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# *Breathing Buildings in a Changing Climate: HVAC-Integrated $CO_2$ Capture and Storage Pathways*

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***Abstract.*** HVAC-integrated $CO_2$ capture has been proposed as a supplementary carbon-management approach for buildings equipped with ventilation and air-conditioning systems that move large volumes of air. This focused structured narrative review synthesises 24 peer-reviewed journal articles published from 2020 to July 2026, examining building airflow, $CO_2$ capture media, HVAC integration, energy and economic performance, gas conditioning, and material-storage pathways. The evidence shows that higher indoor $CO_2$ concentrations increase the available mass per unit airflow, yet annual $CO_2$ recovery is influenced more strongly by sustained ventilation, operating hours, climate conditions, humidity, duct accessibility, and regeneration-energy requirements. Equipment demonstrations confirm that capture modules can be integrated with air-handling units, although additional fan power, sorbent degradation, moisture control, and limited test durations remain important constraints. Model-based studies indicate that energy and carbon performance vary widely with system configuration, control strategy, climate, and electricity or heat supply. Porous sorbents support reversible retention and indoor $CO_2$ concentration management, whereas cementitious utilisation and mineral carbonation offer more durable storage pathways. However, no study identified in this review has yet demonstrated a continuous pathway linking $CO_2$ capture in an occupied building to final cementitious storage. HVAC-integrated capture is therefore most credible as a selective application in buildings with stable airflow, low-carbon energy for sorbent regeneration, and access to a nearby material-processing facility. Future evaluations should distinguish captured, conditioned, delivered, utilised, and ultimately retained $CO_2$ within an integrated mass, energy, and carbon-balance framework.

***Keywords:*** HVAC-integrated $CO_2$ capture, indoor $CO_2$ capture, building ventilation systems, cementitious $CO_2$ utilization, mineral carbonation

## 1. Introduction

### 1.1. Background, research gap, and objectives

Buildings and construction remain central to global decarbonisation efforts because their climate impact extends across operational energy use, material production, renovation, and end-of-life processes [1]. Demand reduction, passive design, efficient equipment, and cleaner energy supply

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therefore remain the main foundations of green building practice. $CO_2$ recovery from indoor or exhaust air has emerged as a supplementary carbon-management pathway, especially where ventilation systems already move large volumes of air through central equipment [2]. Its value cannot be judged by capture capacity alone, since the added energy for airflow, sorbent regeneration, and downstream handling may offset part of the benefit. In this paper, the term "breathing building" is used as a conceptual label for a building that combines air handling with $CO_2$ recovery while maintaining indoor air quality and controlling the additional burden imposed on the HVAC system.

Indoor air commonly contains higher $CO_2$ concentrations than outdoor air due to human occupancy, providing return-air and exhaust-air streams with a concentration advantage compared with ambient air capture [2]. However, this concentration advantage does not directly translate into high annual $CO_2$ recovery. Factors including ventilation rates, occupancy patterns, climate conditions, humidity, duct configuration, and access to central air-handling systems all influence the amount of $CO_2$ that can be captured and the long-term operational stability of the system. Baus and Nehr investigated potential configurations for integrating direct air capture with existing ventilation systems [3], while Milić et al. estimated building-scale capture potential using measured ventilation data from an occupied gym facility [4]. Life-cycle assessments have further demonstrated that electricity sources and system configurations play important roles in determining the environmental performance of HVAC-based $CO_2$ capture systems [5]. Recent studies have expanded the research scope by evaluating humidity control, capture-unit placement within air-handling systems, climate-dependent performance, and practical design considerations [6-9]. Overall, these studies indicate the technical feasibility of HVAC-integrated $CO_2$ capture, although current evidence is still mainly derived from modelling studies, laboratory experiments, and equipment-scale demonstrations, with limited validation from long-term operation in occupied buildings.

