MONTHLY RESEARCH DIGEST

An Executive Briefing on New & Notable Sustainability Research

In This Issue – **June 2026**

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ENERGY

Environmental Cost of AI's Energy Use

By UNU-INWEH, in partnership with the government of Canada

View the full report here

Notable Highlights

- **Corporate AI investment exceeded $580 billion in 2025, a 130% increase from 2024.** Generative AI alone attracted nearly $34 billion in private investment.
- **In 2025, global data centers were estimated to consume 448 TWh of electricity**. If this usage were considered a country, it **would have ranked 11th in global electricity consumption.** Data center electricity consumption is **projected to account for almost 3% of projected global electricity use by 2030** (over 945 TWh).
- Global data centers' 2025 electricity consumption had a **water footprint of 4.5 trillion liters.** The **projected 2030 footprint is 9.3 trillion liters,** enough to meet the minimum annual water needs of all 1.3 billion residents of Sub-Saharan Africa.
- While AI training is highly resource-intensive, **the continuous inference phase** used to generate responses for billions of interactions **is estimated to account for 80-90% of total AI energy use.**
- The physical lifecycle of AI hardware presents a growing crisis. AI infrastructure could generate **up to 2.76 million tons of e-waste annually by 2030.**
- **Nearly half of the world's data centers are in the United States** (over 4,000).
- The following Report Findings include **principles for a responsible AI ecosystem.**

Objective

- To analyze the carbon, water, and land footprints of the energy required to operate AI at scale.

Background

- References are included on pages 53-55.

Report Findings

The global growth of AI (pg. 14-24):

- **The global AI market is projected to grow from $189 billion in 2023 to $5 trillion in 2033.**
- While North America is the global hub for AI capital and model development, **the fastest growth is now in the Asia-Pacific**, with China, India, Singapore, and South Korea investing heavily in AI infrastructure, research, and education.
- **78% of organizations reported using AI in their work** in 2024. About half of the respondents in an IPSOS survey expressed a **lack of trust in companies' abilities to protect their personal data** and concerns that AI systems could reflect or amplify bias.

The environmental footprint of AI's growing energy demand (pg. 25-36):

- **AI workloads accounted for roughly 20% of data center electricity use in 2025** and are projected to account for 40% by 2030.
- The **land footprint** of the energy used to run data centers in 2025 was around **2,664 square miles**, about 4.5 times the area of Greater London.
- Because **electricity mixes vary dramatically** across global data center hubs, even facilities with identical engineering and hardware **can have distinct environmental footprints**.
    - **Understanding the trade-offs is essential,** as reducing pressure on one footprint can shift the burden elsewhere.
    - For example, switching from coal to bioenergy can reduce the carbon footprint of an AI model by 72% on average, but the water and land footprints of bioenergy are over 30x and 100x that of coal, respectively.
- There is **a growing global divide in AI infrastructure:**
    - Only 32 countries host AI-specialized data centers, with over 90% of them concentrated in the U.S. and China.
    - Because data centers serve distributed/cross-border users, **countries that host large compute clusters tend to capture strategic advantages**, while nearby **communities may bear disproportionate environmental burdens.**
- Only a few AI model cards (documentation tools) provide the numbers needed to **estimate model footprints**. OpenAI released an **open-source model** to do so.

The environmental impact of AI tools and tasks (pg. 39-45):

- Even within the same category of AI tasks, the environmental **footprint of an individual query varies** with model choice and configuration. Pages 40-43 break down AI tasks and their respective footprints.
- There are opportunities to lower the energy required for inference. However, **efficiency is often associated with increased consumption:** As models become cheaper and faster, people tend to rely on them more, **which can erode energy-efficiency savings**.

Principles for a responsible AI ecosystem (pg. 46-52):

- **Transparency**: Use shared, decision-relevant metrics and disclosures for electricity, carbon, water, land, and material footprints so impacts are comparable across models, providers, and jurisdictions.
- **Treat efficiency as a design requirement:** Minimize resource demand across product choices and user experience and establish lower-impact baselines.
- **Lifecycle responsibility:** Govern beyond operational energy. Address extraction and manufacturing impacts, supply chain externalities, and e-waste/end-of-life management.
- **Global cooperation:** Harmonize disclosure norms, reporting boundaries, and governance approaches across borders and value chains to reduce regulatory arbitrage and burden shifting, support interoperability, and share benefits.
- **Sustainable use:** Cumulative impacts are driven by volume and everyday practices, not just per-query efficiency. Align deployment with opportunities for societal value and resource constraints, including demand management and model selection.
- **Equity and environmental justice:** Ensure affected communities can meaningfully participate in siting and governance decisions, and that benefit-sharing, safeguards, and remediation are built in where local burdens concentrate.
- **AI developers and producers should** embed efficiency into AI architecture (including user-facing controls such as batch processing); report on AI footprints in comparable, verifiable formats; and strengthen supply chain responsibility through ethically sourced materials, durable hardware design, and responsible e-waste management.
- **Investors and financial institutions** should incorporate AI-related environmental footprints into due diligence, finance efficient compute and cooling, and condition funding on AI accountability.

