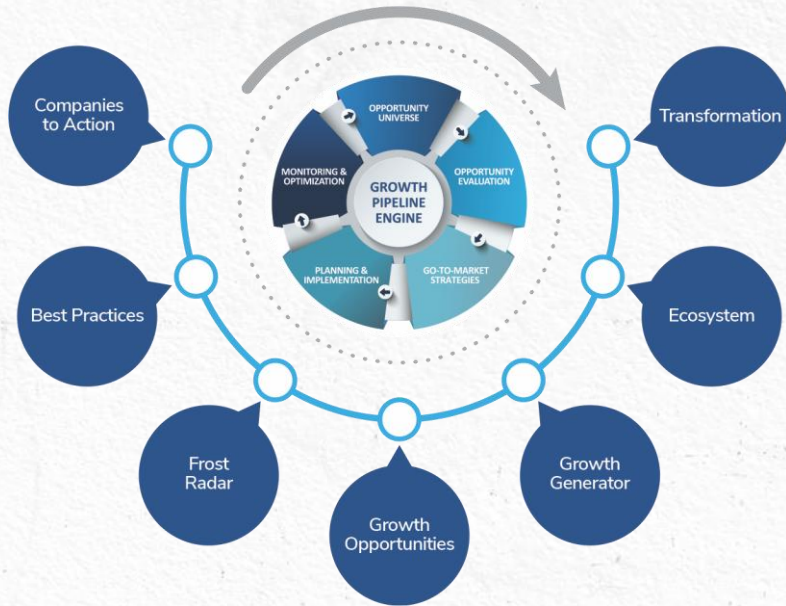


# TRANSFORMATIONAL GROWTH JOURNEY

*"Powered by the Growth Pipeline Engine"*



## Advanced Carbon Materials for Energy Storage Applications *Prepared for the Polymeris-Aramco Workshop June 2025*

### Our Agenda

#### STRATEGIC IMPERATIVES

Why Now? Why This? Why You?

#### BENEFITS & IMPACT

Survive & Thrive: Transformation

#### OUR SOLUTION

Growth Opportunity Analytics

#### NEXT STEP

Driving Your Growth Opportunities

# FOCUS POINTS

## 01 Introduction

## 02 Emerging Technologies

## 03 What Next?



# OVERVIEW: ADVANCED CARBON MATERIALS FOR ENERGY STORAGE APPLICATIONS

## Key Trends

Several key trends influence the use of advanced carbon materials in energy storage and battery applications:

- Growing demand for high-performance batteries, particularly in electric vehicles (EVs) and energy storage systems.
- Development of new battery chemistries that require advanced carbon materials for improved conductivity and energy density.
- Integration of artificial intelligence (AI) in battery energy storage systems (BESS) to optimize performance and efficiency.
- Focus on sustainability and recycling of battery materials to reduce environmental impact.

Drivers	1-2 Years	3-4 Years	5-7 Years
Rising demand for Li-ion batteries in EVs	High	High	High
Technological advancements in battery materials	High	High	Medium
Government incentives for renewable energy adoption	High	High	Medium
Declining costs of battery production	High	High	High

## Market Outlook

The market outlook for advanced carbon materials in energy storage and batteries indicates robust growth driven by:

- Increased adoption of Li-ion batteries for stationary energy storage and electric vehicles.
- Significant investments in battery manufacturing infrastructure to meet rising demand.
- Focus on high-energy density batteries, leading to innovations in carbon-based materials.
- Emergence of new applications in energy storage, automotive, and consumer electronics.

According to forecasts, the global demand for carbon-based energy storage solutions is expected to grow at a robust double-digit rate of around **15.0%** over the next seven years, significantly impacting the overall battery materials market.

