

Change Is Still “Up in The Air”

By Melinda Sokolowski

INTRODUCTION

In recent years, unmanned aerial vehicles (UAVs, colloquially known as drones) have seen a rapid increase in technical innovation of concern to the building enclosure community. At times, development has inundated parties with information on how the devices can aid in research and testing. The remote sensing community has changed and grown with the capabilities of the crafts over the last few years. Pilots are extremely skilled, with a deep knowledge of the building enclosure and necessary inspection deliverables. The latest generation of UAV technology now means that looking at a 200-ft.-high dome in real time from an office thousands of miles away is a reality. Architects, engineers, and consultants have progressed past the understanding that drones could reach difficult areas or elevations that pose safety risks to inspectors. Previous options utilized swing stages, façade drops, and bosun chairs, as well as platform lift trucks with ground-based binoculars. These tools are no longer the only options in an urban setting.

Initially, there were few codified safety regulations of UAVs by the Federal Aviation Administration (FAA) at the national level and even fewer at the local level. Prior to 2015, deciphering the regulations was cumbersome and fraught with unclear specifics as to their use. Pilots are now aware of airspace, altitude, and geographical limitations

and new scrutiny around craft registration and licensure to fly and profit commercially. Today, a modern app (B4UFLY) can be used on any smart device to request FAA clearance, incorporating specifics of flight region, height, and radio interference (Figure 1). Drone suppliers have imposed their own regulations, including geofencing, altitude limits, and firmware limitations that require the pilot to obtain a software license to unlock the ability to fly in certain zones at the expense of identity. National laws describe basic rules, such as minimum age for flying and the need to pass the Aeronautical Knowledge test (known as the Part 107 test). It should be noted that each state has individual drone laws which can be accessed online at uavcoach.com/drone-laws/.

Five years ago, my colleague, William “Bill” Waterston, a member of IIBEC, wrote an article and presented a paper on drone use at the 2015 RCI Building Envelope Symposium. Waterston’s article examined where drones might best be used within the façade inspection industry. The article (<https://iibec.org/wp-content/uploads/2015-bes-waterston.pdf>) was optimistic and filled with new ideas on how engineers and architects could revolutionize the building enclosure inspection process. This article will explore the enhancements made in the drone arena in the intervening years that specifically benefit the building enclosure community.

[Editor’s note: IIBEC’s new *Manual of Practice* also includes a section on “Drone Use.”]

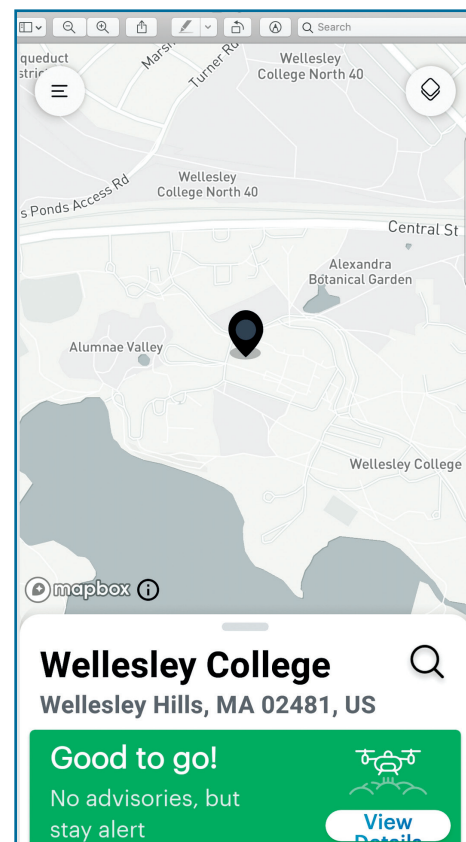


Figure 1 – B4UFLY App. FAA.gov mobile application allows operators to check airspace and stay compliant with FAA guidelines.



Figure 2 – First Church of Christ Scientist in Boston, MA. The dome was an addition in 1903–1906. Drone imagery was collected to show cracks and deterioration in masonry. UAV obstacles included FAA clearance, weather, and incorporating rappelling equipment.

ASSESSMENT CHALLENGES

Roofs with difficult or dangerous points of entry are now UAV accessible. In the exterior review of the above-mentioned Christian Science church in Boston, the large dome could not be seen in its entirety from the small, 224-foot-high cupola. The building (Figure 2) is in a congested area. Once permission was granted, the flight crew flew from three different vantage points, allowing for an expansive collection of imagery.