2026 State of the Market: Corporate Demand, Market Evolution, and Buyer Leadership

By Corporate Energy Buyers Association (CEBA)

View the full report here

Notable Highlights

- Corporate buyers have announced **143.8 GW** (gigawatts) **of new large-scale clean energy capacity in the U.S.** since tracking began in 2014.
- **2024 and 2025 were record years**, **with 24.3 GW and 27.5 GW of clean energy capacity announced,** respectively. 2026 is on track to be another record year, with 13.4 GW purchased in Q1 alone.
- Generation from corporate-contracted clean energy **announced 4% of total US electricity generation in 2025,** exceeding the output of 45 states
- **Clean firm technologies** (e.g., nuclear, carbon capture and storage) **are playing a more prominent role in buyer portfolios**, with nearly 6 GW of clean firm energy capacity committed in 2025.
- **Nuclear surpassed wind as the second-most-procured clean energy technology** among corporate buyers, with over 5 GW of capacity contracted.
- **The number of corporate buyers announcing deals declined by 40%** from 2024, with new entrants at their lowest level since 2016 (31 companies). This is due to rising PPA prices; infrastructure constraints; and tax, trade, and geopolitical instability.
- The following Report Findings include **examples of buyers innovating to enhance the grid** and bring clean power online.

Objective

- To track voluntary corporate clean energy purchases in the United States in 2025.

Background

- CEBA began tracking and reviewing the state of the voluntary corporate energy procurement market in 2014 (pg. 3).
- "Clean firm energy" is zero- or low-carbon power that can be delivered reliably on demand, regardless of weather or time of day.

Report Findings

Organized wholesale markets remain key growth enablers (pg. 7-8):

- In 2025, **approximately 85% of announced capacity occurred in organized wholesale markets**, led by ERCOT (which nearly doubled its cumulative tracked capacity from 2024 levels), MISO, and SPP.
- These markets **provide the scale, liquidity, price transparency, and contracting flexibility** that corporate buyers need to manage price risks.
- The expansion of organized wholesale **markets in the Western U.S.,** including ROWE, **is a significant opportunity**.

Clean firm energy purchases are growing (pg. 9-10):

- In 2025, **nuclear surpassed wind as the second-most-procured technology** among corporate buyers, with over 5 GW of capacity contracted. This **capacity is expected to generate more electricity than solar once operational**.
- Companies procured **more geothermal and hydropower capacity** than in any previous year tracked.
- Google announced a first-of-its-kind agreement to support a natural gas power plant with carbon capture and storage. Meta committed to supporting the creation and maintenance of 6.6 GW of nuclear energy on the US grid by 2035.

There is unprecedented complexity in clean energy procurement (pg. 11):

- Average **prices for wind and solar PPAs** in North America increased by 24% and 13% in 2025.
- **Permitting delays** and transmission constraints are slowing the integration of new generation onto the grid.
- ERCOT, MISO, PJM, and parts of the West and Southeast face growing risks related to **grid resource adequacy** over the next decade.

Buyers are innovating to enhance the grid and bring clean power online (pg. 12-14):

- Corporate buyers are increasingly **shaping how projects are developed, financed, and integrated into power systems by** collaborating with utilities, preserving and extending the life of existing clean energy assets, and driving efficiency and grid flexibility.
    - Google announced the world's largest framework agreement for the purchase of hydroelectricity.
    - Microsoft is partnering with MISO and NVIDIA to use AI to modernize grid planning in Southern California.
- Companies are **developing procurement mechanisms in the Asia-Pacific** to enable greater access to clean energy. For example, in India, Amazon's energy portfolio includes over 50 wind and solar projects totaling over 1 gigawatt of capacity.
- Leading buyers are **selecting projects that pair clean power with broader positive outcomes,** such as land-use and biodiversity protections, and job creation (see examples on pg. 14).

24/7 Renewables: The Economics of Firm Solar and Wind

By IRENA

View the full report here

Notable Highlights

- **As the share of renewable energy increases, a challenge is ensuring that clean electricity is available anytime it is needed**, not just under favorable conditions.
- **Hybrid assets combining solar PV, onshore wind, and battery energy storage systems (BESS) are emerging to provide flat, firm 24/7 renewable power.** They shift output to higher-value hours, enable more generation capacity to connect through existing grid infrastructure, can be deployed faster, and improve capture rates.
- In high-quality resource regions, **hybrid solutions can already deliver reliable 24/7 electricity at costs competitive with new fossil fuel generation:**
  - The firm levelized cost of electricity (F-LCOE) for **solar-plus-storage ranges from $54-$82 per MWh**, vs. new coal in China (LCOE of $70-$85/MWh) and new gas-fired plants globally (over $100/MWh).
  - **Wind-plus-storage F-LCOEs range from $59-$94/MWh** in China, Brazil, Germany, and Australia and are projected to fall to $49-$75/MWh by 2030.
- The following Report Findings include **key drivers of firm renewable electricity costs and four key developments** that will impact deployment in the next decade.

