

EDITORIAL

Acceleration of Green Transition: How Advanced Materials Fuel the Future of Net-Zero

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ABSTRACT

In 2025, the International Association of Advanced Materials (IAAM) celebrates its 15th anniversary and continues to lead the world's efforts to achieve net-zero emissions and climate neutrality. IAAM's comprehensive approach to advancing advanced materials research, bolstering global partnerships, and accelerating green transitions is highlighted in this editorial. IAAM uses cutting-edge technologies, such as carbon capture and renewable energy systems, digitalization, and circular economy models, to reduce environmental impact while adhering to the United Nations Sustainable Development Goals (UN SDGs). IAAM makes sure that both developed and emerging countries gain from sustainable innovation by putting a strong emphasis on cooperative R&D, efficient policy implementation, and the use of digital tools. The editorial also emphasizes how important smart grid infrastructures, hydrogen and electric mobility, and large-scale carbon management are becoming for a variety of industries and urban areas. Lastly, it examines how IAAM can bring together stakeholders from industry, governance, and science to embrace transformative solutions using significant global frameworks like COP summits, the G7, BRICS, ASEAN, and other regional initiatives. In the end, IAAM's leadership serves as an example of how persistent cooperation can propel the global materials community toward science and technology that is resilient, net-zero, and climate-neutral.

Green technologies and advanced materials offer a revolutionary way to reduce the impact of climate change while promoting sustainable development and global advancement. Achieving climate neutrality and net-zero emissions is more important than ever as climate change worsens, as evidenced by extreme weather, rising global temperatures, and unprecedented ecological stress. These state-of-the-art inventions have many advantages, including lowering carbon footprints, stabilizing ecosystems, and creating new opportunities for green growth. Societies can adopt circular economy models, effective resource management, and renewable energy sources that reduce emissions and strengthen environmental resilience by incorporating advanced materials into their current industrial and infrastructure frameworks.

Beyond their positive effects on the environment, green technologies and advanced materials actively spur new economic growth by luring sustainable investments and inclusive jobs. Their worldwide influence is in perfect harmony with global imperatives like the Paris Agreement and the United Nations Sustainable Development Goals

(UN SDGs), and they play a crucial role in facilitating the achievement of global standards for sustainable growth and climate action. These technologies have the potential to revolutionize industries, encourage low-carbon lifestyles, and guarantee that the world community stays on course for a climate-neutral, net-zero, and sustainable future through cross-sector cooperation, strong policy support, and ongoing innovation.

Urgency of Climate Neutrality

To achieve climate neutrality, the amount of greenhouse gases released must be balanced with the amount taken out of the atmosphere. However, new data highlights how big this problem is. According to the most recent UN SDG report, only 17% of the SDG targets are still on track, and more than half have made moderate to limited progress [1]. Over one-third of the targets have stalled or regressed. The UN Secretary-General has underlined that overcoming these obstacles requires audacious investments in energy, food systems, digital connectivity, and financial reform:

“Developing countries urgently require more financial resources and fiscal space. We must reform the outdated, dysfunctional, and unfair international financial architecture to facilitate far greater SDG investment.” – António Guterres, Secretary-General of the United Nations - The Sustainable Development Goals Report 2024.

Global Goals and the 2030 Agenda for Sustainable Development

The 2030 Agenda, which was endorsed by every UN member state in 2015, emphasizes how urgent it is for nations to work together to address interrelated social, economic, and environmental issues [2]. By promoting materials to build a sustainable and green world, the IAAM supports these goals [3, 4]. IAAM's 2030 vision and policy frameworks provide strategic direction for overcoming important sustainability challenges across continents, as shown in Fig. 1.

According to recent scientific studies, tangible net-zero emissions could be achieved by 2100, with a 90% reduction in the gap to meet the Paris Agreement's 1.5°C threshold [5]. Strong collaboration with governmental and non-governmental organizations, coordinated policymaking, and increased research in advanced materials are all necessary to meet these challenging goals [6–8]. Global goals must comprehensively address the social, economic, and environmental aspects of sustainable development, building on frameworks like the United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol (1997), and the Paris Agreement (2015) [6–9].

