weight of vehicles or aircraft, meaning they use less energy per distance and can carry more fuel or batteries instead of structural weight. Even for soldiers on foot, wearable energy solutions (like improved battery packs or energy-harvesting gear that captures solar or kinetic energy) can power communications and sensors longer, reducing the burden of carrying spare batteries and increasing their operational effectiveness.

[5] Instagrid: Startup Developing Electric Generators Raises $95 Million - Business Insider

Furthermore, self-sustaining forward operating bases – essentially combining the ideas of energy and water independence – allow troops to stay deployed longer without a supply line. If a remote base can generate its own power (solar and storage), produce water from air or recycle, and perhaps even grow some food or recycle waste into resources, it can operate for an extended period isolated, if need be.

Cleantech enhances endurance, giving forces greater freedom of action. A naval task force with hybrid ships and onboard solar augmenting power can stay on station longer. An army unit with autonomous solar-powered drones can reconnoitre longer and farther. These capabilities are force multipliers, which can be important for Europe when contemplating defence scenarios far from home or sustaining humanitarian operations in protracted crises.

While many of these solutions may not be ready for the next 10+ years, we need to start building and preparing for the capabilities of the future and implement them into defence planning.

It's worth noting the civilian co-benefits: these same advances help remote communities (for instance, island populations) to be self-sufficient and improve disaster response (longer-flying drones for search and rescue, etc.).

Key technology domains:

- **High-density energy storage**: Solid-state batteries, lithium-sulfur batteries, supercapacitors
- **Hydrogen and fuel cell technology**: Hydrogen fuel cells, methanol fuel cells and air-independent propulsion systems for UAVs and for ground robots
- **Lightweight composite materials**: Carbon fiber-reinforced composites, synthetic graphene-based structural components, metamaterials for aircraft and vehicles
- **Wearable energy solutions**: Kinetic energy-harvesting gear, flexible solar panels for soldiers, next-generation battery packs

- **Self-sustaining forward bases**: Solar microgrids, atmospheric water generators, waste-to-energy conversion systems

Industry examples:

Origin Robotics (Latvia): Developer of autonomous drones with applications in both defence and civilian sectors. They have secured a €4.5 million grant from the European Defence Fund to develop a portable intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) drone equipped with laser target designation. This technology can be adapted for various purposes, including environmental monitoring, which contributes to cleantech efforts.

SFC Energy (Germany): A company specializing in direct methanol and hydrogen fuel cells for off-grid power. SFC's portable fuel cell generators (such as the JENNY and EMILY units) are already used by NATO forces for silent, long-endurance power in the field.[6] These units convert methanol to electricity cleanly, allowing soldiers to charge batteries and sensors quietly without giving away positions – aligning with the military's demand for stealth power sources. SFC Energy is a prime example of an SME bringing cleantech to security applications.

Thales (France) and **Rheinmetall** (Germany) are other examples of big companies in the defence sector that are increasingly investing in energy and climate innovations – from Thales developing smart microgrid solutions to power mission camps to Rheinmetall exploring hybrid drives for combat vehicles and more sustainable ammunition manufacturing. These firms recognize that improving the sustainability of their products can provide competitive and strategic advantages (e.g. a hybrid armoured vehicle is not only greener but has better range and stealth).

[6] Clean Energy from Fuel Cells - SFC Energy AG » SFC Energy AG

Defending Critical Infrastructure from Attacks

European security and daily life depend on a web of critical infrastructure – power grids, communication networks, transportation hubs, pipelines, data centres, etc. These are attractive targets for adversaries in both hybrid warfare and open conflict. We've seen increased attacks on infrastructure: cyberattacks on power grids, sabotage of undersea cables, and drone strikes on energy facilities. In the war in Ukraine, for example, Russia is targeting power stations and transmission grids with missiles and drones, causing nationwide blackouts and stressing civilian resilience. Closer to the EU, the fall of 2024 saw incidents like the deliberate severing of the Estlink 2 power cable between Finland and Estonia, disrupting the electricity supply and raising the alarm about undersea infrastructure security. These events underscore that protecting infrastructure is necessary to ensure military readiness, civilian security, and economic stability.