Objective

- To assess the cost-competitiveness of solar PV and onshore wind energy paired with lithium-ion battery energy storage systems (BESS) (i.e., “firming” variable renewable output into a continuous, dependable supply).

Background

- The report assesses the economics of flat, firm 24/7 renewable power at the asset level using a "firm levelized cost of electricity" (F-LCOE) benchmark (methodology on pg. 8, 51-59).
  - The benchmark is based on the open-source Integrated Energy Systems Optimiser model and data from the IRENA Renewable Cost Database, BloombergNEF, and Renewables.ninja.

    - For any given project, the model identifies the least-cost combination of storage capacity and co-located renewable overbuild (hybrid renewables built at the same site and with excess generation capacity) required to deliver flat hourly electricity for a year, subject to a specified reliability target.
- The report assesses projects in "high-quality resource regions" (with strong, consistent sunlight and wind): Australia, Brazil, China, India, Oman, the U.S., and South Africa.

Report Findings

The rise of 24/7 renewable power (pg. 18-23):

- **Annual matching is increasingly recognized as an inadequate method for measuring clean electricity** because companies can report near-zero emissions by volume, regardless of when or where the electricity was generated.
- **Project-level firming is most relevant where** customers require a continuous, firm supply, grid access is constrained, and conventional alternatives face extended lead times to bring new capacity online.
- As electricity demand from data centers, AI, and energy-intensive industries accelerates, the **deployment speed of hybrid renewable systems becomes a competitive advantage**. They are modular and scalable and can typically be developed and commissioned within 1-2 years of securing permitting and grid connections.
- Some large projects are already **demonstrating technical and commercial feasibility** (see examples on pg. 19).
- **Policy signals are reinforcing the case for firm hybrid renewable systems:**
    - US federal tax legislation had a differentiated credit structure for co-located projects, shifting project economics in favor of co-located and firm designs. As a result, around 20% of utility-scale solar additions in the first half of 2025 were paired with storage.
    - The ongoing revision of the GHG Protocol Scope 2 guidance proposes hourly and location-matched certificates as the basis for emissions claims, a shift already reflected in the European Union's CABM.

The economics of firm renewable power (pg. 9-16, 24-43):

- **Costs for solar-plus-storage declined by over 30% from 2020 to 2025.** Further cost reductions are projected (30% by 2030 and 40% by 2035), bringing the F-LCOE below $50/MWh at the best-performing sites by 2035.

- **China currently sets the global cost floor for firm renewable electricity. Costs outside China are declining rapidly but remain higher across most markets** due to higher financing and infrastructure costs, resource conditions, infrastructure constraints, and policy uncertainty (see details on pg. 27-33).
- **Key drivers of firm renewable electricity costs** (pg. 14-16, 35-43)**:**
  - Pages 35-37 include a detailed **breakdown of technology trends, cost trends, and cost drivers** for solar PV, onshore wind, and BESS.
  - **Decreasing costs for solar, wind, and BESS** are driving a rapid decline in the F-LCOE across all major markets.
  - **Resource quality and weather patterns** primarily determine whether a site can support cost-competitive firm renewable power. Pages 40-41 break down resource-related drivers of firming premiums for solar PV and onshore wind.
  - **Prolonged low-generation events** can still occur at well-resourced sites. Lithium-ion batteries have become indispensable for managing daily solar and wind variability; however, combining solar and wind generation is the most effective way to bridge multi-day or seasonal gaps.
  - **The chosen reliability target:** For most commercial and industrial applications, an 80-90% reliability target is the most cost-effective. Users with demanding supply requirements (e.g., data centers) typically require higher availability standards and backup strategies (e.g., grid redundancy).
  - Firm renewable electricity improves electricity input costs and electrolyzer utilization rates for green hydrogen and other power-to-X processes (e.g., power-to-heat). As a result, **the economics of clean fuels are set to improve.**

Accelerating the deployment of firm renewable electricity (pg. 44-48):

- **Four key developments across leading markets will impact deployment in the next decade:**
  - **Long-duration energy storage technologies** are maturing and becoming less expensive, progressively addressing multi-day and seasonal supply gaps. The most cost-effective firm renewable systems of the next decade will draw on a portfolio of storage durations rather than a single solution.
  - **Advanced digitalization**, including AI-driven forecasting, is allowing hybrid renewable systems to deliver more grid support services.
  - **Expanding interconnection** is providing land- and resource-constrained markets with access to reliable clean electricity from neighboring regions.

