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FaçadeRetrofit.org: An Online Database Resource for the Façade Renovation of Existing Buildings

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Much of the existing tall building stock is burdened with aging and underperforming façades, resulting in opportunities to substantially improve building performance through façade retrofit. Deep-energy whole-building retrofits, with the façade as an integral component, are an effective means to transform the overall performance of the commercial building sector. Yet little data is available on practices or outcomes from past façade retrofits, resulting in uncertainty about the sustainability and effectiveness of current practices. In response, a database of façade retrofits has been developed organizing relevant pre- and post-retrofit conditions. The progress of the database and online resource has accelerated in the wake of funding provided through the CTBUH 2014 International Research Seed Funding with the support of ECADI. A synopsis of the research shows the results to date, progress on the database and website resource, information on how to access and utilize the resource, and plans for future development.

Background

While much of the current sustainable design dialog focuses on new building construction, many people have recognized that an effective method to improve the efficiency of the building sector is by improving existing buildings. Particularly in tall buildings, renovation is likely to be more economically and environmentally preferable than demolition and reconstruction, and façade renovations can make significant contributions (Trabucco and Fava, 2013). Building façade retrofit is a dramatically growing market sector. There is much uncertainty, however, about how to implement retrofits in a manner consistent with sustainable development goals. Precedents are few and largely unevaluated within this context. Design, construction, and owner/operator teams need reliable data about previous projects to help make informed decisions for future projects. Researchers need data to evaluate the performance characteristics of current practices and to develop new strategies based on lessons learned. Upcoming retrofits need to be implemented in appropriate ways, as they will have lasting effects on overall building performance that will directly impact future energy performance and sustainability goals. Prior research completed by the authors has indicated significant shortcomings in current practices.

FaçadeRetrofit.org was developed as the core of an online database-driven resource for the façade renovation of existing buildings. Data has been gathered from interviews, surveys, and online research, and is intended to be updated and expanded by a knowledgeable community. This database fills an important gap by creating readily accessible data for guiding deep energy retrofit projects. The need for more data has been observed by previous researchers (Benson et al., 2011, The American Institute of Architects and Rocky Mountain Institute, 2013). The data is of particular value in early stage decision-making as a source of best practices and design options suitable to specific retrofit applications. It will provide insight into the retrofit process for engineers, architects, real estate and other professionals tasked with renovation projects by providing meaningful access to precedent project means, methods, and performance results. The database and its compilation will also create an important resource for researchers, allowing for an assessment and determination of best practices that can then be presented along with the database. In addition to the database, select projects were developed as comprehensive case studies that will also be available on the website. Ultimately, the database is envisioned as the heart of a web-based information center for the building community, which provides an extensive resource on the façade's role in deep energy retrofits.

Façade Retrofit and Existing Buildings

Façade retrofit refers to the intervention of the building envelope through the fitting, addition, or substitution of new or modernized materials, components, or systems to an existing construct. The goal of a façade retrofit is to improve several aspects of building performance and human comfort. Beardsley and Boyer (2013) describe the inclusion of the façade on what they categorize as a "Phase-3" intervention. Though a comprehensive renovation is certainly more complex, the results of including the façade can include high impacts on building performance. The façade, as a key component in energy performance, is also crucial for the repositioning of an outdated building (Beardsley and Boyer, 2013).

Private initiatives and public mandates are encouraging increased energy efficiency in the existing building stock. Mechanical system and lighting retrofits are common as a result of widespread understanding and clear performance outcomes. Building façade retrofits are much less common (The American Institute of Architects and Rocky Mountain Institute, 2013). Replacing mechanical and lighting systems without examining the façade overlooks synergistic opportunities and violates the spirit of an integrated design practice. A lack of data supporting the decision-making process of façade retrofits has hindered the significant potential presented by the widespread application of appropriate practice.

Evidence-based research is fundamental to support informed decisions for façade retrofit. Existing databases such as CBECS and CEUS describe US commercial building stock, but these tend to rely on generic data for façade systems. There are new initiatives to gather relevant actual data on energy conservation strategies (The U.S. Department of Energy, 2014), while other initiatives have compiled a limited number of refurbished projects (National Buildings

Institute, 2011, AECB/TSB, 2014). Previous studies are insufficiently robust to support the specification of design methodologies in support of the environmental and architectural design features of an individual project. Though there are a few existing façade retrofit research studies, they are typically limited to individual case studies and do not represent a comprehensive survey of the full range of current practice. A promising development is the mandatory release of actual energy use data for buildings in different cities. This data disclosure provides additional facts to aid research in conjunction with the façade retrofit database.