Europe's Climate Commitments and the Road to 2050

In order to attain total climate neutrality by 2050, the EU's First Biennial Transparency Report (BTR) at COP29 emphasizes the significance of reducing greenhouse gas emissions, investing in renewable energy, and having robust financing mechanisms [10]. Important conclusions include:

- Reductions:** In comparison to 1990, the EU reduced its net greenhouse gas emissions by 31.8% by 2022.
- Recent Declines:** According to preliminary data, there will be an additional 8% decrease in 2023, bringing the total decline since 1990 to 37%.
- Future Climate Goals:** To achieve full climate neutrality by 2050, net GHG emissions are expected to drop by 90% by 2040.
- Climate Funding:** To help developing countries reduce emissions and adapt to climate change, the EU and its member states contributed €28.6 billion in public climate financing in 2023, which was augmented by an additional €7.2 billion in private investments.

This roadmap, which emphasizes the need for cutting-edge materials, green technology, and simplified policy frameworks to effectively meet climate goals, is in line with IAAM's global vision. By combining these multi-decadal goals, Fig. 1 highlights how strategic prioritization can hasten global shifts toward a resilient, low-carbon, and inclusive future using renewable energy, carbon capture and storage, hydrogen technologies, and circular economy models.

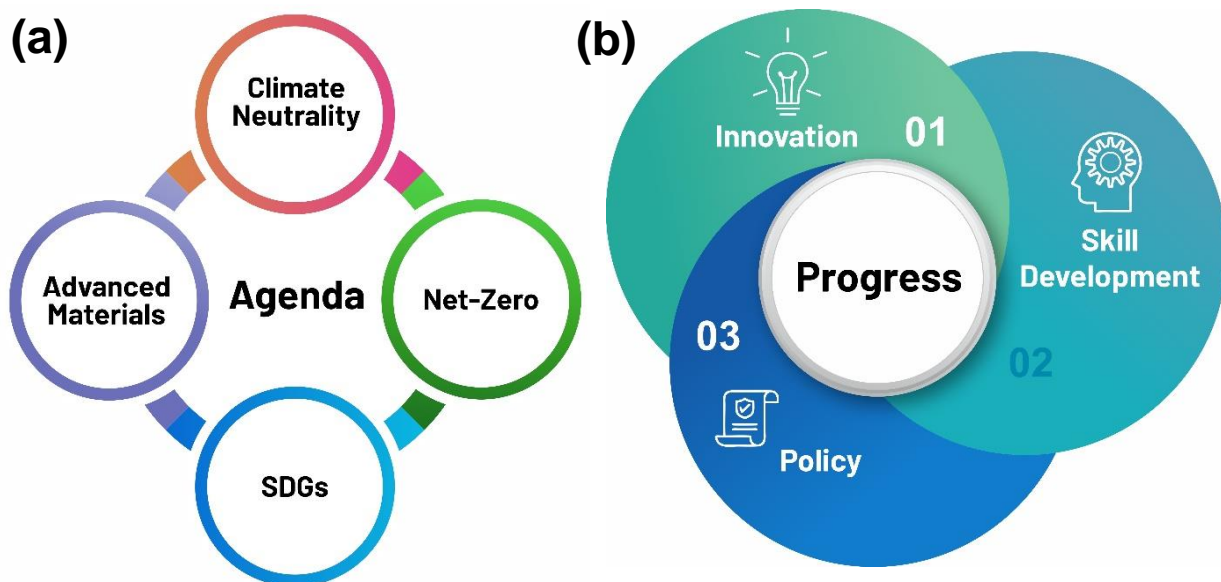


Fig. 1. Policy Guidance for Sustainable Initiatives: Global Strategic Priorities and Vision for 2030 to 2050, China 2060, and India 2070. Within certain timeframes—from 2030 to 2050 for Europe and beyond, extending to 2060 for China and 2070 for India—the figure depicts an integrated (a) roadmap of policy milestones and strategic frameworks that direct nations and regions toward net-zero emissions, climate neutrality, and sustainable development. Referring to both important regional policies like the European Green Deal and global initiatives like the UN SDGs, Paris Agreement, and COP summits, it emphasizes the (b) crucial role of advanced materials and green technology innovations.