  - The maturation of **time-matched energy accounting** is making reliability visible, verifiable, and commercially valuable at a global scale.
- **Critical policy levers for accelerating firm renewable electricity deployment:**
  - **Fiscal incentives** for hybrid and firm configurations.
  - **Mandates** that require storage or firm supply as a condition of grid connection or market participation.
  - **Auction and procurement design** that requires firm, reliable power delivery as a contractual outcome, forcing developers to compete on least-cost configurations.
  - **Demand-side regulations** that require consumers to source power from verified, time-matched clean generation.
  - **Critical enablers** include diversified, resilient supply chains; grid infrastructure that connects resource-rich regions with data centers; and digital technologies such as AI.

The State of Clean Energy Manufacturing

By American Clean Power Association (ACP)

View the full report here

Notable Highlights

- **US manufacturing capacity is now sufficient to meet domestic demand** for solar and battery storage modules, as well as wind nacelles and towers. By 2030, domestic manufacturing **could meet most critical needs across the battery storage supply chain**.
- In 2025, **annual US solar module manufacturing capacity reached 63 GW** (gigawatts) **(a 1,600% increase** from 2020), and annual battery energy storage system **manufacturing capacity** reached **75 GW.** Annual **wind nacelle manufacturing capacity reached 26 GW** by Q1 2026.
- **Over 300 manufacturing facilities in the U.S.** produced primary components for utility-scale solar, battery storage, land-based wind, and offshore wind in 2025.
- Over 70 facilities began operations in 2025, bringing the total operational facilities to over 825 (with another 140 under construction).
- **Operational facilities generated $15.8 billion in earnings**, contributed $31 billion to GDP, supported $62 billion in domestic spending, and provided over 215,000 jobs in 2025. **Solar facilities accounted for half** of this economic impact, with land-based wind and battery storage each accounting for another 25%.
- Over **950 facilities are expected to be operational by 2030**. They're expected to generate $27.7 billion in earnings and support 374,000 jobs.

Objective

- To explore US manufacturing trends for solar, battery energy storage systems (BESS), and land-based and offshore wind.

Background

- The report focuses on various components in the utility-scale solar, battery energy storage, and wind supply chains (listed on pg. 55).
- The report is based on public government data, industry data provided by ACP member companies, and an analysis from the RIMS II model, which quantified the economic

impacts generated during both the construction phase of manufacturing projects and annual facility operations (methodology on pg. 2, 59-62).

Report Findings

The state of solar manufacturing (pg. 16-24):

- **Annual US solar module manufacturing capacity is expected to exceed 85 GW** per year by 2030.
- Over the past five years, **the number of operational plants** for primary solar components **has grown by nearly 150%.**
- Nearly **30 utility-scale solar PV manufacturing facilities started production** in 2025, while another 50 were announced or under construction.
- In 2025, c-Si (chemically treated wafer) module manufacturing capacity was sufficient to meet more than half of US installation demand. **C-Si cells** are expected to account for about **60% of the solar tech market share by 2030**.
- **Onshoring led to a 33% decrease in solar imports** from 2024 levels.
  - Onshoring solar-specific glass production is a **major supply chain opportunity**, as there is currently no domestic capacity.
  - Solar cell capacity has been slower to onshore than module manufacturing, primarily because secure offtake from downstream manufacturers is needed to justify the capital investment.
- There are over 25 solar panel recyclers in operation in the U.S.

The state of battery energy storage system (BESS) manufacturing (pg. 26-35):

- The U.S. is **on track to fully meet domestic demand for battery cells** by the end of 2026.
- **Over 30 battery manufacturing facilities came online in 2025**, bringing the industry to over 140 facilities.
- Domestic BESS **supply chain growth is accelerating**, with over 100 sites planned or under construction. BESS enclosure manufacturing (housing units for battery components) has also rapidly emerged.

- **Energy security concerns have spurred rapid onshoring** of electrical balance-of-system (E-BOS) components. Onshoring is set to reduce Chinese battery imports by over 70%.
- In 2025, Tesla commissioned a full-scale lithium processing plant, **more than doubling domestic lithium processing capacity** to over 28 GWh per year. If all planned capacity comes online, the volume of lithium processed could meet domestic BESS manufacturing demand by the end of 2026.
- The federal permit for **the only graphite mine in the U.S. is being fast-tracked**. Over 10 companies have announced US graphite extraction and processing projects.

The state of land-based wind manufacturing (pg. 37-42):

- **Wind nacelle manufacturing capacity reached 26 GW per year by Q1 2026**, **tower capacity reached 13 GW, and blade capacity reached 5 GW** (which is insufficient to meet land-based wind demand). The capacity increase is **largely due to technology advancements** in turbine efficiency and power output.
- Most nacelles and towers installed in 2025, and roughly half of the blades and hubs, came from US manufacturing facilities.
- Wind **turbine materials are 85-95% recyclable** over their lifecycle. There are at least two active recycling facilities and several labs piloting recycling practices.