Methodology and the Creation of the Database

In order to create the database, buildings that had undergone façade retrofits had to be identified. From the initial gathering, it was decided to focus on key characteristics about the buildings and use those as the basis for the online database. A content management system was set up to allow several research assistants to participate in the product while maintaining a reasonable amount of uniformity in the collection of data. Façaderetrofit.org became both the method for data collection and its diffusion.

Identification of Façade Retrofit Building Projects

Two online surveys were distributed among façade-related professionals, the results of which can be seen in Graph 1 This resulted in a preliminary list of over 300 buildings worldwide as having received significant façade interventions. Reported façade retrofit projects were represented in over 30 countries in the combined surveys. Despite the overall diversity of locations of these buildings, there was a predominance of projects located in the United States, including 54% of the buildings in survey 1, and 63% in survey 2. Of the reported buildings, 60% in survey 1 and 56% in survey 2 were office buildings. Commercial offices represented 72% of those office buildings.

Survey 2 reported commercial office buildings as the main building type comprising 49% of all reported buildings, followed by educational and government offices. The identified buildings ranged in height from one story to over 100 stories. Of these buildings, 38.4% were 14 or more stories (CTBUH defines 14-stories as a rough parameter for "tall"). Additionally, half of the buildings were built between the 1950s and 1980s.

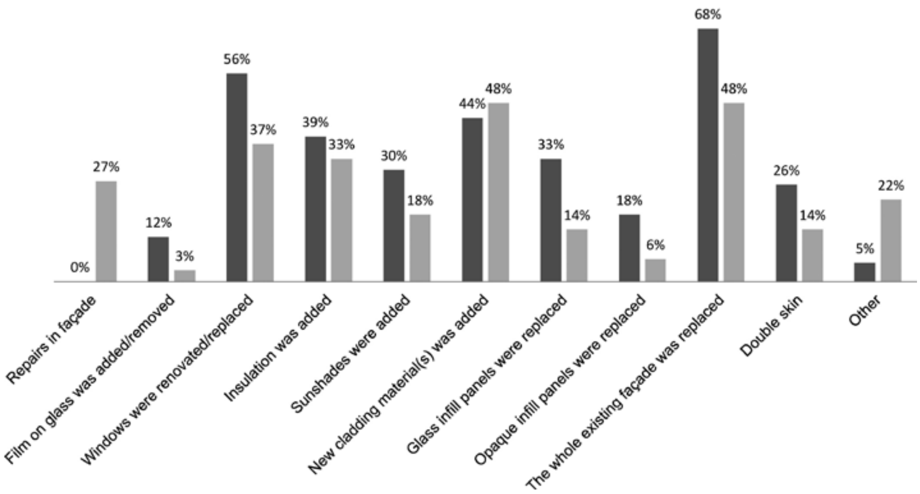
The survey also asked about the original façade systems of the buildings. Curtain walls, ranging from storefront types to highly glazed, were the most common. As the first survey allowed multiple selections, some respondents reported multiple system types in the same project: 67% of the respondents reported the use of curtain wall systems (including window wall and storefront types), 62% with highly glazed curtain walls (over 50% glass), followed by 39% reporting masonry (with punched windows). Based on the number of buildings in survey 2, 29% of the reported façade retrofits corresponded to highly glazed curtain walls, 28% masonry façades, and 16% curtain walls.

The scope-of-work for façade retrofit ranged from minor repairs (re-caulking, sealing, and addition of films in glass) to total replacement of the façade. Survey 1 reported that total façade removal and replacement (re-clad, re-skin) was the main façade retrofit type, followed by refurbishment or replacement of window systems. These two façade retrofits were reported in more than half of the responses. Survey 2 reiterated these results, with an additional predominance of the category: a new cladding material(s) was added to the existing façade.

Other covered areas and details were documented (Martinez et al., 2015). Survey questions included background regarding the respondents companies' role in the façade retrofit; other systems included in the retrofit (HVAC, lighting, etc.); reasons and motivations of the façade retrofit; and scopes and goals of the retrofit plan in regards to building code and sustainable practices.