A larger uncertainty appears after $CO_2$ has been separated from the airflow. Research on HVAC-integrated capture usually concentrates on airflow, sorbent performance, regeneration, and building energy use. Studies of construction-material utilization, by contrast, generally begin with a $CO_2$ stream that has already been delivered at a controlled concentration and under defined processing conditions [10, 11]. Some recent material studies have considered lower-purity or lower-concentration inputs, including concrete fines, carbonation curing, and cementitious surfaces exposed to reduced $CO_2$ concentrations [12-14]. Even so, these conditions remain different from ordinary indoor or building-exhaust air. Between the two research areas lie several unresolved steps: regeneration must release the captured gas, moisture may need to be removed, the stream may require further concentration or compression, and a small building supply must be matched with the timing and input requirements of a material process. Since these stages are rarely assessed within one continuous system boundary, strong performance at the capture stage cannot by itself demonstrate a net reduction in emissions.

This review follows the pathway from indoor or exhaust air to material storage. It evaluates the conditions under which HVAC-integrated capture appears technically credible, identifies the main bottlenecks between recovery and material use, and compares reversible retention in porous materials with more durable storage through cementitious utilization and mineral carbonation. Particular attention is given to the distinction between the amount of $CO_2$ removed from an airflow, the amount delivered to a receiving process, and the amount ultimately retained in a material. The overall objective is to determine whether the available evidence supports a net carbon benefit once operational energy, gas conditioning, delivery, and storage permanence are considered together.

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### 1.2. Scope, significance, and paper structure

The review focuses on $CO_2$ captured from occupied indoor environments, return-air streams, and building exhaust associated with ventilation and air-conditioning systems. The main topics include building suitability, $CO_2$ capture materials, HVAC integration, operational energy requirements, indoor-air constraints, gas conditioning, and storage pathways. Porous materials are considered as a supplementary approach for reversible $CO_2$ retention, as adsorption can delay $CO_2$ release or contribute to indoor concentration management; however, it does not represent permanent storage unless the released $CO_2$ is subsequently transferred to a further storage process [15]. Cementitious utilisation and mineral carbonation are given greater consideration as long-term storage pathways because carbonate formation can immobilise $CO_2$ in a more stable form [10, 11].

Standalone ambient-air direct air capture, industrial flue-gas capture, and geological storage fall outside the main comparison. Their inlet concentrations, flow conditions, equipment scales, and supporting infrastructure differ substantially from those of building ventilation systems. Evidence from these fields is used only where it clarifies a process that also applies to building-derived $CO_2$, such as drying, compression, or material input requirements. Fuel production, chemical conversion, and greenhouse utilization are also excluded from the central analysis because they do not match the paper's focus on material storage.

Building suitability is considered through annual operating time, airflow continuity, occupancy, climate, duct accessibility, and the capacity of the air-handling system to accommodate an additional capture module. The Linköping gym remains an important example because its estimate was derived from measured ventilation data rather than assumed airflow alone [4]. Studies of other buildings and climate zones broaden the comparison by showing how control strategies, equipment location, and local weather can alter energy performance [3, 8, 9]. They do not yet provide a reliable basis for ranking offices, schools, sports facilities, shopping centres, airports, or transport hubs. These building types are therefore treated as candidate settings whose suitability depends on operating characteristics rather than on concentration peaks alone.

By placing capture, conditioning, delivery, and material retention within one analytical boundary, the review connects two bodies of literature that are usually examined separately. A building may provide a technically accessible $CO_2$ stream, yet the complete pathway can lose much of its climate value if regeneration, gas preparation, transport, or material processing creates a comparable burden. The focused structured narrative review and qualitative comparison framework are described under Review methodology. Building airflow, capture media, HVAC integration, energy use, and economic considerations are examined under HVAC-Integrated $CO_2$ capture in buildings. Reversible retention, cementitious storage, and the processes linking capture to material use are evaluated under Storage and utilization pathways. The evidence is integrated, and the conditions under which further development is justified are considered under Discussion and conclusions.

## 2. Review methodology

### 2.1. Literature search and selection

This study adopted a focused structured narrative review with an integrative qualitative synthesis. The principal database search was carried out between 29 May and 3 July 2026 using Web of Science Core Collection and Scopus. ScienceDirect was used to obtain full texts and verify publication details, while Google Scholar supported citation tracking and the identification of closely related journal articles.