THE CHANGING DEFINITION OF A UAS

The term “unmanned aerial system” (UAS), versus the initialism “UAV,” has an all-encompassing meaning that includes ground control as well as any additional communication units, including the pilot. Over the past few years, cameras have become better equipped, with larger camera sensors, and there are built-in safety features on drone bodies, such as collision avoidance and obstacle detection.

Once drones became popular outside of the hobby/racing world, they started being mass-produced and are now being used in professional set-

tings for façade inspections, scientific studies, filmmaking, industrial inspections, and surveillance. Outside of Lockheed Martin (whose main client is the military), the world’s largest multipurpose UAV manufacturer for civilian use is Da Jiang Innovation (DJI). Lesser-known drone manufacturers focus on specific industries, and they

include Kespry (construction and mining), MicaSense (agriculture), and Parrot (for personal sport). These UAV companies are engaged in a race to deliver features desired by their specific users (Figure 3).

Current commercially available drones are capable of being outfitted with a variety of cameras. This includes standard RGB



Figure 3 – Industry-specific UAVs are used to accomplish different goals. With new software integration, job-specific camera sensors, and unique crafts, drones can extract particular data sets based on their size, capability, and the user’s objectives.



Figure 4 – Process to ensure quality and safety when using UAVs.

(an initialism for red, green, and blue, representing the colors visible on a computer's display). Also available are micro four-thirds (MFT) cameras. An MFT camera is an advancement in cameras that allows one to use multiple lenses on a camera body while using a mirrorless design. MFTs have allowed cameras and lenses to be smaller. Drones also use advanced thermal cameras, zooming cameras, and multispectral normalized difference vegetation index (NDVI).

Different sensors allow users to fulfill a wide array of needs, but it is easy to become lured in by gadgetry and forget a company's project goals. Flying should always start with multiple safety assessments, followed

by a slow walk-through of the flight and discussion of data collection techniques. See Figure 4.

UAVs also now come equipped with safety and ease-of-use functionality as a standard feature set. This includes a real-time relay of video or images to the operator or construction headquarters via tablet or cell phone. For image quality, it means camera stability from dampened gimbals. And for control, it means geofencing and on-craft lighting are some great safety features.

Batteries have advanced in how they are made and protected on the craft; some can last for close to an hour. More innovative models come with built-in cooling fans to keep batteries from becoming too hot and,

therefore, presenting a danger.

Current UAV models aid in inspection by combining several data sets. This means possibly overlaying thermal information with visible information and structural building information modeling (BIM) using a variety of specialized cameras. Crafts boast multiple simultaneous camera mounts for combining RGB colors (visible) with a thermal camera and a depth-sensitive camera. Engineers work with off-the-shelf cameras but have also built specialized rigs for specific purposes (Figure 5). Not all commercial UAVs can be modified. It is recommended that companies work with a seasoned engineer if they intend to modify a craft.

APPLICATIONS

Observation of buildings and conditions where UAVs are usable have grown immensely. Aerial companies have expanded upon both the ability to fly and the information that can be produced through exceptional piloting and cutting-edge software.

THERMAL INSPECTION

Infrared applications and techniques have advanced greatly in the UAV world. As data providers, we inform the client that using a drone is a tool in spotting anomalies with qualitative and quantitative deliverables. Best practice involves leaving hands-on and destructive testing up to contractors, building enclosure consultants, and engineers.

However, an infrared-sensing-capable drone can provide a large amount of data, as well as ample supporting imagery and video. Irregularities may or may not mean a leak is present. A competent review of the data and consideration of the techniques leading to data capture are required. Using



Figure 5 – Interior of an uncapped industrial smokestack as imaged by a custom-built UAV.

a thermography drone can be a fast and safe way to examine these potential issues.

Thermographic analysis (thermography) varies in accuracy, based on which thermal camera is being used. The greater the resolution of the sensor and its focal accuracy, the better the results. Focus, range, and distance determine an accurate radiometric reading. *Figure 6* depicts how using a larger camera sensor means a greater resolution. Greater resolution means more image detail and, therefore, more accuracy. Drones can be outfitted for both short- and medium-wavelength detection. Short-wave thermography can be used to observe faulty insulation, energy loss, mechanical overloads, lighting panels, and proper roof and drainage systems, to name a few.

