



## THE ENERGY MANAGEMENT BENEFITS OF

# REFLECTIVE ROOFS

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### Introduction

Roofing, and particularly roof surfacing, can have an impact on energy consumption at commercial facilities. Peak loads and electrical energy consumption are especially affected by ENERGY STAR®-Labeled Roof Products. ENERGY STAR® was developed by the Environmental Protection Agency (EPA) to help reduce peak loads, energy costs, and consumption, while protecting the environment.

ENERGY STAR®-labeled roof products provide a number of benefits roof consultants should consider. Those benefits include: direct and indirect energy savings, environmental benefits, and roof performance benefits. Energy savings as they would relate to facility energy management is the focus here, but other benefits may also be of interest.

### ENERGY STAR®-Labeled Roof Products

The United States Environmental Protection Agency (US EPA) and the United States Department of Energy (US DoE) have been bringing attention to the benefits of reflective roofing products through ENERGY STAR®-Labeled Roof Products. Since its launch in February 1999, ENERGY STAR® has worked to educate roofing professionals and the general public about the benefits of reflective roofing. Manufacturers of roofing products voluntarily participate by signing Partnership Agreements. Manufacturers who participate have products that qualify according to the ENERGY STAR®-Labeled Roof Product specifications.

Manufacturers self-certify their qualifying roof surface products through specific ASTM testing procedures that include minimum values for solar reflectance and reflectance after three years of in-field weathering. Manufacturers who qualify reflective roof products for ENERGY STAR® can then use the ENERGY STAR® logo to identify qualifying products only.

Currently, participating manufacturers have qualified over 180 reflective roofing products that have met these qualifications. These products include single-ply membranes, metal roofing products, coatings, and tile products. A number of case histories demonstrating the benefits of reflective roofing prod-

ucts are available while others are in development. For more information about ENERGY STAR®-labeled Roof Products, visit the ENERGY STAR®'s website at <http://www.energystar.gov/products> to view specific roof product information.

### Energy Management

The Association of Energy Engineers provides an educational program in energy management and continuing education on energy-related issues. It is an excellent resource to learn more about energy management and, if desired, to write an examination to become a Certified Energy Manager.

Energy management is a function of both energy consumption and cost reduction. All aspects of energy are considered during an energy management audit, including fuel procurement (i.e., electricity, gas, oil, diesel, and others). With deregulation, this area may be of even greater importance. The building envelope is an important aspect of the audit, but the largest cost savings typically discovered by our energy management audit are with inefficient motors, improper fuel use, overlooked recovery methods, and inefficient HVAC plant components. Many things are included in an energy audit, such as:

- Instrumentation
- HVAC and thermal energy storage
- Energy accounting
- Utility rate structures
- Economic analysis and life cycle costing
- Lighting
- Motors and applications
- Electrical system utilization/peak load control/power factor correction
- Insulation
- Fuels used
- Waste heat recovery and cogeneration
- Controls
- Alternative financing
- Boilers and thermal systems
- Maintenance

The building envelope and reflective roof surfaces at some facilities have a small overall impact in the scope of a total energy management audit. However, the benefit-to-cost ratio is likely to prove ENERGY STAR®-labeled Roof Products and coatings to be a wise decision.

## The Energy Management Benefits of Reflective Roofing

Direct energy savings result from ENERGY STAR® -labeled roof products during the cooling season. When commercial entities air condition and depend heavily on electricity for that function, they set peak demand loads through higher rates of consumption during utility service peak periods. These increases in peak demand loads impact electric utility use charges, demand charges, and the environment. Managing and reducing peak demands allow generation plants (utilities) to control their production for optimum performance and efficiency that, in turn, affect pollution and consumer cost.

Direct energy savings come to building owners in two ways. Both use and demand peaks for energy are reduced. The energy management perspective is focused on the direct energy savings although indirect benefits can also be added to these savings. For some environmentally-conscious building owners, the indirect benefits (primarily environmental impact and urban heat island reduction phenomenon) may even outweigh the justification by direct energy savings or payback.