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Search terms were grouped according to the main stages of the proposed pathway rather than combined into a single broad search query. The building-capture group included terms such as indoor $CO_2$ capture, building exhaust, ventilation $CO_2$ capture, HVAC integration, and air-conditioning systems. A second group focused on capture materials and operating conditions, including sorbents, absorption, humidity effects, regeneration, cycling stability, and pressure drop. Energy-related searches combined building and HVAC terms with life-cycle assessment, techno-economic assessment, cost analysis, compression, and $CO_2$ conditioning. Material storage searches focused on cementitious utilisation, carbonation curing, concrete mixing, recycled aggregate carbonation, and mineral carbonation. Search strategies, including syntax and database field settings, were adjusted according to the requirements of each database.

Eligible sources were peer-reviewed English-language journal articles published between 2020 and July 2026. A study was retained when it addressed at least one stage of the building capture-to-storage pathway: indoor, return-air, or exhaust-air capture; integration with ventilation or air-conditioning equipment; capture-media behaviour under building-relevant conditions; operational or life-cycle energy demand; techno-economic performance; $CO_2$ conditioning; reversible retention in porous building materials; or storage through cementitious utilization and mineral carbonation. Review articles were included where they supported technology classification, storage mechanisms, or commercial maturity. Numerical conclusions, however, were drawn preferentially from original experiments, equipment demonstrations, measured-data building models, life-cycle assessments, and techno-economic studies.

Preprints and records whose publication details could not be verified were excluded. Studies concerned only with industrial flue-gas capture, geological storage, or standalone ambient-air direct air capture were also excluded when their operating conditions had no clear relevance to building HVAC systems. Research centred on fuels, chemical products, or greenhouse enrichment fell outside the material-storage scope. Broader studies were retained only where they clarified a transferable issue, such as drying, compression, gas purity, or the input conditions required by a material process.

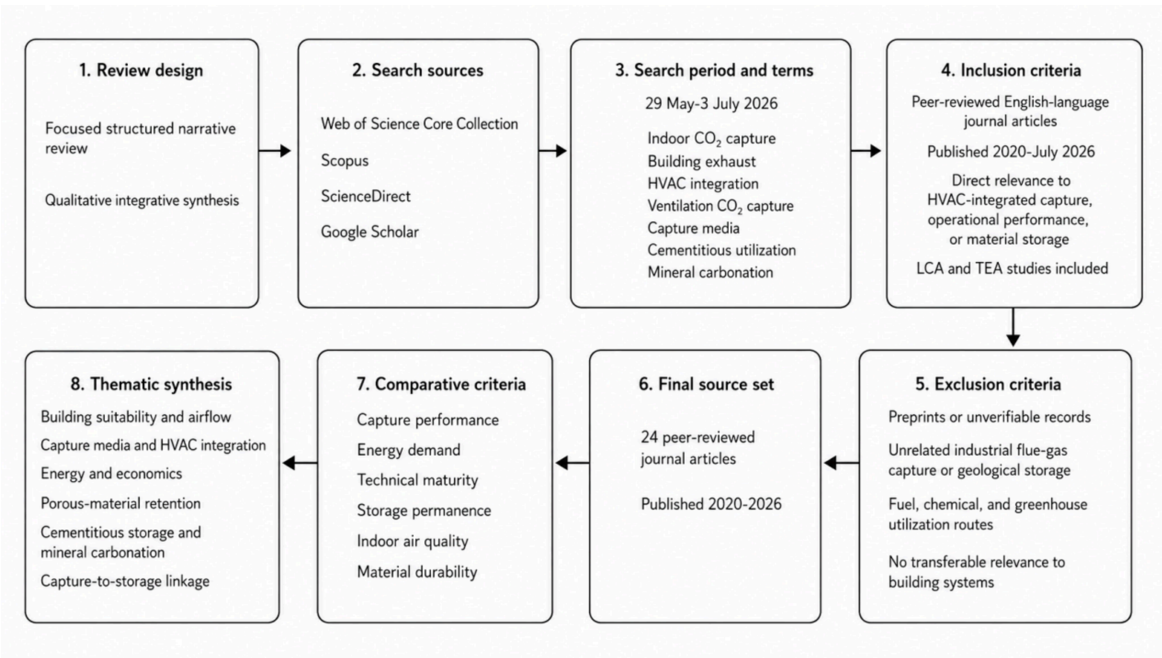


Figure 1. Literature review workflow and evidence synthesis

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The resulting evidence base comprised 24 peer-reviewed journal articles published between 2020 and July 2026. One UNEP report was used to establish the wider building-sector context and was not counted among the 24 journal articles [1].