Cleantech is crucial in making infrastructure more resilient and less prone to catastrophic failure if attacked. Decentralization is one strategy: instead of one big grid, many microgrids, instead of one massive data server, distributed computing, etc. In energy, decentralized renewable generation and storage mean an attacker cannot easily take down power everywhere at once. If parts of the grid are equipped to operate and run independently (with local solar, wind, and storage), towns or bases can keep lights on even if transmission lines are hit. This concept of "hardened microgrids" is gaining traction for European military bases and critical facilities. Europe is also actively pursuing cleantech initiatives to reduce the costs associated with undergrounding electric grid cables, e.g. in 2024, France's transmission system operator, RTE, has signed contracts worth €1 billion with European manufacturers to supply and install 5,200 km of underground cables. This initiative aims to streamline production and installation processes, thereby reducing costs and emphasising RTE's determination to adapt the French grid to support the country's transition towards carbon neutrality by 2050.

Another aspect is active protection: using clean, self-sufficient and minimal maintenance energy systems to power new defence systems that guard

infrastructure. For instance, an array of electric-powered anti-drone lasers or jammers could protect a power plant from drone attacks – running on its own solar/battery system to remain operational even if grid power is disrupted. Sustainably fuelled drones can also be used to protect hard-to-reach infrastructure such as undersea cables.

Material science also contributes: cleantech advancements like smart coatings can protect cables and electronics from electromagnetic pulses or interference by improving conductivity and shielding.

Fire-resistant materials (partially developed from cleantech research for better insulation) can help structures survive wildfires (happening in active conflict and becoming more frequent due to climate change).

Furthermore, modernizing the grid with smart controls (an area of cleantech innovation) can enable self-healing networks that automatically reroute power or isolate faults when physical damage occurs. This kind of resiliency is crucial to minimize downtime after an attack.

Key technology domains:

- **Decentralized energy systems**: Hardened microgrids, distributed solar and wind power, battery energy storage systems (BESS)
- **Resilient grid technologies**: Smart grids with self-healing capabilities, AI-driven fault detection, maintenance monitoring and fault detection, grid-islanding technology
- **Electromagnetic shielding and protective materials**: Graphene-based coatings for cables, EMP-resistant enclosures, fire-resistant insulation, solid lubricants
- **Clean-powered defence systems**: Hydrogen-powered anti-drone lasers, autonomous jamming systems, battery-backed surveillance networks
- **Smart grids and self-healing technologies**: AI-driven automated grid management, real-time fault isolation, adaptive energy rerouting systems

Industry examples:

SatVu (UK) specializes in high-resolution thermal imaging satellites for environmental monitoring, energy efficiency, and national security. Founded in 2016, SatVu launched HotSat-1 in 2023, capturing 3.5-meter resolution thermal imagery. Their technology aids in monitoring strategic sites, such as North Korea's Yongbyon facility, providing valuable intelligence for defence. SatVu's satellites support both climate action and security by delivering real-time thermal data.

Delian Alliance Industries (Greece) specializes in autonomous defence systems, integrating advanced robotics and sensors with proprietary AI software to counter physical threats swiftly. Their flagship product, the Lambda Autonomous Surveillance Tower (LAST), provides continuous monitoring of areas like forests, borders, and critical infrastructure without human intervention. In October 2023, they secured €6 million in seed funding to enhance their AI-driven defence technologies.

3. POST-WAR CONTEXT: CLEANING UP AND BUILDING UP WITH CLEANTECH

Wars have devastating effects on the environment, contributing to large-scale pollution, deforestation, and the destruction of ecosystems and infrastructure. In Ukraine, Russia's invasion has caused extensive environmental damage, with over 2,000 cases of potential environmental damage caused by Russian aggression[7] and the emission of an estimated 230 million tons of CO_2[8]. This doesn't even count for the need to rebuild a large share of Ukrainian building parks, roads, and energy infrastructure. According to Rapid Damage and Needs Assessment,[9] the total cost of reconstruction and recovery in Ukraine by the end of 2024 is estimated to be 506 billion euros over the next decade. 13% of the housing stock has been damaged or destroyed, impacting over 2,5 million households. Clean technologies will play a pivotal role in allowing to depollute, reforest and rebuild efficiently and rapidly in the post-war context.

Bombings, shelling, and the use of heavy artillery leave behind toxic chemicals that contaminate soil, water, and air, making entire regions uninhabitable. The destruction of industrial sites and energy infrastructure often results in oil spills, hazardous waste leaks, and long-term air pollution. Forests and agricultural lands suffer from fires, deforestation, and soil degradation, further aggravating food insecurity. Water systems are frequently disrupted, leading to shortages and the spread of waterborne diseases.