Driving Net-Zero through Advanced Materials

The viability of a cost-effective, renewable energy economy is supported by numerous energy studies [11]. Achieving net-zero emissions requires cutting-edge technologies, such as hydrogen for smart grids and carbon capture for bioenergy. At the core of these changes is advanced materials research, which makes it possible for product life cycles to be more sustainable, more resilient, and more efficient [12,13].

Global Priority Aligned with the European Green Deal

In line with the 2030 Vision for Advanced Materials and Industrial Leadership, the European Green Deal supports a framework that is driven by knowledge and innovation [14]. In order to facilitate digital and green transformations for a circular economy, Europe wants to establish a strong, inclusive materials ecosystem by 2030 [15]. Under the Advanced Materials 2030 Initiative, programs such as EMIRI, EUMAT, SUSCHEM, and MANUFACTURE work together to ensure that early in the innovation process, Safe and Sustainable by Design (SSbD) methods have as little negative impact on the environment as possible [16].

Technologies for Achieving Climate Neutrality and Net-Zero

Extreme climate events are increasing due to persistent greenhouse gas emissions, particularly CO₂, methane, NO_x, and chlorofluorocarbons [17]. Adoption of renewable energy and ground-breaking developments in CCUS (carbon capture, utilization, storage), hydrogen mobility, and electrification of critical sectors are necessary for the shift to net-zero [18–20]. The path to a climate-neutral future is further cemented by carbon avoidance in the production of ammonia, steel, cement, and electricity, as well as by new technologies like Direct Air Capture (DAC) [21].

Carbon Capture and Storage

Projections from the Carbon Sequestration Leadership Forum (CSLF) and the International Energy Agency (IEA) emphasize the urgency of CCS by urging a significant increase in CCS projects by 2030 and 2050 [22]. Even though it will be difficult to immediately align with 1.5°C scenarios, doubling current initiatives could capture up to 0.37 Gt CO₂ annually by 2030 [23]. By 2030, this expanding market, which was valued at \$3.28 billion in 2022, is anticipated to grow at a compound annual growth rate of 6.2% [24].

Renewable Energy Transitions

Reducing global emissions still depends on scaling up geothermal, hydro, solar, and wind energy. Advances in offshore wind, photovoltaics, and battery storage technologies make renewable energy resilient and affordable. An estimated 13,750 TWh of electricity, or half of the current global output, may be needed by 2070 to

produce the 300 Mt of hydrogen produced by electrolysis [25,26]. At the same time, water-energy nexus strategies strengthen climate resilience, and smart grids optimize distribution and integrate variable renewable sources [27].

Digital Technologies

By improving climate modeling, cutting energy use, and improving logistics, big data and artificial intelligence (AI) are transforming sustainability. By 2050, AI is predicted to reduce global carbon emissions by 8–19% and reduce overall energy consumption by up to 40% [28–31]. Nonetheless, obstacles pertaining to funding, technological capability, and human resource development highlight how crucial strong policy measures are [32,33]. Additionally, digital innovations advance materials science and biosensing, two crucial areas for achieving the Sustainable Development Goals [34].