Figure1 shows the literature identification, screening, appraisal, and synthesis process is summarised in Figure 1. The workflow links the review design and search sources with the inclusion and exclusion criteria, final source set, comparative criteria, and thematic synthesis.

## 2.2. Evidence classification, appraisal, and comparative analysis

The selected literature was organised into six connected themes. Building airflow and suitability covered occupancy, ventilation volume, annual operating time, climate, and access to central air-handling systems. Capture media and HVAC modules included liquid absorbents, supported amines, humidity-swing materials, zeolites, structured beds, and continuous adsorption devices. Energy and economic evidence addressed airflow resistance, fan electricity, regeneration, pumping, compression, climate effects, electricity supply, and cost. The remaining themes examined reversible retention in porous materials, long-term storage through cementitious utilization and mineral carbonation, and the connection between building capture and material use.

Study design and technical maturity were classified separately in this review. The types of evidence considered included review articles, laboratory experiments, equipment demonstrations, building-scale modelling studies, life-cycle assessments, techno-economic assessments, and material-process investigations. Technical maturity was evaluated based on the development stage of the technology, ranging from conceptual analysis and laboratory validation to component demonstration, pilot-scale application, and commercial deployment. This distinction prevented modelling studies or life-cycle assessments from being interpreted directly as indicators of technological maturity.

Each source was also assessed for its applicability to the review question. The assessment considered direct relevance, evidence basis, operating realism, system-boundary coverage, and reporting transparency. Studies based on equipment operation, measured building data, or clearly defined material experiments were treated as highly applicable when their assumptions and operating conditions were reported in sufficient detail. Models and life-cycle studies were generally considered moderately applicable because they could examine annual performance or environmental effects without demonstrating long-term physical operation. Reviews and broader material studies were used as supporting evidence for mechanisms, terminology, route classification, and commercial context. These categories describe how directly a study informs the present review rather than the overall academic quality of the article.

Cross-study comparison focused on capture performance, energy requirements, conditioning needs, technical maturity, storage permanence, indoor-air constraints, and material durability. Capture performance was evaluated based on parameters including uptake capacity, removal efficiency, working capacity, or estimated annual $CO_2$ recovery, depending on the type of evidence reported in each study. Energy demand was considered in terms of airflow resistance and pressure-drop effects, regeneration energy, pumping, drying, compression, and other downstream processing requirements. Storage permanence was assessed by distinguishing reversible $CO_2$ adsorption from $CO_2$ retained through more stable mineral or carbonate formation processes.

Direct numerical comparison was limited to studies with sufficiently similar units, inlet conditions, operating assumptions, and system boundaries. Results expressed as sorbent uptake, daily building recovery, energy per unit of captured $CO_2$, annual building energy change, or material storage per unit volume were not placed on a common scale unless the original definitions allowed a

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valid conversion. Model estimates were interpreted separately from measured equipment performance, and laboratory material results were not taken as evidence of full-scale building operation. The analysis also distinguished among $CO_2$ removed from an airflow, $CO_2$ delivered to a material process, and $CO_2$ retained in the final material, since losses and additional energy demands may occur between these stages.

## 3. HVAC-integrated $CO_2$ capture in buildings

### 3.1. Indoor and exhaust air as capture streams

Indoor $CO_2$ concentrations are commonly reported at 1,000–3,000 ppm and may approach 6,000 ppm in densely occupied spaces, compared with an outdoor reference of about 415 ppm in the reviewed literature [2]. The concentration advantage increases the $CO_2$ carried by a given airflow, although annual recovery also depends on ventilation volume, occupancy, operating hours, and access to central air-handling systems.

