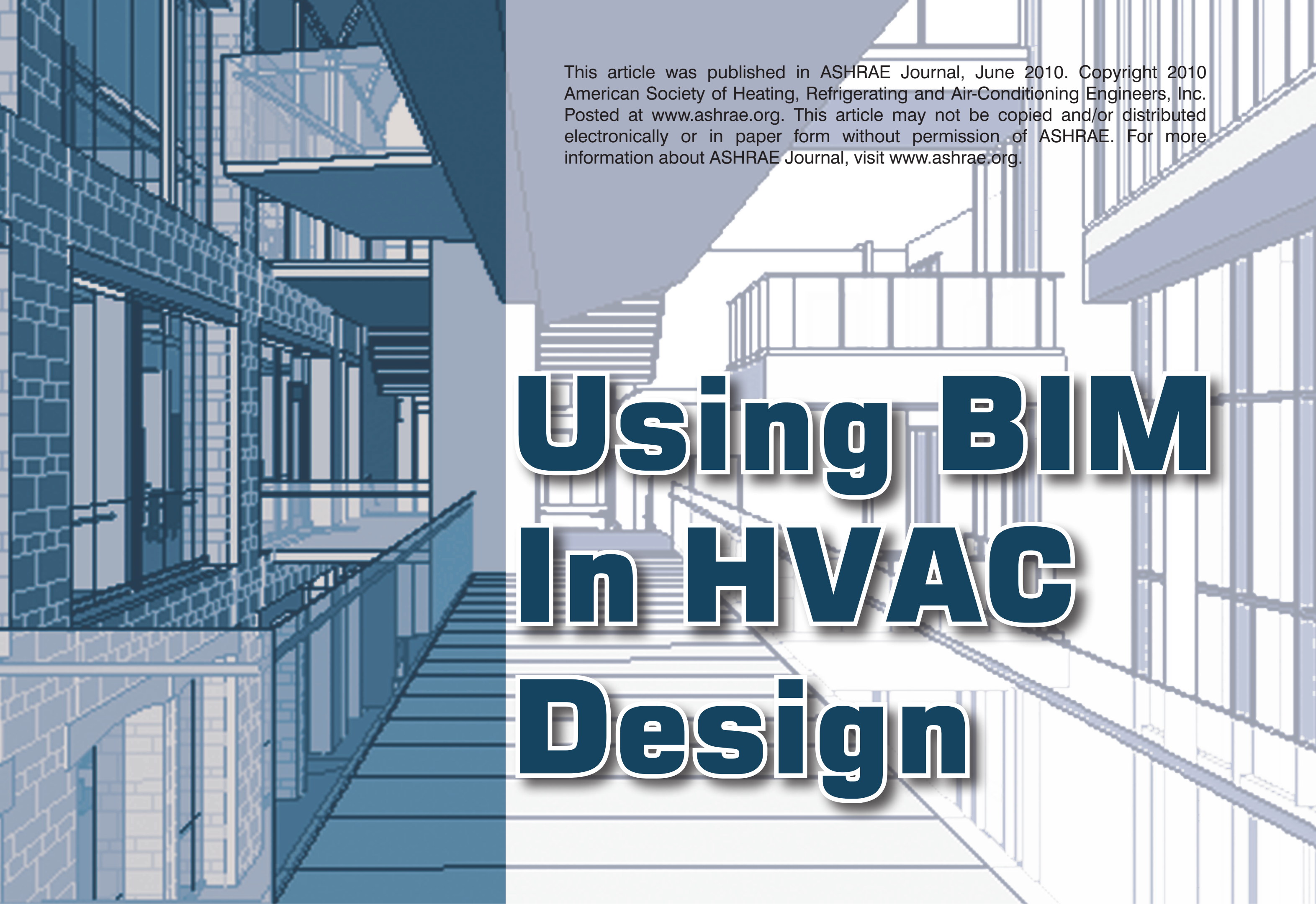

Using BIM In HVAC Design

By Dennis Knight, P.E., Member ASHRAE; **Stephen Roth, P.E.,** Member ASHRAE; **Steven L. Rosen,** Member ASHRAE

Using a building information model (BIM) from the beginning of a project helps engineers and designers make better decisions earlier in the process. A BIM's 3-D graphics of buildings and systems are generated by data that can be easily changed as the project moves along. Most BIM software* links intelligent objects† together, so when a change is made to one object, parametric changes are made to any other objects that are linked. For example, if an engineer changes the airflow of a diffuser, the corresponding duct, diffuser and neck sizes automatically change.