In post-war contexts, societies face severe health consequences from exposure to hazardous materials and the challenge of rebuilding homes, infrastructure, and economies. Destroyed roads, bridges, and power grids hinder economic recovery and prolong the humanitarian crisis. Moreover, landmines and unexploded ordnance pose long-term dangers to civilians and limit the safe use of land for agriculture or

[7] Ecoaction, War Map, 2025

[8] Ecoaction, Climate Damage Caused by Russia's War in Ukraine, 2025

[9] World Bank, RDNA 4

development. The loss of biodiversity due to habitat destruction and pollution can take decades to reverse, making ecological recovery a difficult challenge after conflicts end.

Cleantech offers solutions to mitigate the environmental damage caused by war and rebuild societies in a sustainable way. Drones, remote sensing and AI-powered mapping tools can assist in identifying unexploded ordnance and assessing environmental damage, ensuring safer redevelopment. These are the same solutions we currently use to plan sustainable land-use and agriculture. Water purification technologies, such as portable filtration units and desalination systems, can help restore access to clean drinking water where supply systems have been destroyed. Bioremediation techniques, including microbial treatments and phytoremediation, are the most cost-effective ways to remove toxins from polluted soil and water. Reforestation and land restoration programs can also revive ecosystems and improve climate resilience.

Renewable energy sources like solar and wind can replace damaged fossil fuel-based power grids, providing off-grid solutions for war-torn regions. Locally produced renewable energy also contributes to the country's increased autonomy, thereby improving its geopolitical security and resilience. Sustainable construction materials like recycled concrete, bio-based insulation, and 3D-printed structures can accelerate rebuilding efforts while reducing carbon emissions. Whereas electric and hydrogen-powered vehicles can replace damaged transport systems without further contributing to air pollution, they are probably not the first solutions to be adopted in a post-conflict context due to higher costs. By integrating cleantech solutions into post-war recovery strategies, societies can rebuild and establish more sustainable, resilient, and self-sufficient communities for the future.

Key technology domains:

- **Environmental assessment and hazard detection**: drones and AI-powered mapping tools used for detecting unexploded ordnance, assessing infrastructure damage, and monitoring environmental degradation; geospatial analysis and remote sensing helping to map deforestation, pollution hotspots, and land degradation
- **Water purification and restoration**: portable water filtration units providing clean drinking water in conflict-affected regions; desalination and wastewater treatment purifying polluted or saline water sources
- **Bioremediation**: phytoremediation and microbial bioremediation that removes pollution from contaminated water, soil and air
- **Reforestation and land restoration**: drone-based reforestation allowing to rapidly replant; agroforestry and soil regeneration helping to revive degraded agricultural land
- **Renewable energy and off-grid power**: solar, wind and hybrid renewable systems providing decentralized, resilient energy solutions; hydro and geothermal power; biogases, green hydrogen and clean fuels; power storage solutions like batteries and pumped hydro solutions
- **Sustainable reconstruction and circular economy in construction**: 3D-printed buildings helping to rapidly rebuild homes and infrastructure with minimal waste; recycled concrete and bio-based insulation reducing carbon emissions and promoting circular material use
- **Explosive and hazardous waste cleanup**: autonomous mine-clearance robots that safely remove landmines and UXO's and chemical decontamination solutions that neutralize chemical warfare residues and industrial pollutio

Industry example:

Leonardo (Italy): A major defence and security company integrating sustainability into its operations and products. Leonardo has partnered with energy company Eni to develop joint decarbonisation projects, focusing on sustainable aviation fuels, renewable energy use, and energy efficiency in aerospace production.[10] This cross-sector collaboration exemplifies how traditional European defence primes are adopting cleantech – by testing biofuels and e-fuels in aircraft, improving energy management on military sites, and incorporating circular economy principles (recycling materials, reducing waste) in manufacturing. Such initiatives ensure that the defence industry becomes greener and that its products (like aircraft) can operate on greener fuels, reducing strategic vulnerabilities.

[10] Eni and Leonardo working together on the development of decarbonisation projects

POLICY RECOMMENDATIONS: STRENGTHENING THE SYNERGIES BETWEEN CLEANTECH, DEFENCE, SECURITY AND RESILIENCE

The European Union and its Member States must take decisive action to leverage the synergies between the cleantech sector and European security, resilience, and defence. As geopolitical tensions and climate-related security risks intensify, it is imperative to identify and scale technological solutions that enhance energy, resource, food security and civil preparedness for crisis situations while maintaining the highest standards of operational effectiveness for defence and security stakeholders. These solutions must also prepare us for post-conflict de-pollution and rebuilding.