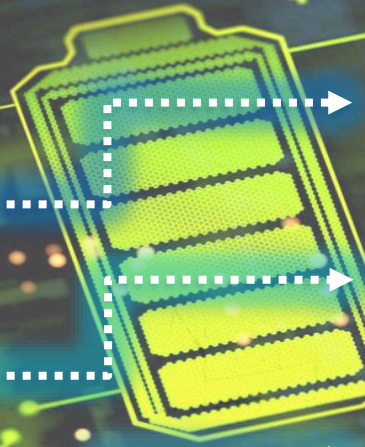
## FOCUS OF TODAY'S PRESENTATION

### KEY FOCUS AREAS

GRAPHITE

GRAPHENE

CARBON NANOTUBES  
(CNTs)



## DID YOU KNOW??

- **Graphite** is the dominant anode material in lithium-ion batteries due to its stability, abundance, and cost-effectiveness, making up almost **90 % of anode composition** and underpinning a **~\$5 billion market in 2024** projected to grow to **~\$12 billion by 2033**.
- **Graphene's** exceptional surface area and conductivity make it ideal for **high-performance supercapacitors and next-generation lithium-ion battery electrodes**, capable of faster charge/discharge cycles.
- **CNTs** (whether single-walled or multi-walled) extend battery life and capacity by reinforcing electrodes and enhancing conductivity, showing strong patenting activity, especially in **lithium-ion and zinc-ion batteries**.

# FOCUS POINTS

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## STAKEHOLDER INNOVATION ANALYSIS: ADVANCED CARBON MATERIALS FOR ENERGY STORAGE USE

US-based **COnovate** has introduced a graphene-augmented alternative to traditional graphite-based battery anode materials. The company has developed novel graphene monoxide material, eCOPHITE, using renewable bio-sourced raw materials as a drop-in replacement for graphite anode. It provides faster charging, higher storage capacity, and greater safety than graphite-based anodes.

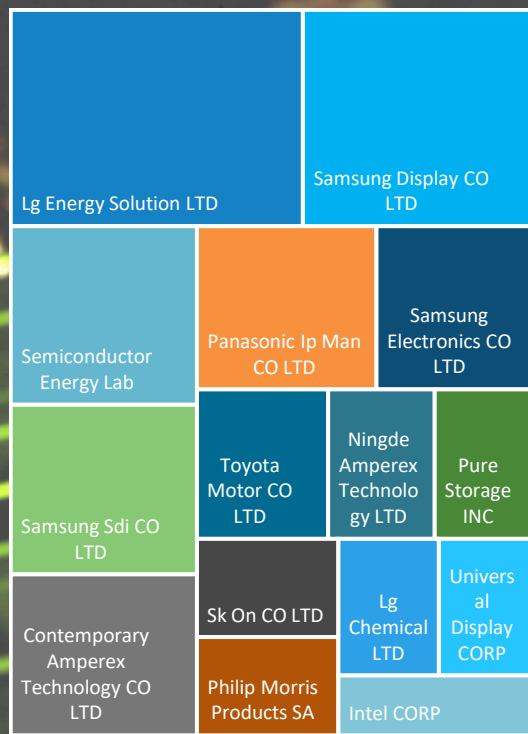
Estonian **UP Catalyst** offers next-generation Multi-Walled Carbon Nanotubes (MWCNTs) prepared from carbon dioxide emissions to boost the cyclability of sodium-ion batteries. The company uses low-energy Molten Salt Carbon Capture and Electrochemical Transformation (MSCC-ET) technology to produce sustainable carbon nanotubes. The CNTs are lightweight, conductive, and enhance battery capacity by up to 10X.

Latvian **Nano Ray-T** uses ultra-pure (99%) carbon nanotubes with metal sulfides as anode materials. The CNT-metal sulfide material has high conductivity, mechanical strength, and a capacity of about 150 mAh/g. This aids the material in outperforming most of the currently available anode materials for Li-ion batteries.

**Lyten** has developed a proprietary 3D graphene material, Lyten 3D Graphene™, for Lithium-Sulphur batteries. The 3D supermaterial graphene is prepared by transforming greenhouse gases and does not rely on critical materials like graphite. It is a lightweight, conductive, and strong material that can power the next generation of electronics.