The data that is the heart of a BIM is similar to data in a spreadsheet. To describe an entire building in a spreadsheet, begin with a room. One column has a room's name or number with other columns describing the room's characteristics such as length, width, height, construction materials and components. To describe a specific room in a spreadsheet, specify orientation and other information relating to the bounding elements (walls, roof, and floors) of adjacent rooms. The description of the bounding elements must be complete so that HVAC analysis software can consider the room as a discrete zone for controlling thermal comfort.

To make the spreadsheet more useful, add columns and subcolumns for openings such as doors, windows, curtain walls, etc. As with a BIM, a spreadsheet can be expanded as the building moves through its design and life cycles. For example, we could add materials information including physical and thermal properties, manufacturer, model number, and full- and part-load performance formulas. To make the objects parametric, we could add formulas linking elements

*The following discussion and case study are generic and may not apply to all BIM physical and/or analytical modeling software on the market today. †For definitions of BIM terms used here, refer to "An Introduction to Building Information Modeling: A Guide for ASHRAE Members" available for free at www.ashrae.org/bim.

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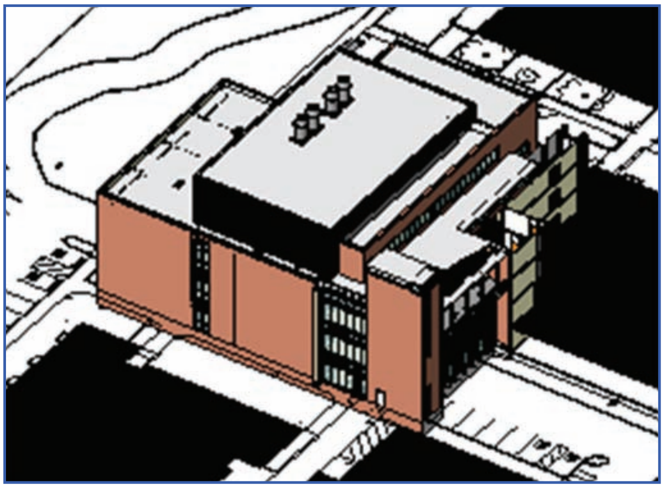

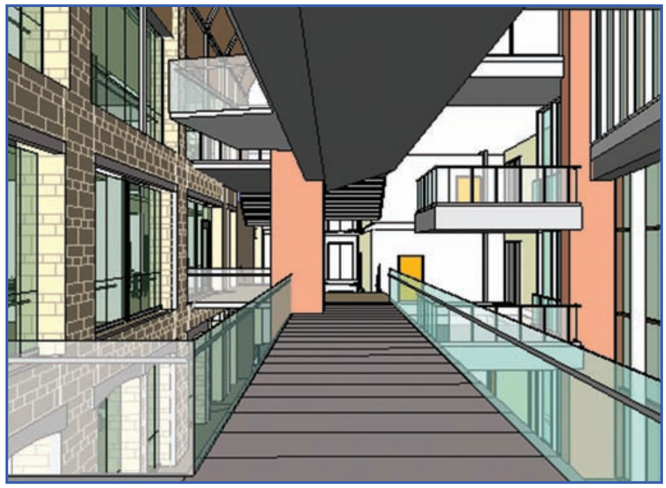

Figure 1 (left): Typical 3-D exterior view. Figure 2 (right): Typical 3-D interior view. Both are created using a BIM authoring application.

that depend on each other for size and location. Eventually, the spreadsheet will have a comprehensive description of a room and, ultimately, the entire building. This is similar to how a BIM authoring tool builds its database of information associated with visible objects in a 3-D drawing.