Integrating cleantech into defence, security and resilience strategies is no longer just an option but a necessity. However, achieving this requires coordinated efforts to bridge the gap between these sectors which often operate in isolation. Establishing a dedicated Task Force on Clean Technologies, Security and Defence would provide the strategic focus and expertise needed to accelerate this integration. The following recommendations outline the mandate, objectives, and activities for such a task force to enhance Europe's security and resilience through sustainable innovation.

1. Establish a Task Force on Clean Technologies, Security and Defence

- **Objective:** Create a dedicated task force to drive the integration of clean technologies with European defence, security and resilience efforts.
- **Rationale:** A specialized body can foster increased collaboration between cleantech, security and defence stakeholders by focusing efforts and streamlining investments and policies.
- **Proposed Actions:**
    - Identify Task Force members and objectives, establish a work plan.
    - Identify and evaluate existing and emerging clean technologies and stakeholders relevant to defence, security and resilience.
    - Address barriers to scaling, including regulatory and supply chain challenges.

- Develop procurement guidelines that prioritize sustainability, security, resilience and dual-use potential.
- Foster collaboration between European Member State defence, energy, climate and economic ministries, technology providers and users, and EU policymakers.

2. Increase Funding for Clean Technologies in Defence and Security Use

- **Objective:** Expand and refocus EU funding mechanisms, such as Horizon Europe and the European Defence Fund, to support clean technologies that benefit civilian and military applications for European defence, security and resilience.
- **Rationale:** Enhanced funding will accelerate developing and deploying key technologies that strengthen civilian autonomy, resilience and defence capabilities.
- **Proposed Actions:**
  - Identify and open existing funding mechanisms to clean technologies supporting European defence, security and resilience.
  - Establish new dedicated funding streams, including grants and debt mechanisms, for clean technologies contributing to defence, security and resilience under the existing EU programs.

3. Remove Barriers to Industrial Scale-Up

- **Objective**: Simplify regulatory procedures and harmonize standards across EU Member States to facilitate the industrial scale-up of cleantech solutions.
- **Rationale**: Streamlining regulations will help overcome delays in deploying clean technologies for increased security, resilience and defence capacities, ensuring faster adoption across defence and civilian sectors.
- **Proposed Actions**:
  - Create fast-track approval processes for cleantech projects with security, resilience and dual-use potential.
  - Harmonize certification standards for clean and defence technologies across the EU to ease cross-border deployment.

4. Ensure Robust and Secure Supply Chains

- **Objective:** Strengthen and diversify supply chains for critical raw materials and components used in clean technologies contributing to European defence, security and resilience.
- **Rationale:** Reducing dependency on single-source suppliers for critical materials and technology components is vital to security, resilience and defence readiness.
- **Proposed Actions:**
    - Ensure that Clean Industrial Deal initiatives support the development and autonomy of clean technologies and critical materials contributing to European defence, security, and resilience.
    - Establish EU-funded strategic reserves for critical materials essential for clean technologies.

By implementing these comprehensive strategies, the Task Force can significantly accelerate the adoption of clean technologies in the European defence sector, creating a more sustainable, secure, and resilient future for Europe. Increasing funding for dual-use technologies will catalyze innovation while removing barriers to industrial scale-up will ensure that promising cleantech solutions can be deployed swiftly and at scale. Strengthening and diversifying supply chains for critical raw materials will enhance Europe's strategic autonomy and reduce vulnerabilities.

As EU member states are procuring increasing amounts of weapons to be delivered as soon as possible, it is clear that few of those major weapon systems will rely heavily on cleantech solutions. However, as they will remain in service for decades, more consideration should also be given to cleantech solutions that will help to modernise capabilities mid-lifecycle. Technology insertion into legacy systems will be a significant issue, and cleantech should find its way into those capabilities through technology insertion mechanisms.

Harmonizing standards and procurement practices will promote interoperability and sustainable sourcing, making it easier for established defence contractors and cleantech innovators to contribute. Meanwhile, fostering cross-border collaboration and knowledge sharing will leverage the diverse expertise of EU Member States, aligning investments with climate and security goals.

By integrating these measures, the Task Force can position cleantech not just as a tool for environmental compliance but as a cornerstone of Europe's strategic resilience. In an era of converging crises, a Europe that leads in clean technologies can protect its people, its infrastructure, and its sovereignty.