IAAM's Pillars for Green World

IAAM, which will commemorate its 15th anniversary in 2025, is dedicated to promoting advanced materials research for a net-zero and climate-neutral future [35]. Research and development (R&D) supports innovative manufacturing techniques, environmental safety, and the development of next-generation products. As illustrated in **Fig. 2**, IAAM's extensive global networking framework fosters partnerships between academia, industry, and government, creating the perfect setting for collaborative R&D [36]. Because IAAM is in line with important international conventions like COP summits and G7, BRICS, ASEAN, and other regional platforms, it is an excellent illustration of how advanced materials can serve as catalysts for long-term, transformative sustainability. IAAM fosters a global, multidisciplinary framework that drives advancements that are net-zero, climate-neutral, and sustainable by integrating technical innovation, skill-building programs, and policy alignment. **Fig. 2** shows the primary functional domains and collaborative networks that impact IAAM's research and development activities around the world. Highlighted are three interconnected pillars: R&D Work & Innovation, Skill Development & Training, and Policy & Agenda. These pillars show how universities, industry partners, and research organizations collaborate to advance cutting-edge materials science. Focus areas include Advanced & Nanomaterials, which includes biomaterials, electronic and optical materials, and hydrogen technology; Production, Synthesis & Development, which includes polymer science, composite and ceramic materials, and green construction; and Technology & Engineering, which includes net-zero solutions, biosensors, and computational modeling. Finally, accelerating green transitions through the use of advanced materials is both a necessity for the environment and an economic opportunity. A compelling example of how persistent work can steer the world toward a resilient, climate-neutral, and sustainably prosperous future is IAAM's leadership in net-zero innovations, strategic policymaking, and international cooperation.



Fig. 2. The research and development pillars of IAAM place a strong emphasis on international networking through R&D labs and consortiums.

IAAM's UNSDGs Focus

The International Association of Advanced Materials (IAAM) promotes ten major United Nations Sustainable Development Goals (UN SDGs)—SDG 3, 4, 6, 7, 8, 9, 12, 13, 15, and 17 [35–37]—through broad research and development (R&D) partnerships. IAAM empowers resilient communities around the world to address pressing issues like greenhouse gas emissions, resource depletion, and global climate volatility by giving priority to net-zero projects and climate-neutral technologies. In order to support sustainable solutions, IAAM's R&D Pillars place a strong emphasis on consortium-building, advanced materials research, and global networking, as illustrated in Fig. 2 of this editorial.

Core Focus Areas in Advanced Materials

The IAAM hosts Advanced Materials Congresses (<www.advancedmater.org>) where professionals discuss important issues impacting the transition to net-zero emissions and climate neutrality. Carbon neutral technology and materials, clean energy research, net-zero translational research, climate-efficient innovations, digital

biosensors, intelligent nanomaterials, functional electronics, optical and catalytic materials, polymers, ceramics, and biomaterials, as well as computational modeling and generative artificial intelligence, are all topics covered in conference sessions and symposia. These specialized tracks accelerate green transitions across industries by propelling the development of advanced materials in fields like energy storage, low-carbon construction, and AI-driven design [38].

Catalyzing Global Collaboration

IAAM's ten-year plan supports the idea of "Advancement of Materials to Sustainable and Green World" and is in line with the UN's 2030 Agenda. IAAM continues to lead conservation and climate resilience initiatives by emphasizing human health and clean environments [35].

- **Water Sustainability at the UN:** IAAM highlighted the use of advanced materials in addressing water crises in a specialized session on drought and flood preparedness during the UN 2023 Water Conference in New York (March 22–24) [39].

- *Policy Frameworks and Forums:* IAAM is positioned to bring together stakeholders from academia, industry, government, and civil society through its wide range of global policy forums, which include the

UN, COP summits, G20, G7, BRICS, ASEAN, and CARICOM (**Fig. 3**). IAAM supports innovative work in digital and energy technologies, carbon capture and storage, and circular economy models by supporting Consortium R&D.