The buildingSMART Alliance is developing an open standard approach to integrating facility management handover using the Cobie2 XML spreadsheet to BIM.[1] When the graphical model is used to perform analysis, either an integrated analytical modeling tool within the BIM software runs the analysis, or the information in the model is exported out of the physical model in a file format that the analytical modeling software accepts. Two of the most common formats are IFC[1] and gbXML.[2]

When the information is exported, it must be identified so that other software applications can recognize and reassemble the building digitally in the same configuration as described in the BIM graphical model. Continuing with the spreadsheet analogy, we use our column and subcolumn headings and room names and numbers as identifiers for each unique piece of information associated with each room. These identifiers in an exported file are referred to as "tags."

The HVAC engineer adds formulas and analytical processes to the spreadsheet to perform load, annual energy consumption and life-cycle cost analyses. This is an example of an integrated approach. When a designer exports only the information needed to perform HVAC analysis from the BIM spreadsheet into a spreadsheet created for load analysis, that is an example of an interoperable approach.

Let's assume most engineers choose the interoperable approach to HVAC systems analysis by using independent software tools to perform HVAC load and performance calculations by exporting the data from the BIM authoring application. In the following case study, we explore how a design engineer can work with a building information model to complete HVAC analysis.

Figure 1 is a typical 3-D view of a BIM an HVAC engineer received from an architect. The 3-D view helps the engineer understand the project's massing and scale. It is easy for the architect to create exterior and interior (*Figure 2*) views from within the BIM. With these views in hand, the HVAC engineer can explore site and system options and design decisions can be weighed against each other. To validate those decisions, heating and cooling loads are necessary.

In this example, the architect has used the data in the BIM to validate and verify the programming needs of the project. In the schedule shown in *Figure 3*, the column titled "Delta" compares an owner's required area versus what is defined in the model.

Room Schedule NW ALT by Level

Level	Name	Area	Use	Required Area	Delta	Department
Level 1	Lab Stockroom	863 SF	Dedicated Support	750 SF	113 SF	Materials Management
Level 1	Dry Stockroom	287 SF	Dedicated Support	300 SF	-13 SF	Materials Management
Level 1	Central Glass Wash	360 SF	Dedicated Support	340 SF	20 SF	Materials Management
Level 1	Central Glass Wash -Equip	165 SF	Dedicated Support	160 SF	5 SF	Materials Management
Level 2	Intro Bio + Non Majors Lab	1,246 SF	Teaching Lab	1,200 SF	46 SF	Biology
Level 2	Intro Bio Lab	1,141 SF	Teaching Lab	1,200 SF	-59 SF	Biology
Level 2	Prep - Intro Bio	567 SF	Dedicated Support	300 SF	267 SF	Biology
Level 2	Stock Manager	93 SF	Office	150 SF	-57 SF	Materials Management
Level 2	General Chem Instruments	562 SF	Dedicated Support	600 SF	-38 SF	Chemistry
Level 2	General Chemistry	1,775 SF	Teaching Lab	1,600 SF	175 SF	Chemistry
Level 2	General Chemistry	1,649 SF	Teaching Lab	1,600 SF	49 SF	Chemistry
Level 2	Prep - Gen Chem	226 SF	Dedicated Support	200 SF	26 SF	Chemistry
Level 2	Chemical Waste	86 SF	Dedicated Support	150 SF	-64 SF	Materials Management
Level 2	Dispensing	164 SF	Dedicated Support	150 SF	14 SF	Materials Management
Level 2	Flammables	121 SF	Dedicated Support	150 SF	-29 SF	Materials Management

Figure 3: Building program analysis automatically generated from data within the BIM.