Using measured ventilation rates, temperature, humidity, and $CO_2$ concentration data from a gym facility in Linköping, Milić et al. estimated a potential $CO_2$ recovery of 54–83 kg/day [4]. This estimate was obtained from a building-scale model assuming the integration of an adsorption system and should not be considered as direct operational data from an actual capture unit. Studies on other building types have similarly shown that climate conditions, ventilation control strategies, and annual operating patterns can significantly influence available airflow and overall energy performance [3, 8, 9]. Therefore, building suitability is determined less by short-term $CO_2$concentration peaks and more by sustained airflow availability, continuous operation, and accessibility for equipment integration. Current evidence remains insufficient to provide a reliable comparison of the suitability of different building types, including offices, schools, sports facilities, shopping centres, and transport hubs.

### 3.2. Capture media and HVAC integration

Equipment testing has confirmed that capture modules can be incorporated into building air-handling equipment. Ilani-Kashkouli et al. tested amine-functionalised polymer-fibre modules on a make-up air unit and reported a working uptake of 1.1–1.4 mmol/g [16]. During the reported tests, unit electricity use rose by about 25%, indicating that physical integration introduces an operational penalty.

Capture-medium stability is also an important factor for practical application. Under simulated indoor $CO_2$ concentrations of approximately 1,000–1,100 ppm, Maity et al. reported that $CO_2$ absorption performance decreased by 54.3% for aqueous monoethanolamine and by 31.24% for a propylene glycol–L-arginine solution after ten adsorption–desorption cycles [17]. The latter formulation also exhibited lower volatile organic compound emissions under the tested conditions, which is an important consideration for capture systems operating close to occupied indoor environments.

For solid sorbents, humidity, pressure drop, and regeneration strategy can outweigh nominal adsorption capacity. Humid climates may require additional moisture control [6], while the preferred location of a capture module within an air-handling unit changes with weather and recirculation strategy [7]. A structured adsorption-bed model reduced fan energy from about 88.7 to 15.1 kJ/mol $CO_2$ by lowering pressure loss [18]. Humidity-swing modules and rotating zeolite beds offer alternative configurations for cyclic or continuous operation [19, 20], although long-term performance under dust, leakage, humidity variation, and maintenance conditions remains largely untested.

New buildings can reserve space, fan capacity, controls, and maintenance access during design. Retrofitting is more restrictive because existing systems may have limited pressure margin or plant-room space. The practical value of a capture medium therefore depends on its integration with the complete air-handling system rather than adsorption capacity alone.

### 3.3. Energy and economic performance

Reported energy values cannot be compared directly unless their functional units and system boundaries are similar. Baus and Nehr estimated that changes in recirculation and air conditioning could make 0.38–2.57 MWh available per tonne of separated $CO_2$, depending on building and weather conditions [3]. This figure describes potential reductions in conditioning demand, whereas the Linköping model included regeneration, mechanical energy, existing fan operation, and additional pressure-drop losses, producing an estimated total of 1.897–3.947 MWh/t $CO_2$ [4].

Mir et al. estimated an electricity requirement of 2.24 kWh/kg $CO_2$ for heating, pumping, and compression processes [5]. Within the defined capture-stage system boundary, the integrated system resulted in 0.206 kg $CO_2$-equivalent emissions per kilogram of captured $CO_2$, compared with 0.242 kg $CO_2$-equivalent for standalone capture. However, the assessment did not include $CO_2$ transport, material processing, or permanent storage, and therefore the results should not be interpreted as representing complete net carbon removal.

Annual performance also changes with climate and control strategy. Across eight climate zones, Xu et al. reported modelled energy savings of 0.39–21.66% under demand-controlled ventilation scenarios [8]. A later capture-integrated ventilation study linked material experiments with building simulation and estimated a break-even period of about six years under favourable assumptions [21]. Heß et al. reported a minimum estimated cost near €280/t $CO_2$ for an optimised modular system using suitable regeneration heat and operating conditions [9]. These figures indicate possible design advantages, although they do not establish a general cost for ordinary building retrofits.