QUALITATIVE ANALYSIS

Qualitative analysis is based on the observation of patterns and differences and does not include temperature measurements, as it is a non-radiometric technique. Drones help spot issues on roofs and façades where thermal conductivity is higher. Infrared cameras are great for viewing areas of wet insulation; having a bird's-eye view can aid in spotting water in the insulation under a roof membrane. Analyzing collected imagery can translate into exposing air leakage, flashing issues, water penetration in exterior walls, roof drain damage, and HVAC issues. (See *Figure 7*.) Water that is leaking or draining into a system can cause the following:

- Increased heating and cooling costs
- Increased weight on the structure from moisture
- Possible interior damage

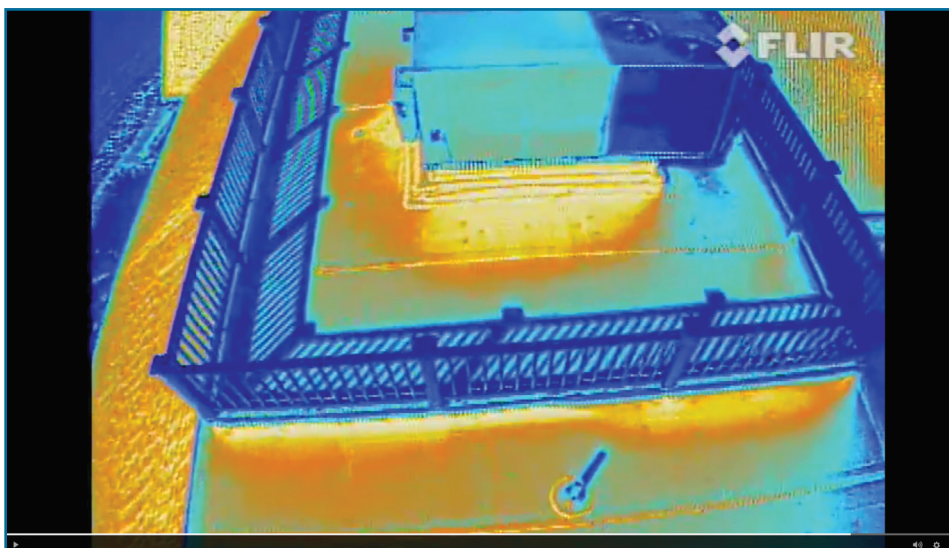


Figure 7 – UAV camera used to fly over HVAC systems.

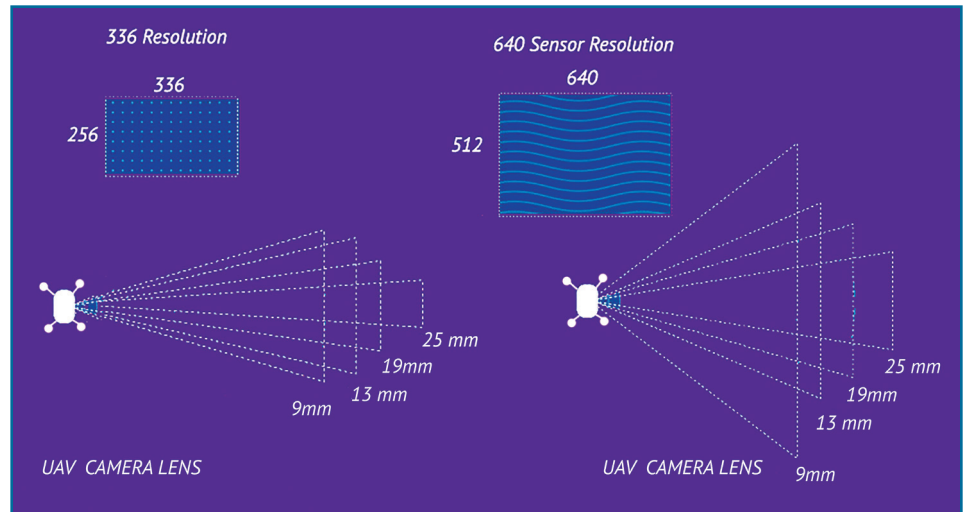


Figure 6 – Spot size comparison between a thermal UAV camera that has 336 pixels per inch and one that has 640 pixels per inch. The larger sensor on the right will yield more accurate thermal information.