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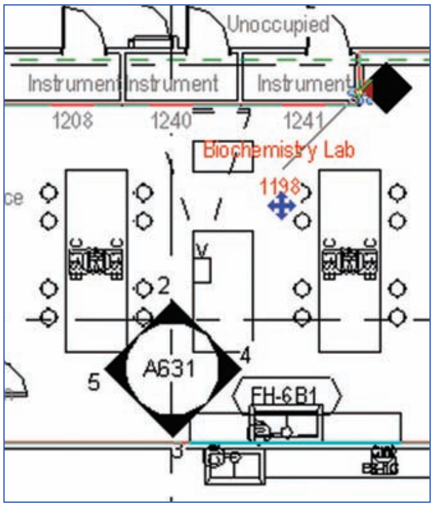


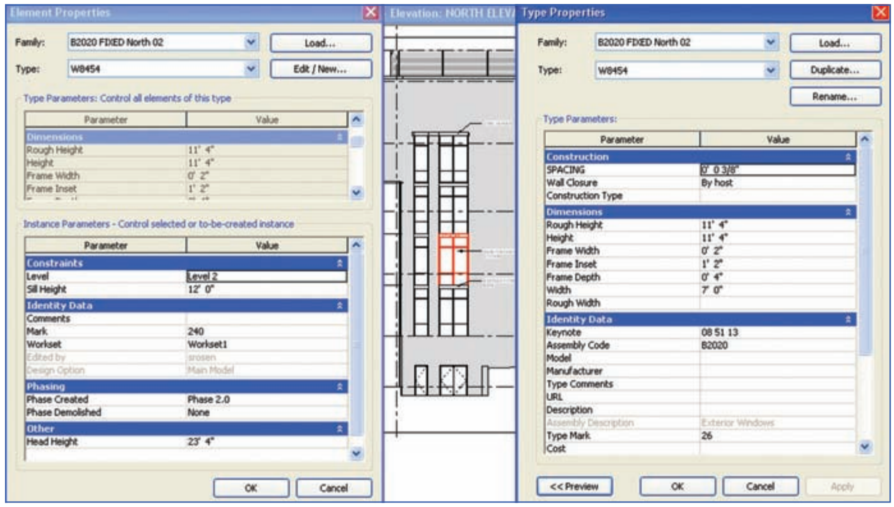
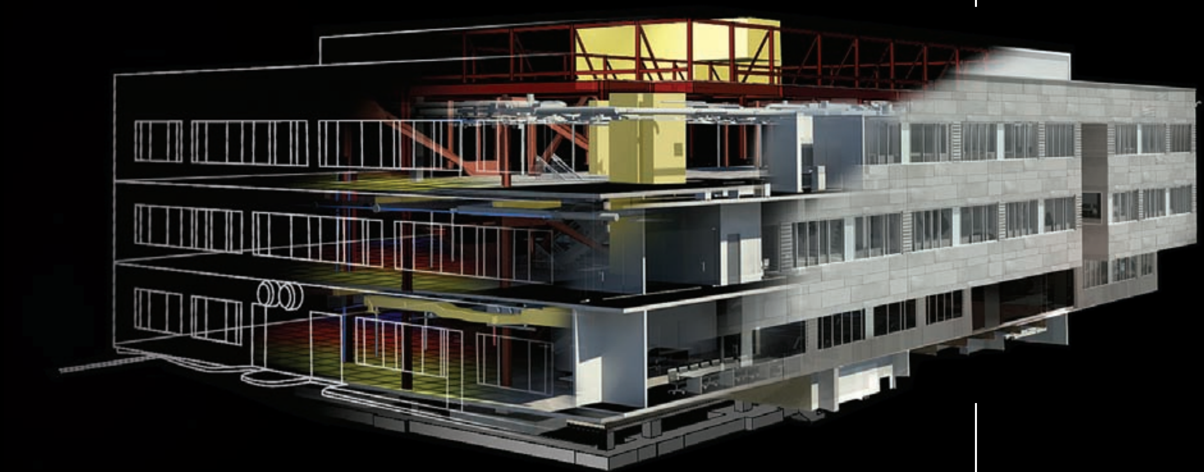


Figure 4 (left): 2-D view of a portion of the BIM. Figure 5 (right): Object type and element properties views in the BIM.

After all of the rooms in a building have been defined by an architect in the BIM, an HVAC engineer creates conditioned spaces or zones in the analytical model from those rooms to facilitate HVAC analysis. The space defined on the HVAC analytical model retains all the room information from the BIM and has additional information needed for HVAC analysis.