The state of offshore wind manufacturing (pg. 44-46):

- There are over **30 domestically manufactured or refurbished offshore wind vessels**. Six became operational in 2025, with another five under construction.
- **Offshore wind requires over 300 tons of steel per MW** (megawatt) **of capacity**.
  - After billions in upgrade investments, **US steel mills can now produce the plates needed** to meet most offshore wind steel demand.
  - If all potential offshore wind came online by 2040, it would create **1.6 million tons of steel demand per year** (a third of the steel needed for the entire US energy sector).
- **Investments in offshore wind infrastructure can benefit the wider energy sector**, as over 90% of the barges, cable layers, and support vessels used in offshore wind can also support traditional energy operations.

CARBON DIOXIDE REMOVAL

The State of Carbon Dioxide Removal

By University of Oxford Smith School of Enterprise & Environment, SWP, Potsdam Institute for Climate Impact Research, University of Wisconsin-Madison La Follette School of Public Affairs, University of Maryland Center for Global Sustainability

View the full report here

Notable Highlights

- **Both carbon dioxide removal (CDR) and emissions reductions are needed to reach Paris Agreement goals**. Across scenarios, emissions reductions account for at least 80% of decarbonization, with CDR contributing the remainder.
- **Total removal from CDR was 2.2 GtCO2 per year in 2023,** equivalent to 5% of gross CO2 emissions. **Conventional, land-based CDR** (primarily afforestation and reforestation) **accounted for 99.9% of total removal.**
- **Novel CDR** (mostly biochar and bioenergy with carbon capture and storage (BECCS)) **accounted for 0.002 GtCO2 per year** but has been growing at 40% per year.
- **88% of all corporate investments went toward soil carbon sequestration** before 2021, and **40% have gone toward DACCS companies since 2021.**
- **CDR companies** have announced capacity targets indicating an **ambition to reach 5.29 Gt per year of novel CDR capacity by 2050.**
- **Global CDR would have to quadruple to 8.75 GtCO2 by 2050** to be on track for meeting the 1.5°C target.
- **Global CDR development depends** not only on technological advances but also on effective societal engagement and communication to gain **public support.**

Objective

- To assess global developments in carbon dioxide removal (CDR) technologies, including R&D, demonstration and upscaling, voluntary demand, and costs.

Background

- CDR is defined as human activities that capture CO2 from the atmosphere and store it durably (i.e., for decades) in products or geological, terrestrial, or ocean reservoirs.
- The report covers 16 CDR methods (listed on pg. 29), which are categorized as:
  - Conventional CDR (e.g., afforestation, soil carbon sequestration): well-established and already deployed at scale
  - Novel CDR (e.g., direct air capture and carbon storage): methods that generally have a longer storage timescale and a lower deployment readiness
- The data in this third edition of the report is based on an analysis of the CDR project pipeline; a survey of CDR companies; a review of country regulatory frameworks; scenario analysis; peer-reviewed literature; and reviews from executives at companies, NGOs, research institutes, think tanks, international bodies, and academic institutions reviewed the report (methodology on pg. 2-5, 77, 115, 135, 188).

Report Findings

Current CDR levels and landscape (pg. 14-15, 162-184):

▷ **Subchapters:** estimating current CDR levels (pg. 164), current conventional CDR (167), current novel CDR (171), carbon transfers between durable stores (177), CDR deployment pipeline (179), outlook (183)

- **The CDR system is highly concentrated:**
  - Deployment and pledges are **concentrated in one method** (afforestation and reforestation), while novel CDR is concentrated in **two methods** (biochar and BECCS).
  - **Over two-thirds** of conventional CDR in voluntary markets is **in Latin America.**
  - **One buyer dominates** the purchases of novel CDR (Microsoft).
  - Most **demonstration funding is concentrated** in Sweden, Denmark, and the U.S.

Paris-consistent CDR scenarios (pg. 187-213):

▷ **Subchapters:** temperature, emissions, and CDR (pg. 191), CDR portfolio trade-offs and opportunities (195), country and regional pathways (202), developing robust strategies despite uncertainties (209), outlook (212)

- In scenarios that represent the Highest Possible Ambition (full buy-in by all nations), global temperature peaks at 1.7°C-1.8°C around 2050.
- **Increasing required CDR volumes raises sustainability concerns** regarding land, water, ecosystems, and the resource demands of such deployment.

The CDR gap (pg. 217-229):

▷ **Subchapters:** the CDR gap (pg. 218), the size of the CDR gap (222), outlook (228)

- **The next five years are critical for establishing novel CDR.** The current project pipeline is too small, and delaying emissions reductions would significantly increase cumulative CDR needs.