Façaderetrofit.Org: A Tool for Data Collection and Diffusion

A website, *façaderetrofit.org*, was created as an open platform of information about



Graph 1: Scope of façade retrofit projects reported in both surveys -Survey 1 referred to a company's project(s) generally, while Survey 2 referred a specific project (results thus add to more than 100%). Source: University of Southern California

	Type of Entry	Original	Retrofit
Project name *	text	x	
Registered as a historic landmark	check box	x	
Street address		x	
City *	text	x	
State (US)		x	
ZIP/Postal Code		x	
Country *	single choice-dropdown	x	
Images	attachment		
Completion	numeric (year)	x	x*
Building type	single choice	x	x*
Number of stories	numeric	x	x
Building height	numeric	x	x
Total square feet	numeric	x	x
Owner	text	x	x
Developer	text	x	x
Design Architect	text	x	x
Executive Architect	text	x	x
Engineer	text	x	x
Construction Manager	text	x	x
General Contractor	text	x	x
General Contractor	text	x	x
Façade Consultant	text	x	x
Façade Contractor	text	x	x
Other consultants/contributors	text	x	x
Primary motivation for the façade retrofit	single-choice		x
Retrofit type	single-choice		x
Façade Design	multiple-choice	x	x
Certifications + Ratings	multiple-choice		x
Explicit goals (beyond code)	multiple-choice		x
Activities included as part of the retrofit	multiple-choice		x
Other systems included in the retrofit	multiple-choice		x
Extent of the façade intervention	multiple-choice		x
Project description	text box (2,000 characters max.)		
First Name	text		
Last Name	text		
e-mail *	text		
Company	text		
Phone Number	number		
Sources+References	Text and file attachment		

Table 1: Fields included by project in façaderetrofit.org. Source: University of Southern California

façade retrofits and the main repository of the database. The website is structured in four main sections. An about page describes the project, goals, main authors and sponsor information. The project database can be visualized in the main list included in the second tab. The third section contains a glossary of terms relevant to façade retrofit, structured for alphabetic search and filtering. Finally, additional sources of information and links to related databases and websites are contained in the last section.

The database was initially populated with the list of buildings from the identification phase, which was complemented by additional entries of cases identified through a literature review of case studies.

General architectural and technical information about the building projects was mainly obtained from online sources such as the Skyscraper Center website (CTBUH, 2015). Complementary information about involved professionals, structural information, and other general aspects were obtained from widely used databases in the building community (e.g., skyscrapercity.com and structurae.com).

Multiple searchable and sortable fields are contained on the database page. Besides a general keyword search, the page includes advanced filter options accommodating selective search by building type, façade type, retrofit type, location, and other significant variables. Table 1 describes the set of parameters for search and filtering options.

Opposite: Main project page of the Aon Center, Chicago. Source: University of Southern California

The project page displays a building image(s) alongside building name, city, state (US), and country. Detailed information is organized in two tabs for both the original (pre-retrofit) and the retrofit (post-retrofit) building conditions. The designation of historic landmark status is also indicated.

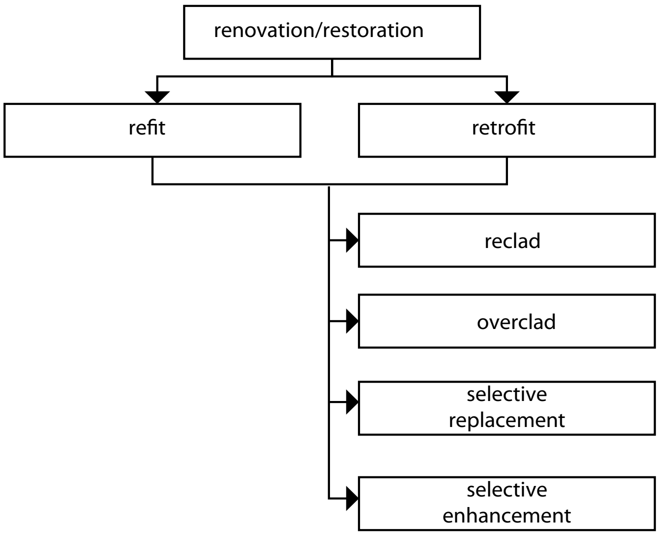
A major goal of this research was to provide a public and open platform for both users who wished only to view the data and those who wished to add more information, the website allows either the collection of new cases and/or update of existing project profiles. New retrofit projects and edited projects are submitted online, reviewed, and posted to the database as appropriate by database administration personnel. A minimum number of required fields (identified by an asterisk) are displayed to guarantee a basic amount of data for building identification: project name, country, year of completion (or expected) of façade retrofit, building type, and email address of the person submitting information. All the fields are listed on Table 1.