# PATENT ANALYSIS: ADVANCED CARBON MATERIALS FOR ENERGY STORAGE USE

## Advanced Carbon Materials for Energy Storage Applications, Top Applicants, Global, 2023–2025\*



### Key Trends:

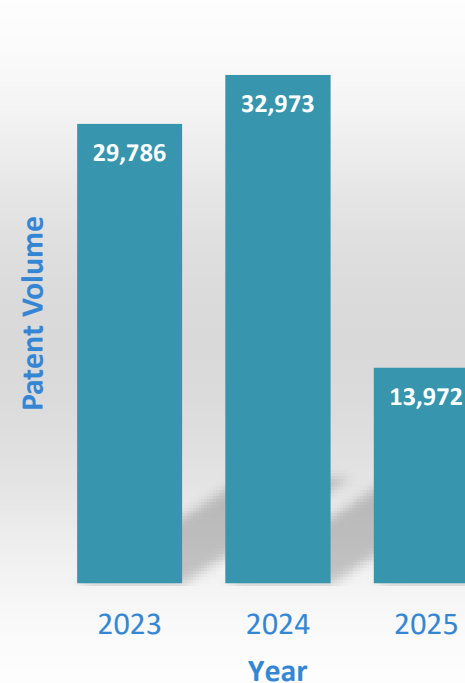
- **Top Applicants:** Likely dominated by:
  - **Asian tech giants** (Samsung, LG, Panasonic)
  - **US/EU material science firms** (Nanotech Energy, Skeleton Tech)
  - **Universities** (MIT, Stanford, Chinese Academy of Sciences)
- **Technology Focus:**
  - **CNT/graphene anodes** for Li-ion batteries (higher capacity, faster charging)
  - **Flexible/stretchable supercapacitors** (wearable energy storage)
  - **Hybrid materials** (e.g., graphene-metal oxide composites)
- **Geographic Hotspots:**
  - **China** (>50% of filings), **US**, **South Korea**, **Japan**, **Germany**
- **Commercialization Signals:**
  - Many patents focus on **scalable synthesis methods** (lower-cost production)

### Notable Gaps:

- Few patents address **recycling CNT/graphene batteries** (sustainability gap)
- Limited filings on **solid-state batteries** using graphene (an emerging opportunity)

## Advanced Carbon Materials for Energy Storage Applications: Patent Submission, Global, 2023–2025\*

### Total Patent Published



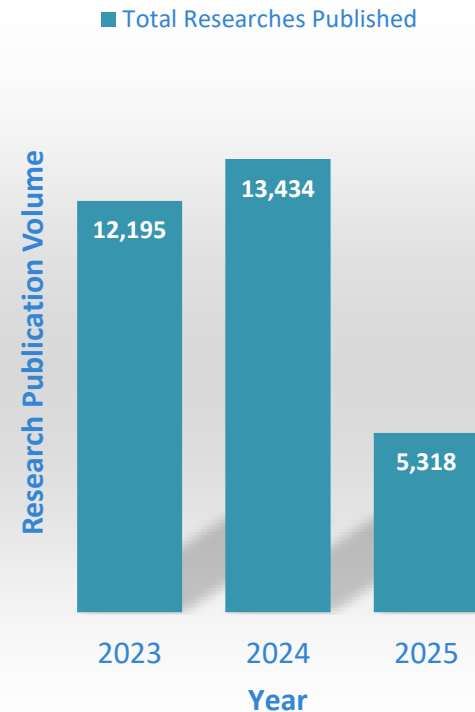
# RESEARCH PUBLICATION ANALYSIS: ADVANCED CARBON MATERIALS FOR ENERGY STORAGE USE

## Advanced Carbon Materials for Energy Storage Applications, Top Institutions, Global, 2023–2025\*



- **Key Trends:**
  - **Top Institutions:**
    - Chinese Academy of Sciences, Nanyang Tech (Singapore), MIT, UC Berkeley
  - **Research Themes:**
    - **Graphene oxide** for supercapacitors (high surface area)
    - **Defect engineering** in CNTs to enhance ion transport
    - **Machine learning** to optimize graphene-based battery designs
  - **Collaboration Networks:**
    - Strong **China-US-EU collaborations** in fundamental research
- **Emerging Areas:**
  - **Sustainable synthesis** (e.g., biomass-derived graphene, flash upcycling of agro-waste).
  - **Quantum effects** in graphene supercapacitors (e.g., twisted bilayer charge bursts, edge-termination tuning).
  - **AI-accelerated material design** (e.g., generative models for CNT-graphene hybrids).
  - **Solid-state integration** (e.g., graphene-enhanced sulfide electrolytes).