Demonstrating and upscaling (pg. 57-83):

▷ **Subchapters:** trends in demonstration projects (pg. 58), government funding of CDR demonstrations (61), CDR startups and investment (69), company ambition for novel CDR (77), outlook (83)

- **CDR funding rebounded** after a dip in 2023 and 2024, **reaching $1.6 billion in 2025.** Its share of all climate-tech funding grew from 1.9% in 2022 to 2.6%.
- The number and capacity of **demonstration plants have grown dramatically** in recent years. Support for projects is strengthening in many countries, but it **has weakened in the U.S.** due to uncertainty surrounding the DAC Hubs Program.
- **Two programs provide around 70% of global funding for CDR demonstration and pilot projects:** the US DAC Hubs Program (44%, if all originally allocated funding is awarded) and the reverse auction program in Sweden (25%) (focusing on operational subsidies for BECCS projects).
- 88% of all **corporate investments** went toward soil carbon sequestration before 2021, and **40% have gone toward DACCS companies since 2021.**
- CDR companies and industry groups have announced **capacity targets indicating an ambition to reach 5.29 Gt per year of novel CDR capacity by 2050**, comprising 71% from DACCS, 19% from soil carbon sequestration, and 10% from biochar.

- **Meeting long-term novel CDR deployment goals will require rapid scale-up**—at rates on the high end of those seen for solar PV and electric vehicles, the fastest-growing climate technologies.
- CDR companies require a diversified, skilled workforce. This is essential for scaling CDR from pilots to large-scale deployment. **Talent availability is a key bottleneck**.

Voluntary CDR demand (pg. 89-105):

▷ **Subchapters:** the role of voluntary demand (pg. 90), voluntary CDR demand across markets (94), quality considerations (102), outlook (104)

- **CDR demand has grown.** Conventional CDR projects and mixed emission-reduction/CDR projects accounted for **7.6% of active projects on the voluntary carbon market** (VCM) from 2024 to 2025. Novel CDR projects accounted for 4.9%.
    - Afforestation, reforestation, and forest management accounted for the bulk of conventional CDR activity across all transaction types.
    - **Novel CDR credit issuances are growing much faster (over 100% year-over-year)** than conventional issuances. Contracted novel CDR volumes increased 4x and overtook contracted conventional CDR volumes for the first time.
    - Latin America and the Caribbean host 74% of all conventional CDR projects, while Europe hosts 48% of novel credit projects.
- **Conventional CDR credits often face challenges with additionality and the permanence of mitigation outcomes. Novel CDR credits** are often designed to address those challenges. However, **evidence of performance remains nascent for many methods,** and significant scientific uncertainties and MRV challenges persist.
- **Robust demand in carbon markets is critical to scaling CDR.**
    - **Demand is highly concentrated** among a small number of voluntary buyers. Microsoft purchased over 80% of novel CDR credits from 2024 to 2025.
    - Emerging sources of voluntary demand, including CORSIA, are unlikely to provide substantial new offtake given their lower average market prices relative to most CDR credits. **Additional mandatory sources are needed.**

CDR costs and removal potential (pg. 233-260):

- **Subchapters:** CDR method costs and global potential (pg. 237), wide variation in CDR potentials (250), cost drivers and uncertainties (253), CDR side effects (257)

- **CDR costs vary from $10 to over $1,000 per ton.** Most methods have upper limits exceeding $200 per ton.
  - Pages 237-248 break down the **global removal potential and costs for each CDR method.**
- **Carbon-removal potential also varies significantly across methods due to** low scientific understanding and data availability, inconsistent definitions, and assumptions about sustainability and durability. **The lower-range estimate for most methods is around 1 Gt of CO2 per year.**
  - **Diversifying portfolios** of CDR methods and **limiting reliance on methods** to well below their maximum potential can help balance risks, mitigate resource constraints, and optimize costs.
  - **Side effects can substantially affect the viability** of CDR methods. Some CDR elements compete with other climate actions (e.g., biomass constraints), while others create co-benefits (e.g., biochar can increase crop yields).

CDR policymaking and governance (pg. 108-129):

- **Subchapters:** status of CDR policy (pg. 36), targets inform policy (120), policy deep dives by country (124), outlook (129)

- **Conventional CDR policy is more prevalent** and more developed across countries, with a focus on afforestation and reforestation. **Most novel CDR policies focus on building capacity through supply-side support** rather than on creating demand.
- **Policy uncertainty and dismantling pose a risk to CDR momentum.** The U.S. has shown the most significant recent policy shifts (details on pg. 124-125).
- Pages 116-117 include an **overview of CDR policy development** across G20 countries and regions. The EU, the U.K., and Switzerland are exploring frameworks that could enable the future use of novel CDR in regulatory schemes.
- Governance frameworks for novel CDR remain largely underdeveloped, with some exceptions, such as the EU's CRCF.
- Over 100 countries have set net-zero targets, but only around one-third mention novel CDR in their long-term strategies.