HVAC-integrated capture is most credible where airflow is regular, pressure loss remains limited, and regeneration can use low-carbon heat or electricity. A complete carbon assessment must still include gas conditioning, delivery, and final storage.

Table 1 summarizes the main evidence on HVAC-integrated $CO_2$ capture, including the evidence type, key findings, and principal limitations of each study.

Table 1. Selected evidence on HVAC-integrated $CO_2$ capture

| Study | Evidence | Key result | Main limitation |
|---|---|---|---|
| Milić et al. [4] | Building model using measured airflow data | 54–83 kg $CO_2$/day | No operating capture unit |
| Ilani-Kashkouli et al. [16] | Equipment demonstration | 1.1–1.4 mmol/g; electricity use +25% | Short testing period |
| Maity et al. [17] | Cycling experiment | Ten-cycle decline: 54.3% for MEA; 31.24% for PG–Arg | Laboratory scale |

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Table 1. (continued)

| | | | |
|---|---|---|---|
| Chen et al. [18] | Structured-bed model | Fan energy reduced from 88.7 to 15.1 kJ/mol | No field validation |
| Xu et al. [8] | Annual building simulation | Energy savings of 0.39–21.66% | Sensitive to climate and controls |
| Heß et al. [9] | Design model and TEA | Minimum estimated cost near €280/t $CO_2$ | Optimised assumptions; no long-term deployment |

## 4. Storage and utilization pathways

### 4.1. Porous sorbents and reversible retention

Porous building materials can retain $CO_2$ on their internal surfaces, but the gas remains recoverable during regeneration. Jia et al. reported adsorption capacities of up to 7 mmol/g for modified aerogels under laboratory conditions, while a lower-pressure example at 60% relative humidity reached approximately 1.85 mmol/g [15]. Performance varies with pore structure, surface chemistry, humidity, $CO_2$ pressure, and regeneration temperature, so maximum laboratory values cannot be converted directly into the annual capacity of a building component.

Aerogel composites may combine $CO_2$ adsorption with thermal insulation properties, although increasing aerogel content can reduce the mechanical strength of cement-based materials [15]. Once the adsorption capacity is reached, the material requires regeneration or replacement, during which the captured $CO_2$ is transferred into another gas stream. Therefore, porous materials are more suitable for temporary $CO_2$ retention or indoor concentration management, while permanent removal requires the released $CO_2$ to be further processed through a separate storage pathway.

### 4.2. Cementitious utilization and mineral carbonation

Cementitious materials provide a more durable route because $CO_2$ reacts with calcium- or magnesium-rich phases to form stable carbonates [10, 11]. The main pathways include carbonation curing, injection during concrete mixing, treatment of recycled aggregates or concrete fines, and mineralization of alkaline wastes [22, 23].

Original experiments show that the required gas conditions depend strongly on the process. Ho et al. reported a maximum uptake of approximately 0.13 g $CO_2$/g concrete fines during direct aqueous carbonation, although the process also required water, mixing, and solid–liquid handling [12]. Xian et al. demonstrated carbonation curing near atmospheric pressure, but the supplied gas was still 99.9% $CO_2$ [13]. Chen et al. found substantially lower uptake and shallower carbonation at 3% $CO_2$than at 20% [14]. Since 3% corresponds to about 30,000 ppm, even this "low-concentration" condition remains far above ordinary indoor or exhaust air.

Review-reported values are approximately 15 kg $CO_2/m^3$ for concrete mixing and 25 kg $CO_2/m^3$ for carbonation curing, although the figures combine different materials and process boundaries [23]. Commercial systems such as CarbonCure, Solidia, and Carbon8 indicate that several cementitious routes have progressed beyond laboratory testing [24, 25]. These applications generally depend on metered and controlled $CO_2$ supplies, making direct connection to a small and variable building stream difficult without intermediate conditioning and storage.

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### 4.3. Conditioning and system-level carbon value

$CO_2$ removed from an HVAC airflow is not immediately ready for material use. Depending on the capture medium and receiving process, the gas may require desorption, moisture removal, concentration, compression, temporary storage, and transport. Three quantities should therefore remain distinct: $CO_2$ captured from the airflow, $CO_2$ delivered to the material process, and $CO_2$ retained in the final product.