Concerning energy management and direct savings from reflective roofing, the benefit-to-cost ratio provides a starting point. In many cases, there is no additional cost in using an ENERGY STAR®-labeled Roof Product or coating when compared

*Previous page: Application of an Eco-Fast Deck Coating System by Carlisle Coatings & Waterproofing Inc. shows its remarkable reflectivity. Photo courtesy Carlisle.*

to a non-labeled product that would be used anyway. In these cases, the calculation of savings is easy. Since there is no additional cost, the issues of savings calculation and payback periods are not needed. ENERGY STAR® has included, as a part of its labeled roof product program, the qualification that performance warranties of the labeled roof product must be equal to or better than those of non-labeled products.

In cases where the cost of utilizing an ENERGY STAR®-Labeled Roof Product represents an increase in the project cost, two components (in addition to the increased cost) are needed to evaluate the benefit. First, the direct energy savings need to be calculated. Second, the payback period must be evaluated. Oak Ridge National Laboratories (ORNL) and Lawrence Berkeley National Laboratories (LBNL) have developed some useful aids to demonstrate the savings. These can be found at their respective websites.

The calculator developed by ORNL is the model used here for the calculation of savings. ENERGY STAR® has a roof savings calculator under development. Along with any calculation method used, an understanding of a commercial electric utility billing and rate structure is needed. Once the cost savings information is known and the effects of the applicable electric utility costs are understood, the life of the product or coating and desired payback period must be considered.

When the payback period cannot be met or the life of the product is exceeded before payback or break-even occurs, the added cost cannot be justified. Some clients will already have a payback period established for their operations ranging from one to ten years. If they do not, first make a judgment of a reasonable payback period. Clearly, if the cost can be recovered long before the component reaches the end of its useful life, the economics justify the expense and can be presented to the client as a positive added initial cost. Other factors, such as the anticipated cost increase in utilities, the cost of financing additional initial project costs, and maintenance costs, may need to be factored into the equation for a complete economic analysis.

There are many variables to factor out of the complicated longhand equations to calculate savings. Those variables make the results less dependable and, if included, the time to calculate the potential savings is significant. The longhand results represent selected conditions only. Without computer modeling, calculations at each angle of incidence, temperature, and other climatic and physical site conditions that change continually represent multiple calculations that would need to be performed. Due to this fact, there are several demonstrations of savings derived from reflective roof surfacing. Some resources that allow viewing of these results include web sites for ORNL, LBNL, or the Florida Solar Energy Center (FSEC). These represent only a few of the sites with this type of information.

The demonstrated savings vary greatly, even for similar roofs in similar locations. This is due to the variables that apply. Data have been gathered for about ten years through research projects, and the information has been annualized. This process has allowed for some calculators to be developed. The FSEC site has



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a calculator available based upon Department of Energy-2.1e (DoE-2.1e); it is a commercial building energy software fully capable of simulating the impact of roof reflectance but not as a variable parameter.

Numerous calculation tools are in development and several are available for use now. The extent of data used in model development and input should be reviewed to understand the results obtained. Most provide annualized savings that account for at least one year, including winter and summer cycles. Some models may include more than one year of data, allowing for some confidence concerning the roof surfaces becoming less reflective over time. With additional time and study, it is likely that the calculators will even better recognize that the roof surface will become dirty and less reflective. All calculator models must include some assumptions, but model results compared to field measurements tend to be underestimated. In discussion with representatives from FSEC concerning the DoE-2-based calculator, it was presented that the underestimation averages about 5% with the greatest underestimation occurring at facilities with ducted air conditioning directly beneath the roof deck. At these locations, the coolest air is being ducted through the hottest space and typically with poorly insulated ductwork.

The calculators available, and especially the one available at the ORNL website, are generally based upon demonstrated savings and data gathered from instrumentation in the field. One item these calculators do not generally include is the impact on demand cost charged by electric utilities. This cost varies among utility companies but can be a major part of a commercial electric service utility bill. It has been shown that demand charges alone can account for the majority of a total commercial electric bill. A commercial utility rate structure is reviewed below for a better understanding of demand charges.