Public perceptions of CDR (pg. 134-156):

▷ **Subchapters:** why public perceptions matter (pg. 36), public perceptions of CDR (139), communications about CDR (145), outlook (156)

- **Public support for CDR is uncertain. Attitudes toward CDR are driven by** concerns about its impacts on ecosystems and biodiversity, the need for good governance, an expectation of co-benefits, trust in relevant actors, broader values and beliefs, and a preference for low costs and financial benefits.
- **Recommendations for responsible communication related to CDR:**
    - Provide guidance, training, and administrative support to adopters.
    - Prove the reliability and effectiveness of CDR projects, including conveying local benefits.
    - Frame issues with care. Framing CDR as “geoengineering” lumps it together with controversial solar radiation modification technologies.
    - Communicate what is known and acknowledge what is not known.
    - Make field trial data readily accessible.
    - Facilitate dialogue to offer stakeholders opportunities to raise concerns and strengthen decision-making.
    - Develop local, context-aware communication approaches.

CDR research and development (pg. 35-54):

▷ **Subchapters:** R&D funding (pg. 37), patenting activity (48), outlook (52)

- **Total CDR funding increased by about 13% per year from 2022 to 2025** due to a shift toward larger, higher-value projects.
- CDR research grants accounted for **4.4% of all low-carbon technology grants** awarded from 2005 to 2025.
- **The total funding volume** for CDR research grants **is estimated at $5.6 billion,** with $1.9 billion (34%) being awarded in the last three years.
- **Soil carbon sequestration accounted for the largest share** of active grants from 2023 to 2025 (24%).
- **Mineral products are a significant focus** of CDR innovation, accounting for 14-30% of annual patenting activity between 2005 and 2022.

BUILDINGS

Global Status Report for Buildings and Construction 2025-2026

By UNEP, Global Alliance for Buildings and Construction

View the full report here

Notable Highlights

- **Global building sector decarbonization has plateaued** since the COVID-19 pandemic, reaching just 2.8% in 2024.
- From 2015 to 2024, **global building operational emissions** increased by **6.5%, energy demand** increased by an estimated **11%,** the **share of renewables** in buildings' energy supply increased by **4.7%,** and **energy consumption** per square meter decreased by **8.5%.**
- To align with a net-zero pathway, **by 2030, building operational emissions must decrease by 56%** (from 2024 levels), the **energy intensity** of the global building stock **must decrease by 25%** (from current levels), and the **share of renewables in buildings' power supply must increase from 17% to 46%** (from 2024 levels).
- **Around $2.3 trillion has been invested to improve building energy efficiency worldwide since 2015**, with annual investment reaching **around $275 billion in 2024** (a 38% increase from 2015 and a 3% increase from 2023). **An additional $3.6 trillion is needed by 2030** to align with a 2050 net-zero pathway.
- Building and construction **decarbonization must be accompanied by adaptation and resilience measures.** Adaptation and resilience risks can be measured in different ways depending on the geographic context and the availability and quality of data. Page 88 includes **examples of adaptation and resilience indicators.**
- **T**he following Report Findings include **recommendations and priority actions** to reduce building emissions and energy intensity, increase the share of renewables in building energy supply, and accelerate investment in building energy efficiency.

Objective

- To assess annual decarbonization progress in the global building and construction sector.

Background

- The report monitors progress toward the goal of net-zero building emissions by 2050 (according to the IEA's NZE Scenario) from 2015 to 2024, with extensions to 2025 where data permits.
- The report data is based on seven indicators: building operational emissions; energy efficiency investments; the growth of green building certifications; NDCs with extensive building plans; building energy codes aligned with zero-emission principles; building stock energy intensity; and the share of renewable energy in final energy demand (methodology on pp. 5, 104-106).
- Executives from consultancies, academic and research institutions, industry and business councils, government agencies, and intergovernmental bodies contributed to and reviewed the report.

Report Findings

Global building and construction sector trends (pg. 28-35):

- In 2024, the **global floor area of buildings increased by 1.7%** (1.06 million square miles), roughly equivalent to a land area four times the size of New York.
- The global **construction market is projected to grow** from $11.4 trillion in 2024 **to $16.1 trillion by 2030**, driven by urbanization, digital transformation, and the energy transition.
- This expansion of floor area and construction activities is **putting pressure on raw material extraction and energy demand**, thereby driving building emissions.
- **The housing sector plays a key role in reducing the climate impacts of buildings.**
    - Residential buildings **account for 70% of total energy demand** worldwide.
    - **Housing affordability is an interrelated challenge**. Around 1 billion people live in informal settlements. These are typically built outside regulatory standards or require upgrades people can't afford, making them vulnerable to climate impacts.
    - **Both challenges should be tackled together** to harness synergies and ensure that actions addressing one don't exacerbate the other (see examples on pg. 35).
- Widespread **estimates of new and retrofitted buildings** are lacking, limiting the understanding of buildings' quality and capacity to withstand climate change. **New infrastructure is needed to collect and aggregate such data.**

Building carbon emissions (pg. 36-44):

- **Embodied emissions** (generated from the production and transport of building materials) from cement, steel, and aluminum have **remained unchanged since 2015**.
- **Recommendations to reduce buildings' operational and embodied emissions:**
  - Develop **emissions requirements** for existing and new buildings, including clear principles for measuring, disclosing, and limiting lifecycle emissions.
  - Develop **explicit, time-bound plans** to phase out fossil fuels from buildings' energy supply and limit fossil fuel use in new buildings.
  - Integrate behavioral change, energy efficiency, electrification, and renewable energy targets into **building policies**.
  - **Harmonize definitions** for reporting on near-zero-, zero-emission, and resilient buildings, based on existing regional and international definitions.