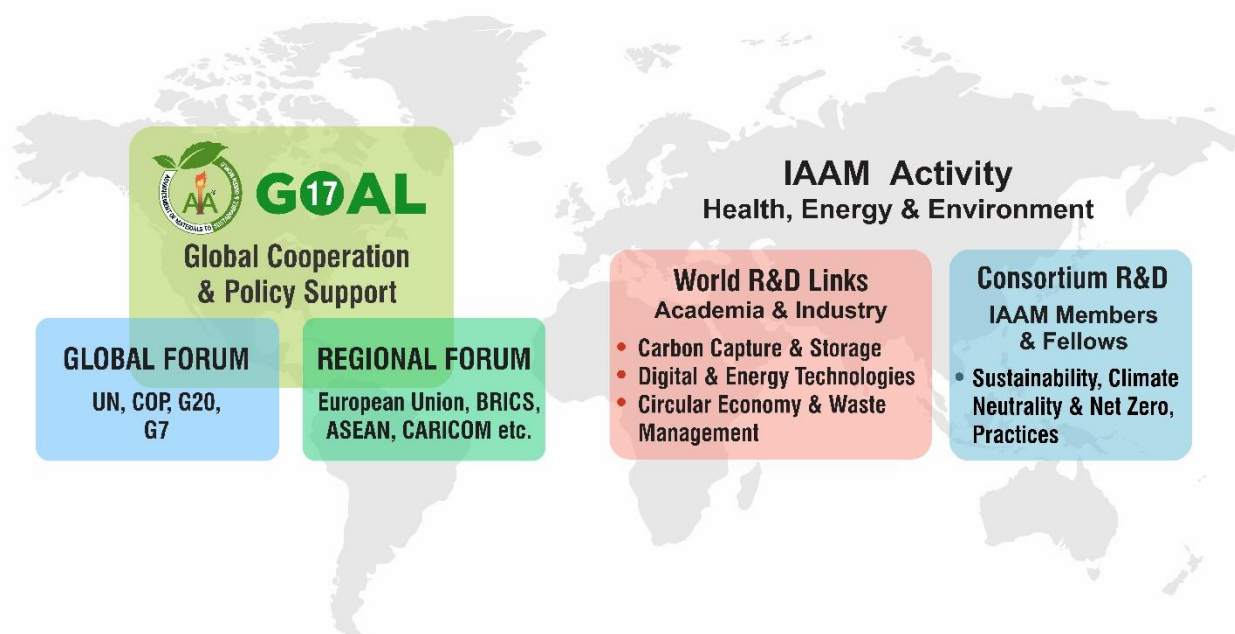


Fig. 3. The "Advancement of Materials to Sustainable & Green World" is the focus of IAAM's global policy frameworks, networks, and forums.

IAAM led high-level discussions on climate-efficient materials, greenhouse gas reduction, and carbon sequestration as a COP28-29 observer [40–42]. These talks highlight how important advanced materials are to reaching net-zero goals. Building on this momentum, IAAM keeps pushing for creative solutions at every COP forum to keep climate neutrality plans at the forefront of international agendas [43].

Driving Sustainable Technologies for a Green Future

The goal of sustainable technologies is to lessen their impact on households, workplaces, and entire communities [40–44]. Throughout its 15-year history, IAAM has promoted the use of cutting-edge materials in fields that are revolutionizing the industry, such as:

- Utilization, Storage, and Capture of Carbon in Agriculture and Forestry.
- Digital and Clean Energy and Healthcare Innovations.
- Smart Structural Materials and Carbon Neutral Engineering for the Development of Cities and Regions.

IAAM supports the shift to a climate-neutral world by combining net-zero research, green-energy investments, and circular economy strategies [42–46].

Sustainable Agriculture for Net-Zero Emissions

Approximately 25% of greenhouse gas emissions worldwide are attributable to conventional agriculture [47]. In order to reduce waste and increase crop yields, IAAM advocates precision agriculture, which combines drones, sensors, and AI analytics. Lab-grown meats and plant-based substitutes present promising low-emission options. These developments demonstrate how innovative agriculture can promote climate resilience since they frequently rely on new materials and digital technologies that lower energy consumption [34,48,49].

Building a Circular Economy and Managing Waste

The goal of a circular economy is to maximize resource reuse and reduce waste. Innovations in bio-based materials and the recycling of metals and plastics drastically cut down on emissions from the extraction of raw materials and landfill usage [50–52]. IAAM's roadmap to lower global carbon footprints and promote more sustainable production pathways is in line with the focus on natural materials and green manufacturing.