## The Commercial Electric Utility Bill

Potomac Electric Power Company, PEPCO, is an electric utility service provider in the Washington, DC area. The PEPCO website offers an easy view of the commercial rate structures for commercial buildings and one is used below. Most electric utilities make this same information available on line. Several rate structures are used by each utility, but most commercial facilities are on a time-metered schedule, meaning the cost of electricity varies with the time of day use. Schedules are set for facilities based upon demand. Another way to reduce electric energy cost is to reduce consumption and peaks to allow for a change in the schedule used. The schedule information presented below, in short summary form, is the current Maryland (MD) – GT 3A (General Service – Primary Service). Rates charged may be seen in *Table 1*.

From this rate structure schedule, it can be seen that the demand charge is not only a substantial part of the overall bill, but varies with consumption of electricity. In the summer months, not only is the billing demand charge impacted, but so is the on-peak demand charge. In the winter season, the peak demand remains constant with time of day because the demands are substantially reduced. This will be true for most electric utility

Distribution charges		
Customer charge	\$275.67 per month summer and winter	
Kilowatt-Hour (KWh) charge	\$0.00590/Kwh summer and winter	
Kilowatt (KW) charge	\$1.77738/KW on-peak summer	
Transmission Charges		
Kilowatt-Hour (KWh) charge	\$0.00265/KWh summer and winter	
Kilowatt (KW) charge	\$0.7154/KW on-peak summer \$0.2940/KW maximum other times	
Generation Charges		
Kilowatt-Hour (Kwh) charge	<u>Summer</u>	<u>Winter</u>
On-Peak	\$0.03994/KWh	\$0.03265/KWh
Intermediate	\$0.03323/KWh	\$0.02708/KWh
Off-Peak	\$0.01745/KWh	\$0.01438/KWh
Kilowatt (KW) charge		
On-Peak	\$7.39/KW	
Maximum	\$3.04/KW	\$3.04/KW
Rating periods were defined as follows:		
Summer - June to Oct.	Winter - Nov. to May	
On-Peak, noon to 8 p.m.	Off-Peak, midnight to 8 a.m.	
Intermediate, 8 a.m. to noon; 8 p.m. to midnight		
Billing demand for monthly on-peak summer is defined as the maximum 30-minute demand for the billing month. Billing demand for all months is defined as the maximum 30-minute demand for the billing month.		

Table 1

providers. There are varied methods of charging for demand from utility to utility (and even within the same utility, from rate structure to rate structure). Consequently, most calculators do not include demand cost savings. Even though one saves on the amount used, savings also occur when demands are set at lower levels. The demand charge applies for all months and, for this rate schedule, is set on a monthly basis.

In the summer months, the peak set during the on-peak demand period is charged, in addition to the maximum demand charge, for the summer period and calculated similarly. This makes for high summer period electric utility bills. The utilities presented here highlight demands set on a monthly basis. Electric utilities may utilize a ratchet that applies for a longer period. Some electric utilities set demand ratchets that take the highest demand set for the peak period and then apply a generation charge at a percentage of 60% to 100% that continues up to 12 months or until a new peak is set. In those instances, the new, higher demand applies until it is either exceeded or the time period elapses. Maximum and on-peak demand charges are the way electrical production capacity costs are assessed to the customer. In essence, this is the way new electric generation facilities are funded, at least in part. Reducing demand is a very effective way to reduce the electric utility costs overall. It is the high peak demand cost that provides incentive for energy-saving ideas like thermal energy storage, allowing cooling in the summer season to be done off peak when rates and demand charges are lower. The stored cooling energy is then used during the peak cooling period to reduce the electric demand load.

## Example Calculation

For the purpose of providing an example calculation, an actual building utility invoice was obtained. The example building is located in Fairfax, Virginia. It is a 13-story building with a 7,500-square-foot roof and footprint. The information used below was gathered from the building. The July electric utility invoice was obtained for use as well as other information, including the applicable rate structure and schedule. This building is served by Virginia Power and shows a use charge (KWh) of \$1,116.00 with a demand charge of \$16,533.

The ORNL calculator was utilized in the following example. This calculator is available at the ORNL web site. The underlined components were entered into the calculator.