Building energy demand, efficiency, and intensity (pg. 45-52):

- The total energy demand of buildings has grown more slowly than the expansion of the building stock. Between 2015 and 2024, global floor area increased by 20%, while energy demand increased by 11%. **Without energy efficiency improvements, the increase in energy demand would have been twice as large.**
- Global building energy **demand increased by 2% from 2023 to 2024**, driven by growth in floor area, consumer product demand, and the effects of extreme weather.
- **Recommendations to reduce building energy intensity:**
  - Introduce energy efficiency and sufficiency requirements for procurement, financial, and technical support schemes, as well as requirements for electrification and the deployment of renewable energy where appropriate.
  - Promote passive thermal comfort strategies to meet heating, cooling, and ventilation demands with minimal energy use. Consider urban-scale measures (e.g., vegetation, shading, and urban design) to reduce cooling demand.
  - Accelerate **retrofitting and electrification** before 2030 by strengthening workforce capacity and streamlining permitting.

Building energy supply, renewable energy share, and electrification (pg. 53-58):

- The share of **buildings' energy supply generated by on-site renewables has hovered at approximately 5%** from 2015 to 2024, largely due to high upfront costs and regulatory and policy hurdles.
- The **US heat pump market grew by around 11% in 2024**, the fourth consecutive year in which heat pump sales exceeded gas furnace sales.
- **Recommendations to increase the share of renewables in building energy supply:**
    - Promote existing and emerging **technologies** appropriate to the local building stock and climate.
    - **Set clear targets** for deploying renewable energy and phasing out fossil fuels.
    - **Couple electrification initiatives** in new and existing buildings with a clean, renewable electricity supply.
    - Align **heating and cooling policies** to optimize the deployment of efficient in-building technologies.

Investment in sustainable and resilient buildings (pg. 80-85):

- Global annual investment in building energy efficiency reached around $275 billion in 2024, a 3% increase from 2023. **Budget constraints led governments to reduce financial incentives** for energy efficiency, particularly in the EU.
- A key challenge for investors is determining where capital can deliver the greatest impact. **Taxonomies that define criteria for green building investments can support decision-making.**
- **Recommendations to accelerate investment in building energy efficiency:**
    - Conduct **opportunity-cost analyses** for energy-efficiency interventions and for extending the life of buildings.
    - Strengthen **public-private collaboration** (e.g., through partnerships that enable private financing of government-backed initiatives).
    - Utilize neighborhood- and district-level **financial support schemes**, retrofitting, repurposing practices, and technical solutions.

Policies for climate-resilient buildings and construction (pg. 59-67):

- **Notable changes in national buildings and construction policies in 2025:**
  - **The U.S. saw the most notable shift** away from climate-focused building policy with the passage of the OBBBA, which repealed support for retrofits and rolled back federal programs promoting low-carbon building materials.
  - The UK Future Homes Standard came into effect, which aims to reduce carbon emissions from new buildings by around 75% relative to existing standards.
  - China announced plans to expand its emissions trading scheme to include steel, cement, and aluminum.
- No G20 country has submitted an NDC with an extensive strategy for cutting building and construction emissions.

Building energy codes (pg. 68-74):

- As of mid-2025, **building energy codes covered approximately 60% of new construction worldwide**.
- Only **the U.S. and Canada have zero-emissions-aligned building codes**, **which are voluntary** at the state level.
- In the U.S., the IECC is gradually being adopted by states. It is expected to reduce energy use by 7.8% in residential buildings and by 10% in commercial buildings.

Green building certifications (pg. 75-79):

- From 2015 to 2024, **the number of green building certifications worldwide nearly tripled**, equivalent to about two-thirds of the increase needed to reach net zero by 2050.
- Strengthening **post-certification monitoring and performance** verification can help ensure certified buildings deliver measurable energy and emissions reductions.

Priority actions to accelerate building decarbonization (pg. 93):

- **Develop building decarbonization strategies**, including actions and targets for energy supply, appliance efficiency, green building certifications, material supply chains, circularity, urban planning, and finance.
- **Drive demand for low-carbon building energy solutions** by adopting plans to phase out fossil-fuel heating and cooking, scaling up deep retrofitting, and leveraging public procurement. Focus on plans that deliver quantitative results.

- **Reduce building energy intensity** by setting minimum performance standards for existing buildings, incorporating energy efficiency and sufficiency (reducing demand by consuming only what is genuinely needed) into building energy codes, and promoting passive heating and cooling designs and retrofits.
- **Strengthen capacity building** and knowledge transfer of low-carbon construction practices.
- **Use green certification schemes**, including integrating them into building procurement.