Additionally, the form allows for the submission of images (image size is 760 pixels wide by 428 pixels tall or proportionally larger), which can be sorted by original (pre-retrofit) and retrofit (post-retrofit). Additionally, further information can be submitted as an attachment or as text in a section provided at the end of the form.

Results

Aside from the project database itself, there are three other important outcomes from using the database for research purposes: typology, metrics, and simulation. The proposal of a typology derived from the cases contained so far examines how façades are upgraded, for example, by adding items or by replacing components. The descriptive statistics give an overall picture of the buildings in the database that can also be used to make generalizations about retrofits. Knowledge and numbers for simulations can be extracted from the database.

“Researchers need data to evaluate the performance characteristics of current practices and to develop new strategies based on lessons learned. Upcoming retrofits need to be implemented in appropriate ways, as they will have lasting effects on overall building performance that will directly impact future energy performance and sustainability goals.“



Left: Diagram of the main retrofit classifications. Source: University of Southern California

A Proposed Typology

Based on the observed façade retrofit interventions contained in the database, retrofits are generally classified as addition/modification or replacement actions. Enhancements include additions and/or modifications that maximize the reuse of existing façade components. Enhancements also include adding components to the façade such as sunshades or insulation. Replacement actions include the change of some or all components of the façade system.

Façade retrofit is distinguished from minor interventions such as painting, sealing or any action that involves similar surface-level action. For this study, retrofit interventions involve at least those on a component-level, either by addition or replacement. Façade retrofit considers enhancements such as the addition of layers or elements to parts of or to the whole façade such as sunshades, insulation, or glass layers. Replacements at the component level can include vision or opaque infill panes, whereas the whole façade can be replaced by what is termed a re-skin.

Descriptive Statistics

At the time of this report, the database describes the following metrics:

Over 500 buildings are contained in the database. Buildings in the US are predominant, representing 61% of the database, followed by UK with 8%. Of the total buildings in the US (338), 28% are concentrated on three cities: New York, Chicago, and Los Angeles.

Buildings range in size from 5,300 to 4,477,787 square feet, with a median value of 418,645 square feet and a standard deviation of 636,039. Building height ranges from 1 to 108 stories, with a median value of 15, and standard deviation of 16.72. Fifty percent of the buildings are 14 or more stories. Buildings with available height information ranged from 18 to 2,220 feet, with a median value of 320 feet. Building function data largely corresponds to commercial office buildings. Including commercial, corporate and government facilities, office buildings account for 65% of the total buildings. Graph 2 shows the relationship beteween building function and height.

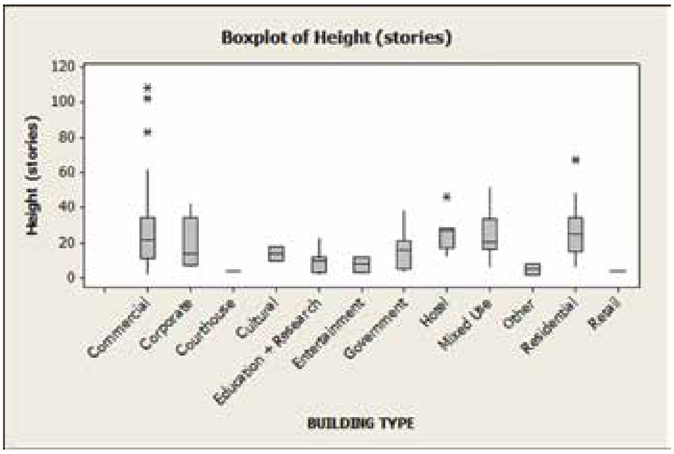
According to initial façade retrofit data, 58.5% are of the curtain wall façade type, followed by highly glazed curtain walls (14.4%), masonry walls 11.01%, and precast concrete (9.32%). The two major retrofit types are selective replacement (windows) and total replacements of the façade (re-clad). These two retrofit types account for over 80% of the buildings.

The year that the buildings were constructed ranges from 1850 to 2009, with 1961 as the median year, and a standard deviation of 23 years. Records of retrofit implementation range from 1967 to 2015, with 2007 as the median year, and a smaller standard deviation of 7.5 years. A comparison of the median values of buildings on the database indicates that façades are being retrofitted after roughly 46 years, as seen in Graph 3.