Goal 17 and IAAM's Worldwide Collaboration

Effective implementation of green technologies requires strong governance, laws, and private sector innovation. SDG 17 emphasizes the necessity of cross-sector

cooperation and promotes partnerships for sustainable development [53]. Carbon pricing, financial incentives, and strategic policies can accelerate the adoption of advanced materials and net-zero practices, as demonstrated by IAAM's Global Cooperation model [54].

Amplifying Climate Action through NDCs

Each country's plans for cutting emissions and preparing for climate change are outlined in its Nationally Determined Contributions (NDCs). The global climate agenda is shaped by 168 NDCs from 195 Parties [55]. IAAM emphasizes the significance of careful risk assessment and steady investment in agrifood systems, which currently receive only a small portion of total mitigation and adaptation funding, as conversations surrounding solar radiation modification (SRM) pick up steam, especially as COP29 approaches.

Raising Biodiversity Ambitions

Global biodiversity depends on initiatives to reduce harmful subsidies by \$500 billion, conserve 30% of land and water, and cut food waste in half by 2030 [56]. Reaching an agreement on sustainability measures is still a major challenge for the 198 UNFCCC Parties. Nonetheless, programs such as the Kunming-Montreal Global Biodiversity Framework indicate a growing dedication to low-carbon development while preserving ecosystems.

Spotlight on COP 29: A Global Climate Milestone

The most important annual forum for climate change negotiations is COP 29, which is set for November 11–22, 2024, in Baku, Azerbaijan [57]. Adaptation, resilience, climate finance, transition, and the global assessment of net-zero progress will all be covered. In keeping with UNFCCC principles, it also seeks to bolster global initiatives on youth, children, and community-driven climate action [6].

Climate Technologies under the UNFCCC Framework

Climate technologies are the cornerstone of international mitigation strategies, ranging from carbon capture and low-emission industries to solar and wind solutions. In order to close resource gaps and promote inclusive solutions, developed countries are expected to speed up technology transfers to developing countries [58].

Regional Pillars on the Global Stage

- *AI and the Digital Economy at the G20:* T20 Brazil and the Digital Economy Working Group's initiatives emphasize AI-driven growth and fair digital governance [59].
- *G7 Leaders' Summit:* Environmental preservation, climate action, and poverty alleviation were the main topics of the 2023 G7 summit in Hiroshima [60–61].

- In August 2023, Argentina, Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates joined BRICS, further solidifying its emphasis on sustainable development and inclusive multilateralism [62,63].
- *ASEAN Commitments:* By using 29 SDG indicators, Southeast Asian countries monitor their progress toward the 2030 Agenda, promoting digital connectivity and green infrastructure [64].
- *CARICOM Initiatives:* Partnerships in renewable energy, agriculture, and healthcare are highlighted by India's seven-pillar approach to engagement [65].

IAAM offers publication platforms and R&D consortia to support net-zero targets, sustainable development goals, and eco-friendly manufacturing as part of its global outreach [66–68]. In order to achieve concrete SDGs, IAAM's Global Roadmap promotes integrated approaches for emissions reduction, circularity, and cross-border cooperation.

CONCLUSION

Despite the many obstacles in the way, achieving net-zero emissions and climate neutrality is possible thanks to advancements in digital technologies, advanced materials, renewable energy sources, and cross-sector collaborations. It will take revolutionary scientific discoveries, strong international collaboration, inclusive policies, and significant investments to create a sustainable and green future. IAAM is essential in addressing the world's climate issues because of its steadfast commitment to green transitions, SDG alignment, and net-zero R&D. By combining knowledge from the scientific, governmental, and industrial domains, IAAM shows how strategic cooperation can hasten the adoption of sustainable technologies and ensure a healthier planet for everybody. IAAM is still a lighthouse for advancing advanced materials and guiding societies toward a resilient, net-zero, and climate-neutral future through its global networks and ongoing projects.

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