QUANTITATIVE MEASUREMENT

Reflectivity and emissivity must be taken into consideration in the analysis of temperature differences (also known as Delta-T analysis). Drones have the ability to safely measure hazardous, unsafe, or unreachable surfaces. Using a UAV equipped with a thermal camera is a hands-off alternative for inspecting power lines, power plants, chimney stacks, and unwalkable roofs. Flying from a bird's-eye vantage point allows the roof to remain untouched and minimizes the risk of injury, while allowing for nimble data collection. Conducting quantitative analysis provides information that allows the user to arrive at a ratio of radiation being emitted from a surface. For example, if an object reflects 20% and transmits 30% of incident radiation, it will absorb 50% radiation. Once a baseline estimate is achieved of these per-

centages, an approximate temperature can be equated, allowing for an overall picture of the severity of a problem. Utilizing the thermographic information allows an informed team to write simple reports and suggest where further investigation is needed. Pilots benefit from rudimentary understanding of typical roof damage scenarios to understand how they affect a thermal reading.

If your company executes thermal inspections, invest in a capable thermal camera. Less expensive drones may only produce JPG images and not imagery that can be supported by professional analysis software. Flying with a dual-gimbal camera series allows one to fly a standard RGB and a thermal camera at the same time. This provides easy reference when reviewing the imagery, and data co-registration (accurate layering of pictorial historical data with current drone data to make comparisons in topography through photogrammetry) while reporting.

ROOFING ASSESSMENTS

Vaulted roofs can be dangerous and difficult to access. Viewing a small portion of the roof from a swing stage can be both ineffective and inefficient. An aerial UAV view would be of great value and is a quick and safe way to assess an unreachable section of a roof, while eliminating the time and effort of ladder climbing and swing staging. The cost savings and benefits for scheduling work are immense and help free up capital for firms to take on more clients.

The slate roof in *Figure 8* was between 100 and 150 years old. The roof had gone through several iterations of repairs, including



Figure 8 – UAV images of sloped, gable-style roofs covered with slate. The roof has lead-coated copper valley and ridge flashings. The one on the left has hung copper gutters and a snow rail system.

Figure 9 – This roof was previously surveyed in 2019. A large New England campus was imaged using unobtrusive UAVs. Shown is the sloped gable-style roof covered with slates that had undergone considerable damage.



different quick fixes along the way. It suffered from both broken slate and disconnected pieces of copper. Using a drone helped to build the necessary documentation and to create a plan of action.

Figure 9 shows a building constructed in the early 1900s. The last survey of this building was conducted in 2019. The aerial image shows a roof dormer with slate and copper flashing in the valley and along the ridge. The roof converts to a low-slope ethylene propylene diene monomer (EPDM) roof system on the right. Painted metal coping runs along the front of the dormer on the left. The drone was able to view peeling paint and rust on the coping, as well as slate that is stained from drippage from the EPDM roof adhesive or the asphalt from a previous built-up roof. Although damage of this type may have been suspected, imagery helped confirm that if left undiscovered and

unaddressed in its current state, deterioration of the metal coping, copper flashing, and slate could worsen and potentially result in water infiltration into the building.

Roofing inspections with a hands-on approach are sometimes not possible due to deteriorating conditions. Walking on the

roof may not be an option. In this scenario, a drone can safely image for data to be analyzed in real time or cataloged for later use. Imagery can be cloud-based and shared with architects, engineers, roofing contractors, and owners. In Figure 10, the roof was not structurally sound; however, images were obtained via a UAV, showcasing the extent of the damage to the flashing shingles and bell tower.



Figure 10 – Church with significant damage imaged using a UAV in lieu of a bucket truck due to safety issues. Amongst many issues, damage was observed in an inappropriately sized cricket. The cricket should divert water from the high roof around the chimney.