Existing assessments cover only parts of this chain. The life-cycle model by Mir et al. included heating, pumping, and compression but ended before transport and permanent material storage [5]. The building-system assessment by Heß et al. examined capture design and cost without modelling a connected cementitious process [9]. Material studies, meanwhile, usually begin with a controlled gas supply [12-14]. Because the studies use different system boundaries, the available evidence cannot identify one universally dominant energy burden or demonstrate that HVAC capture and cementitious storage already form a continuous net-removal system.

Table 2 compares the principal material pathways for captured $CO_2$ in terms of their evidence stage, storage characteristics, and main constraints.

Table 2. Material pathways for captured $CO_2$

| Pathway | Evidence stage | Storage character | Main constraint |
|---|---|---|---|
| Aerogel adsorption [15] | Laboratory studies and review | Reversible retention | Humidity, regeneration, and material strength |
| Concrete-fines carbonation [12] | Laboratory process | Stable carbonate | Water and solid–liquid handling |
| Carbonation curing [13, 14] | Laboratory and process studies | Stable carbonate | Controlled concentration and curing time |
| Mixing, injection, and mineralization [22-25] | Review, pilot, and commercial evidence | Durable, route-dependent | Metered supply, processing, and transport |

## 5. Discussion and conclusions

### 5.1. Discussion and future directions

The reviewed evidence supports further development of HVAC-integrated $CO_2$ capture, although its application is likely to remain selective. The strongest case appears in buildings with long HVAC operating hours, sustained airflow, accessible central ducts, sufficient equipment capacity, and low-carbon energy for regeneration. Differences among existing studies arise from climate, humidity, recirculation strategy, capture-unit location, sorbent behaviour, and the boundaries used for energy and carbon assessment. Results obtained for one building or operating condition therefore cannot be transferred directly to another.

The main challenge currently lies in connecting $CO_2$ capture from buildings with durable storage pathways. Building-based capture systems typically generate relatively small and variable $CO_2$ streams, whereas cementitious utilisation processes generally require stable $CO_2$ supply, controlled delivery conditions, and consistent operation schedules. Porous materials provide reversible $CO_2$ retention, but regeneration releases the captured $CO_2$ into another stream that requires further

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treatment. Cementitious utilisation and mineral carbonation provide more promising options for long-term storage, although gas conditioning, temporary storage, transport, and process control requirements may reduce the overall carbon benefit. Within the reviewed evidence base, no study has yet demonstrated continuous operation linking $CO_2$ capture from occupied buildings with final cementitious storage.

Progress in capture media and HVAC integration depends on lower pressure loss, improved humidity tolerance, stable cycling, limited solvent emissions, and regeneration compatible with low-carbon energy. Long-term demonstrations in occupied buildings need to establish annual capture output, energy use, indoor-air conditions, maintenance demand, and sorbent replacement rates. System-level studies should connect captured, delivered, and retained $CO_2$ within one mass and carbon balance, while accounting for conditioning, transport, material performance, cost, monitoring, and verification. Such evidence would clarify whether local building-to-material pathways can achieve genuine carbon reductions.

## 5.2. Conclusions

HVAC-integrated $CO_2$ capture has progressed from conceptual analysis to equipment demonstrations and detailed building models, yet long-term evidence from occupied buildings remains limited. The central challenge has shifted from removing $CO_2$ from ventilation air to converting a small and variable building-derived stream into a conditioned supply that can be retained in a durable material.

Porous materials are more appropriate for temporary retention or indoor $CO_2$ management. Cementitious utilization and mineral carbonation provide the stronger route for long-term storage, but their continuous connection with building capture has not yet been demonstrated. HVAC-integrated capture is therefore more likely to serve as a supplementary measure in selected buildings than as a standard feature across the building stock. Its development is most defensible where airflow is continuous, integration penalties remain low, regeneration uses low-carbon energy, and a nearby material process can accept the recovered $CO_2$ under controlled conditions.

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