## Advanced Carbon Materials for Energy Storage Applications: Research Publication Submission, Global, 2023–2025\*



# FOCUS POINTS

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# FUTURE OF ADVANCED CARBON MATERIALS FOR ENERGY STORAGE USE

1

## Hybrid Architectures Will Dominate

Integration of graphene, CNTs, and other nanostructures with metal oxides or polymers will push boundaries in battery and supercapacitor performance.

2

## Scale-up & Standardization

Overcoming production, dispersion, and integration issues will be critical — expect movement toward scalable synthesis and robust standards.

4

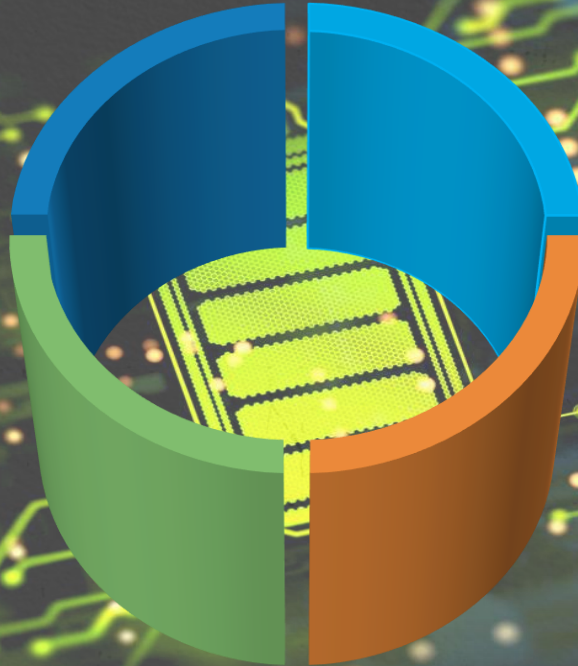
## Cross-Disciplinary Innovation

Convergence with AI, quantum simulation, and digital twins will accelerate discovery and deployment of new energy materials.

3

## Circularity and Green Sourcing

Focus will shift to sustainable feedstocks (e.g., bio-derived carbons) and recyclability of composite materials to align with ESG mandates.



# JOIN WORLD LEADING INNOVATORS AS A TECHVISION CLIENT



## USER BASE OF TOP 50 EMERGING TECHNOLOGIES



## CLIENT TESTIMONIALS



The Top 50 report and the convergence workshop were very helpful for our team to consider emerging technologies for our Research & Development roadmap. We cover various technology areas and then report coverage across the 9 Technology Clusters is very useful.

- Research Head, Premier Research Agency in Taiwan



We leveraged the TechVision workshop as an input to our long-term technology vision exercise and found it an excellent source of thought-provoking insights.

- Group Technology Leader, Global Tier 1 Oil & Gas Company



We used the Top 50 Tech methodology to scout for potential technologies that are relevant for our business divisions. This helped us to scan for opportunities for business expansion. The turnaround time was quick and the output very useful.

- Vice President, Corporate Strategy at a Japanese Conglomerate



Frost & Sullivan's team did excellent work on 3D printing landscape analysis through the workshop, helping us put in place strategic next steps to assess future impact across our products segments.

- Head of Global Technology Sourcing, A British Multinational Consumer Goods Company

**TAKE THE NEXT STEP**  
**MAXIMIZE YOUR FUTURE GROWTH**

**SCHEDULE A GROWTH PIPELINE DIALOG™**



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