"Biochemistry Lab 1198" is the name of the room in the BIM (*Figure 4*) assigned to the area by the architect. Selecting the window (an element or object) shown in red in *Figure 5* allows the engineer to see its element and type of properties. Dimensions and other parameters can be filled in with data. In this example, there is no U-value. A parameter with that



What's Holding Back BIM

Almost 50% of all firms report using BIM for a portion of their projects.[3] Despite the prevalence of BIM, some disadvantages to applying BIM tools prevent widespread adoption.

BIM requires more effort at the front-end of a project to establish the initial framework. This is due to two factors:

1. BIM software is more complex than traditional CAD software. Some say it requires a new way of thinking about virtual building design. Designers entrenched in using conventional 2-D or 3-D CAD software may find it difficult to transition to BIM software tools. Designers up to date on current technology or practitioners recently educated in technology-based design tools are more receptive to the new workflow required by BIM.

2. BIM software requires so much information to be inputted that it may be overwhelming to the average designer. To properly calculate thermal properties of a building requires a lot of accurate information. If all the required information is not input or input incorrectly, the thermal analysis will be incorrect. BIM software tools are incorporating more "model-checking" capabilities that provide feedback to the end-user regarding the quality of the information in a model, but these functions still have a long way to go to be considered reliable.

BIM allows changes to be made easily, so clients may make changes late in the process, impacting construction and design costs. Also, the parametric nature of some BIM tools makes it easy to make changes that propagate throughout other related models and analytic tools. This could cause confusion, unintended problems with non-parametric tools, and other coordination problems for those parties that are downstream in the building life-cycle process.

BIM tools produce larger file sizes than traditional CAD software tools. Plus, the complexity and amount of information in a BIM far exceed those of traditional 3-D CAD models. Therefore, BIM tools require computer hardware with processing speeds and memory capacities that are greater than those of other 3-D CAD tools. In fact, many complex BIM software tools only work well on 64-bit computers with at least 8GB of memory. These computers are more expensive than conventional office computers.

BIM requires thinking in 3-D and visualizing the final product before design even begins. It is imperative that those new to BIM (and even BIM veterans) have sufficient training on these tools. Because BIM is relatively new, good training is scarce and often expensive.

1198 Biochemistry Lab

	COOLING COIL PEAK				CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 7 / 1				Mo/Hr: 7 / 1	
Outside Air:	OADB/WB/HR: 78 / 70 / 102				OADB: 78	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	1,728	1,728	7	0	0
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	478	76	554	2	478	2
Partition/Door	8,188		8,188	35	8,188	40
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	8,666	1,804	10,470	45	8,666	42

	HEATING COIL PEAK		
	Mo/Hr: Heating Design		
	OADB: 30		
	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-3,344	16.26
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	-640	-740	3.60
Partition/Door	-7,018	-7,018	34.12
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-7,658	-11,102	53.98

TEMPERATURES	Cooling	Heating
SADB	55.9	74.0
Ra Plenum	75.5	67.4
Return	75.5	67.4
Ret/OA	75.5	67.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS	Cooling	Heating
Diffuser	343	343
Terminal	343	343
Main Fan	343	343
Sec Fan	0	0
Nom Vent	0	0

Figure 6: Example HVAC load analysis output data.

value can be added to the window/wall "family." However, this wall or window composition in the BIM does not have R-values already assigned to the components.

Although the process is not yet automatic, the engineer can quickly assign common U-values to most objects in the BIM for use in HVAC analysis either within the BIM or when using standalone HVAC analysis software. Fortunately, many manufacturers and third-party vendors are beginning to provide BIM object libraries populated with many of the physical and analytical characteristics needed to perform HVAC analysis.

Once spaces are defined in the model, HVAC loads can be generated from within the BIM software (integrated approach) or exported to an IFC[1] or gbXML[2] file that can be used with another software package (interoperable approach).

Figure 6 shows the HVAC load analysis outputs that can be generated from a combination of gbXML data exported from a BIM and other data inputted directly into the HVAC analysis software for the Biochemistry Lab used in this example.