97,500 square foot commercial building – 7,500 footprint and roof (13-stories)

- State of MD/VA and City of Baltimore/Richmond (actually Fairfax, VA)
- R-value of 24
- Solar reflectance of 0.65
- Infrared emittance of 0.65
- Average summer cost of electricity \$.004/KWh
- Air conditioner Coefficient of Performance of 2.34
- Heating source - electric at \$0.004/kWh
- Heating system efficiency 100%

The results from the ORNL calculator obtained follow (simulated using reflective roof products):

- Cooling savings and net savings at \$0.0077 and \$0.0087 for Baltimore and Richmond respectively.
- The building is located in Fairfax, so results were extrapolated to \$0.0084/SF per year savings calculated.
- For a 7,500 SF, 13-story building, there would be annual savings of \$63.00.

Cooling savings obtained from the calculator are important and may vary from net savings, because they allow for a better correlation with demand charges. In this example, the cooling savings and the net savings were the same. Because the ORNL calculator is based upon demonstrated or measured data, savings and losses as well as several other variables are factored into the results it provides. The calculator allows the user to make his own assumptions concerning the entered data and change any of the variables entered to allow a view of the impact on results. Because the only utility cost entered is electricity on a KWh basis, one factor not included is the peak demand charge. To understand this, we need to look at the building-specific commercial electric rate structure. To simply divide the total electric utility bill by the number of kilowatt hours used would provide skewed results and may not account for the summer season period and rates that vary.

To factor in the demand charge savings:

- Divide \$63 by 12 months for \$5.25 per month.
- The building had \$1,116 use charge and \$16,533 demand charge for July.
- \$5.25 divided by \$1,116 is .0047.
- 0.0047 times \$16,533 is equal to a \$77.70 demand savings for July.
- Calculating the demand savings for the five summer

months ( $\$75^* \times 5$ ), the results are equal to a \$375 summer peak demand charge saving.

\*\$77.70 rounded to \$75/month in demand savings to account for variance over the 5 months

The \$375 saved on summer demand plus the \$63 in calculated annual savings result in \$438 saved per year. If this 13-story, 7,500-square-foot per floor facility paid an additional \$0.10 per square foot for an ENERGY STAR®-labeled roof to achieve a 0.65 reflectance, this product would cost \$750. Remember that the use of a reflective roof surfacing may eliminate the need for other products to be installed. Therefore, use only the actual net additional cost. Payback on a benefit-to-cost basis is 1.7 years. Another way to evaluate benefit-to-cost using the Oak Ridge calculator is presented as a result. The calculator provides a comparison of the additional R-value required to obtain the same savings. In this case, it was an additional R-value of 10. So consider the cost of increased insulation and flashing heights to the cost of the ENERGY STAR®-labeled roof product. Please note this additional insulation requirement method does not include the demand charge savings.

The example building presented above is not the best case for showing the benefit of reflective roofing. Multiple stories and a small roof area and footprint will not demonstrate the maximum conditions for reflective roof savings. Beyond that, this building was already well insulated, further reducing the impact of a reflective roof surface. This information was used because most building owners do not want their energy bills published. Even this owner requested anonymity.

## Benefit Analysis Discussion

For client-specific and actual demand savings analysis, obtain the actual electric utility invoices from the building owner. From the savings calculated, obtain the percent of use (KWh) savings by dividing the calculated annual savings by the annual use charges as shown in the example above. The percent of demand charge (KW) savings to apply as they relate to reduction of the use charges can be calculated by multiplying the summer month peak and maximum demand charges by the percentage of use savings. Demand charge savings have been demonstrated in numerous field studies to be greater than percentage of use savings.

Research information may eventually allow us to identify specific percentage of demand savings. Until then, it is probably best to err on the conservative side. Remember, only cooling savings are being considered, so they apply only during the summer rate period defined by the electric utility. The analysis using the calculators available and the methods shown above, once the data are collected, does not require a lot of time. The savings do vary from building to building and region to region.

Clearly, if the payback occurs in the first year or less, the issues of cleaning and maintenance, expected life of the product used, and other similar factors are of less importance. The product may need to be refreshed or reapplied before the end of the life of the roof. It may be desirable to check the payback of the product chosen on the cost basis in present value dollars. Of course, both the cost of reapplication and the cost of the electric utility service are likely to rise with time and should be considered.