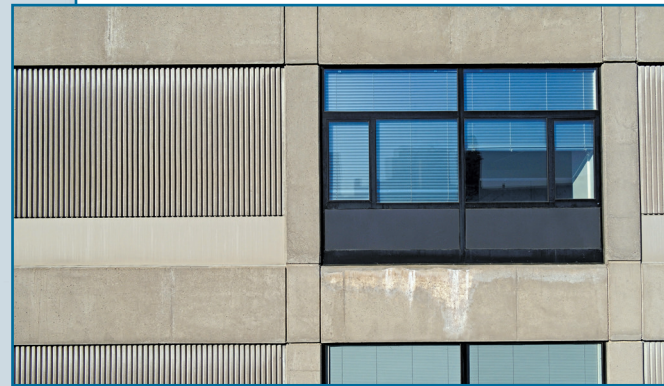
FAÇADE INSPECTIONS

Modern data-viewing platforms show a hierarchical approach to digging deeper into data, and they often accompany analytical metrics. The datasets are sometimes the culmination of several hundreds to thousands of images and can often be associated with other imaging modalities to enhance inspection, regardless of whether one is capturing video, grayscale, visible, or thermal images. The source images are geo-referenced, allowing for accuracy and model cohesion (see Figure 11).

Nevertheless, there is still a need for competent UAV operators and data analysts. You may get a concrete panel building of Brutalist style (see Figure 12), exhibiting monochromatic and repetitive architectural



Figure 11 – UAVs are used as tools to render 3-D models of a facade inspection. Interactive software allows the client to access and inspect a building façade one high-resolution image at a time while maintaining a sense of location (native image inset).



features. This presents problems for both human and computer analysis. The answer to delineating between very similar photos can sometimes be as mundane as marking varying elevations with differently colored tape, acting as fiducial markers for increasing spatial awareness. According to Richard Keleher, utilizing a drone on a building that is repetitive or ornate is something that can be done in any season and saves a great deal of time:

I like the thoroughness of having high-resolution photographs of the whole façade in an ordered way, that I can refer to when doing my analysis and report. Also, it was the middle of winter, and I didn't like the idea of spending hours and hours on a swing stage.

CONSTRUCTION MONITORING

In the past, if a construction firm or developer wanted aerial documentation, they had to hire a plane or a helicopter to do a flyover. The flyover was viewed and then cataloged. Today, drones are used to collect concise information that can be cataloged and referenced for the interested parties (such as investors, a board of directors, or project members) and to highlight ongoing efforts, producing ample information for documentation (such as in an insurance claim—specifically when construction is paused and a site is left unmanned). Information is stored on a local server and a cloud platform. Now we use repetitive imaging to monitor changes on

construction sites. Artificial intelligence (AI) rebuilds a digital model like puzzle pieces to provide a hands-on artifact that can be manipulated to show the perfect angles of a newly developed structure (see Figure 13). Over time, data are compiled and changes due to nature or man can be recognized. The VP of a Boston campus has had his site monitored with a drone for over a year. When asked the value of the site being monitored by drones in times of ongoing operation versus monitoring during breaks in construction, he observed:

Frankly, the modeling is more helpful as a visual aid to remote individuals to monitor the progress of the

work for myself, the lenders, and even investors, so they understand the stage and scope of the project as well. We have used multiple imaging modalities on several occasions to verify some issues.

TIPS

Our company has experienced the wide range and number of urban capture circumstances, and it has a few tips:

- Always contact your local government prior to flying the UAV. Use the B4UFLY app (and adhere to it).
- Provision a policing detail to include individuals with certification obtained from available flagging classes. Include someone on

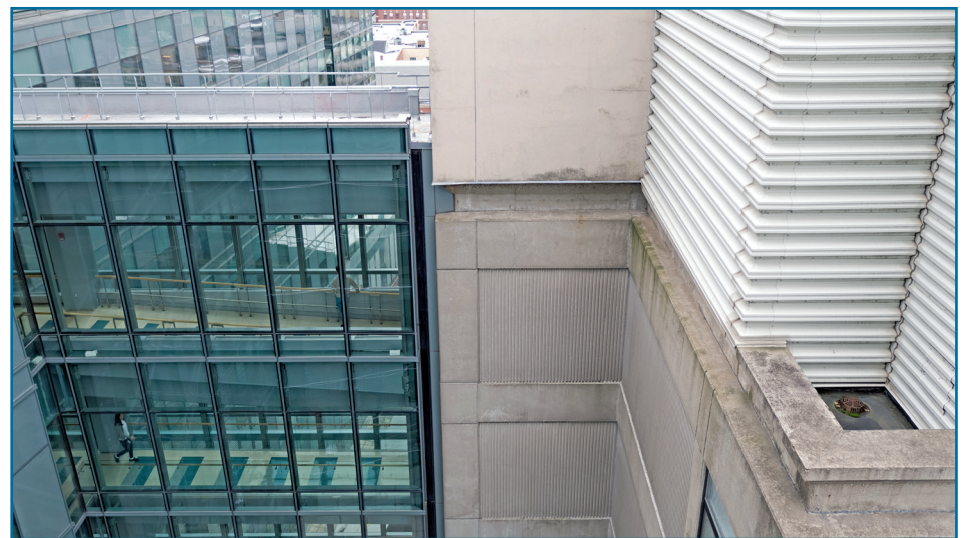


Figure 12 – Façade study completed with a UAV due to limited access in an urban setting. Elevations on three sides were blocked by foot traffic, narrow alleys, and complex adjacent structures.