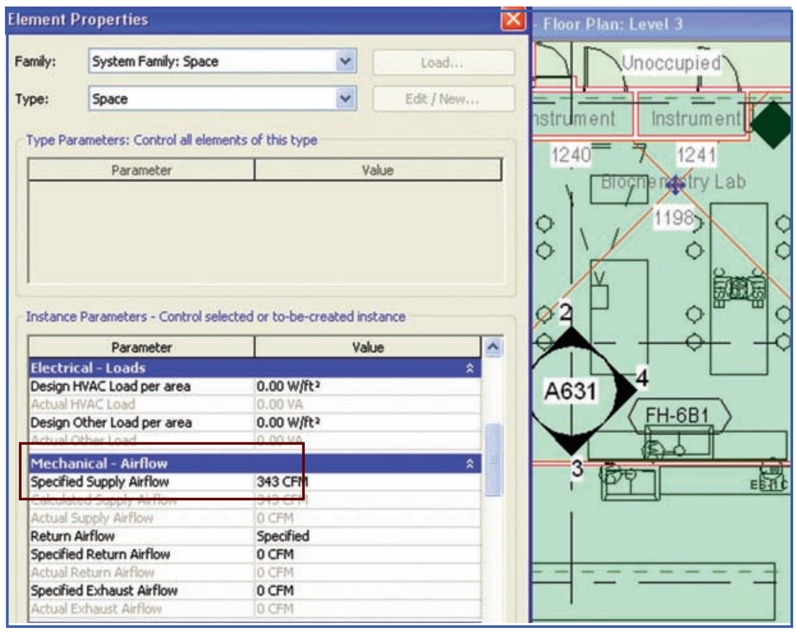


Figure 7: Biochemistry lab element properties view in BIM.

The output data in *Figure 6* is from an interoperable BIM software package and can be updated from the HVAC analysis program and imported back into the BIM. The engineer now can view the HVAC load analysis properties from within the BIM.

Focusing again on the biochemistry lab load data in *Figure 6*, we see that the calculated airflow is 343 cfm. In the BIM, airflow value is populated with the calculated 343 cfm value.

The HVAC engineer can place diffusers in this space in the BIM authoring tool. If two diffusers of 175 cfm each are assigned to the space, the parameter listed in *Figure 7* ("Specified Supply Airflow") is 350 cfm.

Just as an architect used BIM to create a schedule to review the difference in values of room area programming, an HVAC engineer can use a similar workflow and view a schedule that will indicate the differences between the specified and calculated airflows. This process can flag any values that have a determined significant delta to allow the design engineer to identify and address any large discrepancies.

Similar to the HVAC load analysis example, energy analysis, life-cycle cost analysis, scheduling, etc., for any system or component associated with a building may be conducted through a combination of capturing common data consistently stored in the BIM authoring application and exported using IFC or gbXML to standalone analytic software.

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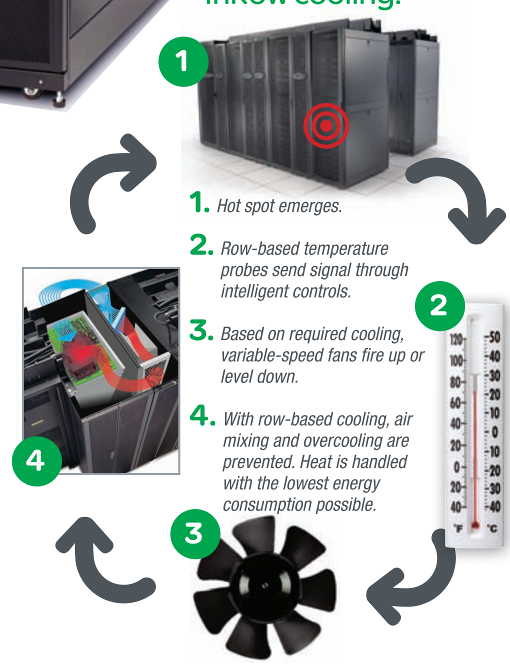

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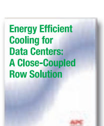

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