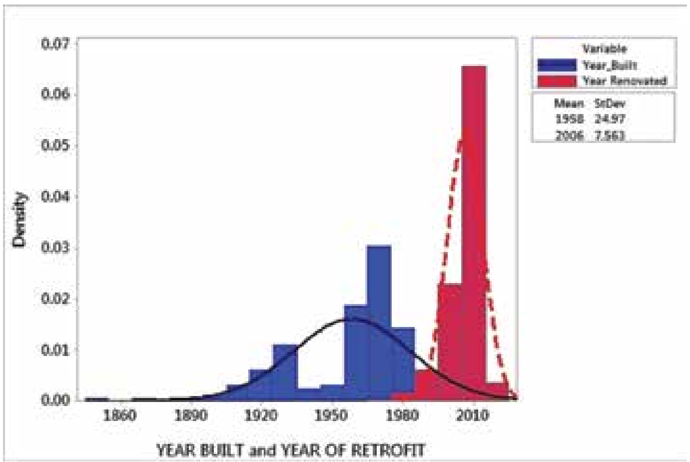
Only a small portion of the buildings (N=42) contained in the database recorded some level of green certification such as ENERGY STAR and LEED. "Commercial buildings and industrial plants can earn the ENERGY STAR, EPA's mark of superior energy efficiency. ENERGY STAR certified buildings and plants operate among the top 25 percent of similar facilities nationwide" (Energy Star, 2015). LEED is also voluntary and provides pathways for certification in several areas applicable for retrofits especially operations and maintenance and building design and construction (USGBC, 2015). This database could help determine, in combination with other information, if green retrofits beyond mere code compliance levels are being achieved, or if certification is not a major concern when retrofits are occurring.

Simulation

As mentioned previously, the database can be used to provide knowledge and numbers for other research projects. A study was undertaken to determine which façade retrofit strategies tended to be the best for three cities (New York, Chicago, and Los Angeles). A base case model was made for each city. A typical office floor plan was used as a reference. Floor plate dimensions of 200 feet by 130 feet, a 1:1.5 aspect ratio, accommodated a perimeter zone of 40–45 feet deep (Kohn and Katz, 2002). Building dimensions of height and window-to-wall ratios were identified from buildings from each city and compared to CBECS national statistical referents. The models were assumed to be located in downtown areas, for which the specific angle of orientation of the urban grids was adopted.



Graph 2: A boxplot graph that shows the relationship between building function and height. Source: University of Southern California



Graph 3: Distribution of year of original construction and year of retrofit for projects contained in the database. Source: University of Southern California

Based on the location, each model responds to the features of buildings contained in the database for the specific city. Age, window-to-wall ratio, and height are defined based on median values of the sample buildings for these parameters.

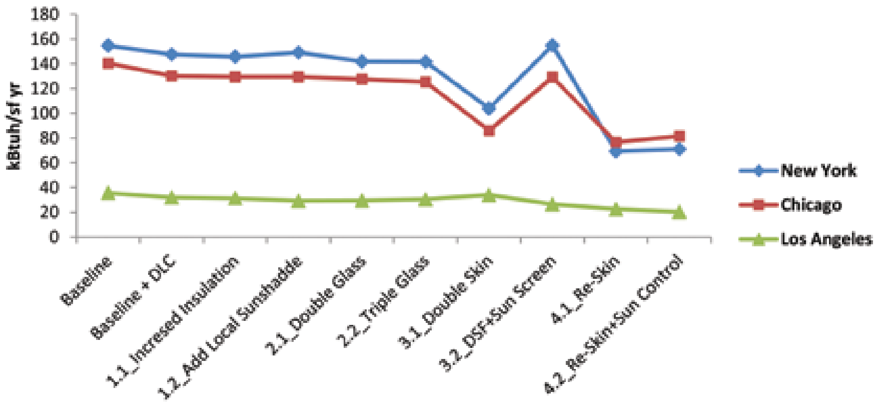
Eight strategies of façade retrofit were explored, which were determined based on those more commonly reported in the database that constitutes the four types, indicated in Table 2. Even though some of these retrofits were not common for a specific city (for example, double skin in L.A.) they were transversally applied to the three models to have an estimation of quantifiable impact.