If the payback occurs after more than one year, perform an economic analysis. If the results from the benefit-to-cost analysis

are satisfactory, stop your calculations at this point. If not, check the calculator model to be certain it does not already include real world reduction in reflectivity over a reasonable time period. If it does not, include adjustments for service and performance of the reflective surface beyond the one-year period of time. If the model being used includes only a one-year period starting with a clean roof, it may be advisable to consider the maintenance cost of cleaning the roof surface and frequency of cleaning. This adds to the cost side of the equation. If achieving premium performance of the reflective coating is desired, it may be wise to clean the roof at least once a year at the beginning of summer (also a good time to check for roof maintenance and repair items).

Once the costs associated with maintaining the reflectivity level desired are obtained, begin an economic analysis. The savings for the first year will stay the same as calculated above. If the solar reflectance factor is modified, the savings will change for subsequent years and should be added accordingly to the first year savings for the number of years used for the analysis. If there is not an established payback period (defined by the building owner), determine the life of the product. Of course, this will vary based upon the product being used. The warranty period offer by the ENERGY STAR® qualifying roof material being used might provide a reference for service life. With the savings, costs, and period of service or payback desired, perform a thorough economic analysis and include other factors important to the client, possibly including anticipated energy cost increases, longevity of the roof, and the cost of financing the initial investment over the payback period.

## ASHRAE 90.1-1999

ASHRAE 90.1, published in February 1999, allows for a trade-off between insulation requirements and roof reflectivity. Some codes recognize the benefits of reflective roof surfaces, and this matter should be considered on a case-by-case basis.

The consideration to reduce thermal insulation values and offset requirements should be carefully considered. In the example above, the building is in a heating mode for nearly as many months as it is in a cooling mode. A significant period of time for heat loss each year would be experienced. This is not factored into the calculations shown (but loss from emissivity and lacking benefits in the heating season are) unless the calculations are run at the reduced R-value being considered.

Do not confuse the ORNL output showing the added R-value to achieve the same savings with the energy trade-off attributes of ASHRAE 90.1. Reducing R-value in the roof assembly of the building envelope without calculating heating loss and dewpoint locations thoroughly may result in serious problems. Only a few buildings in the U.S. are in a constant cooling mode, and thermal insulation is the best defense against heating season loss. Therefore, it is wise to calculate the heating season loss through thermal calculations and the cooling season savings with reflectivity savings to assure the heating season loss does not offset some or all of the savings used to provide a benefit-to-cost or economic analysis justification.



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## Other Energy Issues Related to Roofing (Heating and Cooling)

Other areas of energy management related to roofing include keeping an eye out for "energy gobblers." Many roofs have penetrations and conditions that result in wasted energy and increased energy cost. These can be treated to avoid that loss when identified. Obviously, the thermal insulation system at the roof is important. *The NRCA Energy Manual* is helpful with the consideration of energy loss and the value of adequate insulation. Some of the calculators noted above also assist with this function. Also, look for breaks and breaches in the thermal envelope. They can typically be found at roof area perimeters and penetrations. These thermal breaks not only result in energy loss but also occasionally generate leak symptoms from condensation. As an example, some expansion joint details allow for only a fraction of the R-value prescribed for the remainder of the roof.

Ventilation can also be a factor that either enhances or reduces thermal transfer resistance. As an example, the use of an inverted roof system with drainage channels vented to the outside air dramatically reduces the value of the insulation, allowing outside air to flow across and in direct contact with the structure beneath the insulation (similar to venting an attic space). Ensure that there are thermal stops that do not allow the channel areas to become vented air spaces. Skylights, gravity vents, and other open chases from the inside to the outside with little or no resistance to heat flow may exist and should be treated. In the case of skylights, also consider the solar gain directly into the space, dramatically increasing the heat load. Some shading or tinting may provide substantial benefit.

## Reflective Surface – Roof and Environmental Benefits

Other benefits of ENERGY STAR® roof products may also be of consideration. A reflective roof surface will reduce surface temperatures.

Reduced roof surface temperatures can provide improved resistance to thermal shock caused by rapid cooling. Reduced ultraviolet aging of products that otherwise do not perform as well when exposed to the sun also provides a benefit. It is clear from many roof surveys that roof flashings perform better when a reflective surface is used. This is also indicated at the surface of south-

facing flashings that deteriorate more quickly due to solar exposure. These indicators are telling us something, and it applies to the entire roof surface. To maintain reflectivity at its optimum level, it may be wise to consider periodic cleaning that could be coupled with preventive maintenance rooftop checkups. This would pay serious dividends to roof performance while maintaining reflectivity.

