(a) PCA Projection with Cluster Boundaries

Legend: Warm-Climate Educational, Cold-Climate Educational, Temperate-climate Educational

PC1 (41.9% variance) | PC2 (34.4% variance)

(b) t-SNE Projection with Cluster Boundaries

Legend: Warm-Climate Educational, Cold-Climate Educational, Temperate-climate Educational

t-SNE Dimension 1 | t-SNE Dimension 2

(c) Cluster Quality: Silhouette Analysis

Buildings (sorted by score within cluster) | Silhouette Score

Average: 0.339

C0, C1, C2

C0: Warm-Climate Educational | C1: Cold-Climate Educational | C2: Temperate-climate Educational

(d) Peer Group Sizes and Quality Scores

Number of Buildings | Average Silhouette Score | Peer Group

Warm-Climate Educational (n=1,611): 1,611, 0.34
Cold-Climate Educational (n=2,119): 2,119, 0.48
Temperate-climate Educational (n=1,216): 1,216, 0.10

FIGURE 1. Building peer groups show clear separation in reduced dimensional space.

(a) PCA projection preserving 76.3% of total variance reveals three distinct building clusters. Convex hulls (boundary lines) delineate cluster territories; X markers indicate cluster centroids. Point transparency reflects silhouette score (darker = better cluster fit).

(b) t-SNE projection emphasizes local structure, confirming cluster separation patterns observed in PCA. The warm-climate cluster (blue) and temperate-climate cluster (green) show tight groupings, while the cold-climate cluster (orange) is more dispersed.

(c) Silhouette analysis quantifies cluster quality. Scores > 0.25 indicate reasonable structure; scores < 0 suggest potential misclassification. Average silhouette = 0.339 confirms meaningful peer group formation. Negative scores (red zone) identify buildings that may benefit from manual review.

(d) Peer group sizes range from 1,216 to 2,119 buildings. The Cold-Climate Educational cluster shows highest cohesion (silhouette = 0.48), while the Temperate-climate Educational cluster has more internal variation—presenting opportunities for best-practice sharing between high and low performers.

KEY INSIGHT FOR POLICYMAKERS: These visualizations confirm that building stock naturally segments into distinct peer groups based on climate, building type, and size. Energy benchmarking within these groups enables fair comparison and targeted interventions.