Preliminary simulation results suggest that New York and Chicago models were similar in energy use and trend, except for one retrofit type. New York and Chicago resulted in energy intensities commanded by heating requirements in the 100 kBtu/sf/year. Due to the characteristics of template weather, Los Angeles' model resulted in lower energy intensities, but also a more flat trend among all strategies, indicated by a green line in Graph 4.

In this case, the results were less important than the methodology of the study with regards to the project database. The researchers were able to use the database to ascertain information that they needed and to draw general conclusions about other data to enter into the simulation. As features were determined in a sample of buildings from each city instead of on a national level, the models achieve a closer representation

Type 1	**Selective Enhancements**	**1.1**	**insulation**	**increased R-value of wall to R-15 (u-value=0.066)**
		1.2	local sunshade	overhang 1.0 m.
Type 2	Selective Replacements	2.1	double-glass	Dbl LoE (e2=.2) Clr 6mm/13mm Arg./ UPVC window frame
				U-value= 0.299
				SHGC= 0.63
				Tvis= 0.721
		2.2	triple-glass	Trp LoE (e2=e5=.1) Clr 3mm/13mm Arg
				U-value= 0.137
				SHGC= 0.474
				Tvis= 0.661
Type 3	Overclad	3.1	double skin	a single clear glass layer skin
		3.2	sunscreen	louvre (angle 0, blade depth 1', 5 blades)
Type 4	Reclad	4.1	re-skin	best practice 85% glass curtainwall
				U-value= 0.348
				SHGC= 0.687
				Tvis= 0.744
		4.2	re-skin + sun control	best practice 85% glass curtainwall
				U-value= 0.348
				SHGC= 0.687
				Tvis= 0.744
				+ mid-pane blinds with medium reflectivity slats

Table 2: Input for façade retrofit strategies. Source: University of Southern California



Graph 4: Trends of strategies on energy use intensity (kBtuh/sf yr) for New York, Chicago, and Los Angeles. Source: University of Southern California

of existing buildings for the specific climate and location. Still, existing statistical information on a national level was needed to have a reference in terms of energy use; window areas (DOE and EIA, 2015) were used to consider the age of specific building types. Also, previous research about representative commercial building models (Torcellini et al., 2008) was relevant to identify features common in pre-1980s buildings.

Where Are We Now and What Is Next?

FaçadeRetrofit.org, the online database-driven resource for façade renovation of existing buildings, has been created with currently 500 buildings. An open and public online platform, this pioneering tool focuses on what real building owners are doing to update their older buildings to achieve better energy performance, sustainability practices, or market repositioning. Based on the information collected, a typology of façade retrofit was proposed, which was applied to the buildings contained in the database. A number of case studies were identified and described more in depth. In addition, a study was undertaken to determine which façade retrofit strategies tended to be the best for three cities (New York, Chicago, and Los Angeles).

The intent is to continue to develop the website as an extensive resource regarding façade and deep building retrofit for the building community, from researchers to practitioners and industry professionals. The website is envisioned as a hub for façade retrofit activities, including future funded research initiatives.

Potential future research initiatives to be pursued are:

- The design of façade systems that anticipate the need for future retrofit (zero-net-energy-ready façade systems)
- Life Cycle Analysis (LCA) for a comparative analysis of various façade retrofit strategies
- The potential of using evidence-based research in façade retrofit to improve energy efficiency in the commercial building sector
- The assessment of façade retrofit opportunities in targeted urban sectors, including economic and durability analysis involving life cycle assessment techniques incorporating maintenance and partial renovation cycles as a strategy to extend building and building system service life
- Studying the ravages of time and weather on a façade. Very little data exists to show how façade performance has been affected over time; there is a pressing need to establish a testing protocol and proceed with gathering data on a variety of commercial buildings at various stages of service life.
- The development of software tools, guidelines, and best practices that facilitate various aspects of façade retrofit as an integrated, holistic practice

These initiatives represent very rich and largely unexplored research veins that will certainly lead to additional opportunities.

More than half of the commercial building stock was built before the 1980s (US Energy Information Administration, 2006), before energy codes came into effect. The retrofit of existing buildings, therefore, has great potential as a strategy for meeting challenging energy and carbon reduction targets as established by various government and non-government agencies. Buildings consume about 40% of total energy in Europe (European Commission, 2015), and those built before 1980 represent 95% of this energy consumption. In the United States, nearly 75% of commercial buildings are more than 20 years old and are in need of energy improvements (US Department of Energy, 2012).

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