The environmental benefits are something in which we should all have an interest. Thirty years ago, air quality indices and ozone levels were not part of our local weather forecasts. They are today. What will we hear 30 years from now? Will the local weather report include the level of filter we need to use in our respirators? If the trend continues, the future may be clouded with smog. The prospect sounds grim but could become a reality. The good news is we have options and can make a difference.

## Conclusion

Electric energy consumption is reduced by the use of ENERGY STAR®-labeled Roof Products. This affects the cost of electricity based upon rate of use and demand. There are calculators available to evaluate the savings, and more are being developed. Be certain you understand the components of calculation included in the results. A good rule of thumb is, "if you don't enter the information, then it is not included in the result." The demand charge savings should be included in the evaluation of total savings. Winter season losses and resistance to heat flow must also be considered. The use of ENERGY STAR®-labeled Roof Products provides cost savings and environmental benefits. As energy costs and demand continue to rise, the savings and environmental benefits will become even more important.

At some facilities, the energy management impact or savings from an ENERGY STAR® roof product may be small, but every little bit helps. Individuals and companies make economic choices each day. We now have even more tools to understand the impact of technology. It is rare when we can choose to save

## ENERGYSTAR® Roof Products Program Product Specifications

LOW-SLOPE ROOFS: Surfaces with a slope of 2:15 inches or less*	
Characteristic	Performance
<b>Energy efficiency</b>	
Initial solar reflectance	Greater than or equal to 0.65
Maintenance of solar reflectance	Greater than or equal to 0.50 three years after installation under normal conditions.
<b>Reliability</b>	
Manufacturers warranty for defects in materials and manufacturing.	Each company's warranty for reflective roof products must be equal in all material respects to the warranty offered by the same company for comparable non-reflective roof products. A company that sells only reflective roof products must offer a warranty for comparable non-reflective roof products.
STEEP-SLOPE ROOFS: Surfaces with a slope greater than 2:12 inches*	
<b>Energy efficiency</b>	
Initial solar reflectance	Greater than or equal to 0.25
Maintenance of solar reflectance	Greater than or equal to 0.15 three years after installation under normal conditions.
<b>Reliability</b>	
Manufacturers warranty for defects in materials and manufacturing.	Each company's warranty for reflective roof products must be equal in all material respects to the warranty offered by the same company for comparable non-reflective roof products. A company that sells only reflective roof products must offer a warranty for comparable non-reflective roof products.

\*For roof products that can be applied to either low-slope or steep-slope roofs, manufacturers should refer to the low-slope roof tables for ENERGY STAR® specifications.

Table 2

money, improve roof performance, and benefit the environment, all at the same time. The cumulative benefit to society through environmental impact can be substantial, even on a small, incremental basis. One person clapping does not make much noise, but 5,000 people clapping can be quite a force. The same is true with the savings resultant from ENERGY STAR®-labeled Roof Products. One 97,500 square foot facility saving \$438 annually may be considered a small savings, but if all the facilities in just one major city were to do the same, the impact on the electric utility demand would be tremendous. So, start clapping; we all win. ■

## References

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## Key Web Sites

- Association of Energy Engineers – [www.aeecenter.org](http://www.aeecenter.org)
- ENERGY STAR® – [www.energystar.gov](http://www.energystar.gov)
- Florida Solar Energy Center – [www.fsec.ucf.edu](http://www.fsec.ucf.edu)
- Lawrence Berkeley National Laboratory – [www.lbl.gov](http://www.lbl.gov)
- Oak Ridge National Laboratory – [www.ornl.gov.roof+walls](http://www.ornl.gov.roof+walls)
- Potomac Electric Power Company – [www.pepco.com](http://www.pepco.com)

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Besides various management positions with HVAC manufacturers and consolidator organizations, Abremski's trade and field experience was gained through nine years employment with a commercial HVAC contractor, including experience as an installer, technician, service manager, estimator/designer and energy efficiency specialist. Fieldwork included installation of rooftop HVAC units with coordination of roof installations, penetrations, and repair through roofing consultants and contractors. Abremski holds an AA degree in Construction Technology and a BS in Business Marketing.