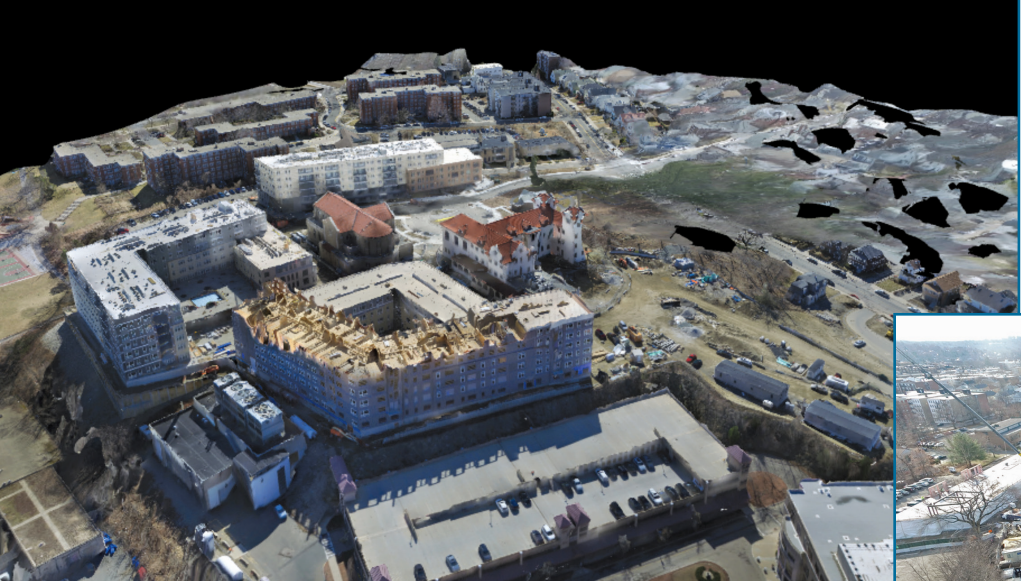



Figure 13 – Construction site audit including 3-D models (orthomosaic) accurately stitched from thousands of photos to annotate and track building changes over time. The aerial image inset was taken at the onset of construction in July of 2018.



the team with CPR and emergency procedure knowledge.

- As a purveyor, you must go beyond notifying the occupants of the target building and the adjacent neighbors; you must be comprehensive.
 - Make sure that local law enforcement is aware of your flight plan.
 - Have an attendant on hand to answer questions of possible bystanders.
- Employ an exacting and well-coordinated team who will not engage in unnecessary banter. Focus professionally on the task at hand.

SUMMARY

Drones have dramatically changed daily life for hobbyists and professionals. As UAVs and sensors become more advanced, so, too, will the need to be educated and to understand the ever-advancing technology. Being a drone pilot no longer means you can simply take images; it means you can be impactful and make a real change in the health and well-being of buildings and their inhabitants. 

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Mindi Sokolowski

Mindi Sokolowski is the CEO of MS Aerial. She has a combined degree from the School of the Museum of Fine Arts in Boston, and Tufts University. Her company focuses on aerial data collection with UAVs. She also holds 107 drone certificates, is a Level 1 thermographer, and is OSHA 10 certified. Sokolowski recently obtained a master’s degree in business management. She has overseen some of the most complex UAV façade inspections on the East Coast.

TA-019 Withdrawn for Additional Review

After further review, IIBEC has determined that IIBEC-TA-19-2020, “Modified Bitumen Cool Roof Cap Sheets,” is unintentionally incomplete and could be misconstrued; as a result, the technical advisory has been withdrawn. The IIBEC Technical Advisory Committee has begun a process to revise and update the technical advisory. Additionally, the process for reviewing and approving technical advisories is being revised to ensure a more thorough process.