An Engineer's Guide to Capturing Energy Retrofit Opportunities

Experts agree that buildings are the biggest source of emissions and energy consumption both in the U.S and around the globe. As such, retrofitting existing buildings can lead to a significant reduction in building energy consumption. This white paper explores how MEP and structural engineering firms can realize the environmental and economic benefits of these building retrofit opportunities.

Research shows that over 50 percent of commercial buildings built prior to 1980 (when energy codes largely did not exist) have not had any energy related renovation. Over 70 percent of existing buildings have not had an HVAC or lighting upgrade, or have not had their windows replaced. And nearly 90 percent have not had an insulation upgrade.[1] These existing buildings present huge opportunities for retrofitting to reduce building energy consumption.

What is energy retrofitting? Energy retrofitting is the improvement, replacement, and substitution of new or modernized equipment, parts and systems almost exclusively to better their energy efficiency. For the purpose of this paper, retrofitting affects both the inside of the building (primarily the systems) as well as the building envelope. During retrofits, the primary focus of attention is indoor air quality—helping to deliver lower monthly utilities bills for owners and a better environment for occupants. Retrofit projects are primarily engineering driven, with the MEP engineers being responsible for the accurate evaluation and design of existing and replacement systems. Structural engineers' responsibilities on energy retrofit projects typically involve evaluating and retrofitting the existing structure to support the new MEP system equipment, and ensuring that the existing structure is in compliance with updated building codes.

Why is the retrofitting of existing buildings so important now? First and foremost, to mitigate the impact of buildings on the environment. From a pragmatic viewpoint, the 2009 economic stimulus package in the United States contains $4.5 billion to increase the energy efficiency of federal buildings and $6.3 billion for grants to state and local governments to make their energy usage more efficient, including public buildings.

[1] http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#consumexpen03

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Other countries outside the US are also making funds available to support similar efforts. This represents a major opportunity at the municipal level, where there is an abundance of government and state owned buildings. For example, it is estimated that nationwide there are roughly 80,000 public school buildings[2]. In addition, international, national, state and local laws and codes are mandating changes in the way buildings are constructed and how they perform—so they can be more energy efficient with lower or zero carbon emissions. This is creating a surge in the market for building engineers and designers to capitalize on these types of retrofit/rehabilitation projects. In fact, these changes have created an entirely new market around energy services—one that is expected to reach $40 billion in spending by 2013[3], according to market research firm Frost and Sullivan.

The demand for retrofit services is rapidly increasing as more building owners search for ways to reduce their monthly energy costs. Retrofitting projects are demonstrating a rapid return on investment at a time when the economic climate is forcing companies to find new ways to save money. In fact, 73 percent of respondents in a green retrofit survey[4] (released in a 2008 report entitled *The Dollars and Sense of Green Retrofits*) reported cost reductions as a result of green retrofits.

In 2006, a study done by U.S. Green Building Council (USGBC) found that by retrofitting buildings, owners can save 90 cents a square foot annually, on average, in energy and other costs and earn back their investment in 2 to 2½ years[5]. Given our existing building stock, it is likely that retrofitting existing buildings as opposed to greening new construction, will have a greater impact on the environment. The average building certified as green using the USGBC's Leadership in Energy and Environmental Design (LEED) rating system uses 32 percent less electricity and saves 350 metric tons of CO^2 emissions annually[6].

MEP Engineers: HVAC Retrofitting

MEP engineers have been involved with retrofits for many years. They play a pivotal role in identifying opportunities to decrease the lifecycle cost of buildings—helping building owners to invest in energy-efficient systems up front to gain long term benefits for the life of their buildings. With the emergence of new building codes and the availability of stimulus packages to support building retrofitting for energy efficiency, MEP engineers are now presented with a plethora of opportunities in existing buildings for tenant improvements and/or energy retrofits.

A building's HVAC systems are responsible for up to 40 percent of the total energy consumed by a commercial building[7] and their proper design and operation are essential for energy efficiency. Most HVAC systems can be retrofitted to improve reliability and to help reduce energy consumption. Studies have found that the majority of energy problems related to HVAC systems have to do with inadequate air flow, poor maintenance, and insufficient outside air flow.

When the HVAC system is identified as the cause of a problem, a system retrofit may be required. An HVAC system retrofit generally offers improved energy efficiency and reduced operating costs, as well as improved tenant comfort and satisfaction. Greater attention to ozone depletion and global warming may also be used to market "environmentally friendly" buildings. MEP engineers are in a prime position to help building

[2] www.msnbc.msn.com/id/30057212
[3] www.frost.com/prod/servlet/press-release.pag?docid=158725257
[4] *The Dollars and Sense of Green Retrofits*, Deloitte LLP and Charles Lockwood, 2008
[5] *Green Buildings Don't Have to Be New*, Amy Cortese, New York Times, January 27, 2008
[6] *The Dollars and Sense of Green Retrofits*, Deloitte LLP and Charles Lockwood, 2008
[7] www.allbusiness.com/operations/facilities/329282-1.html

owners improve existing conditions—enabling them to outwardly market these improvements and demonstrate their commitment to improving the built environment.

Energy retrofit projects nearly always use whole building energy analysis as a means for helping the building owner understand how the retrofitted systems can meet the energy savings being proposed. Any replacement of equipment triggers energy code certification, often resulting in the need for energy modeling and analysis.

Autodesk® Revit® MEP software is Autodesk's building information modeling (BIM) solution for MEP engineers—providing purpose built tools for building systems design and analysis. In addition, tools like Autodesk® Ecotect® Analysis software can help engineers and designers to conduct detailed environmental simulations and visualize those results. The Revit MEP design model can also be used for energy modeling—the first step of analysis. Once the design model is created within Revit MEP, critical information from the model can be exported to whole building energy analysis applications via the gbXML file format. Ecotect Analysis provides powerful web-based whole-building energy, water and carbon analysis capabilities through Autodesk® Green Building Studio® web-based service (which is available to Autodesk® Ecotect® Subscription customers during the term of their Subscription).

Once whole building analysis has been conducted, information can be sent to energy simulation tools such as Ecotect Analysis desktop tools or eQUEST (which offers the ability to generate energy use reports using the DOE-2 engine). Conducting analyses on the design model is critical since studies show that when a design team uses whole building energy analysis they can save an average 20 percent on energy use[8]. For retrofit projects, the potential for energy savings are even greater because older buildings tend not to have had any tenant or system improvements over the years. This creates an opportunity for greater reductions in energy consumption—reductions that can be calculated using whole building energy analysis.

During an energy retrofit project, MEP engineers decide how to replace or substitute new or modernized parts or systems, and/or how to change the elements within the existing building (such as lighting fixtures) to better the building. MEP engineers drive the design, analysis and documentation of these retrofit projects. Typically, the MEP engineer on an energy retrofit project will:

- *Assess and document existing systems to determine if they are meeting building energy requirements.*
- *Model the replacement systems and conduct analyses to determine peak heating and cooling loads of the building.*
- *Create an energy model that can be used in analysis applications to determine the performance of the new systems.*
- *Ensure that clashes are minimized and that there are no interferences between the MEP, structural and architectural design.*
- *MEP engineers will also engage with structural engineers to analyze and design the support of new systems to ensure that the building can support the new loads and requirements of the replaced systems.*

[8] "Final Report 2003 building Efficiency Assessment Study - An Evaluation of the Savings By Design Program," RLW Analytics, *http://www.calmac.org/publications/BEA_2003_Final_Report__080105_.pdf*, Table 16, page 21.

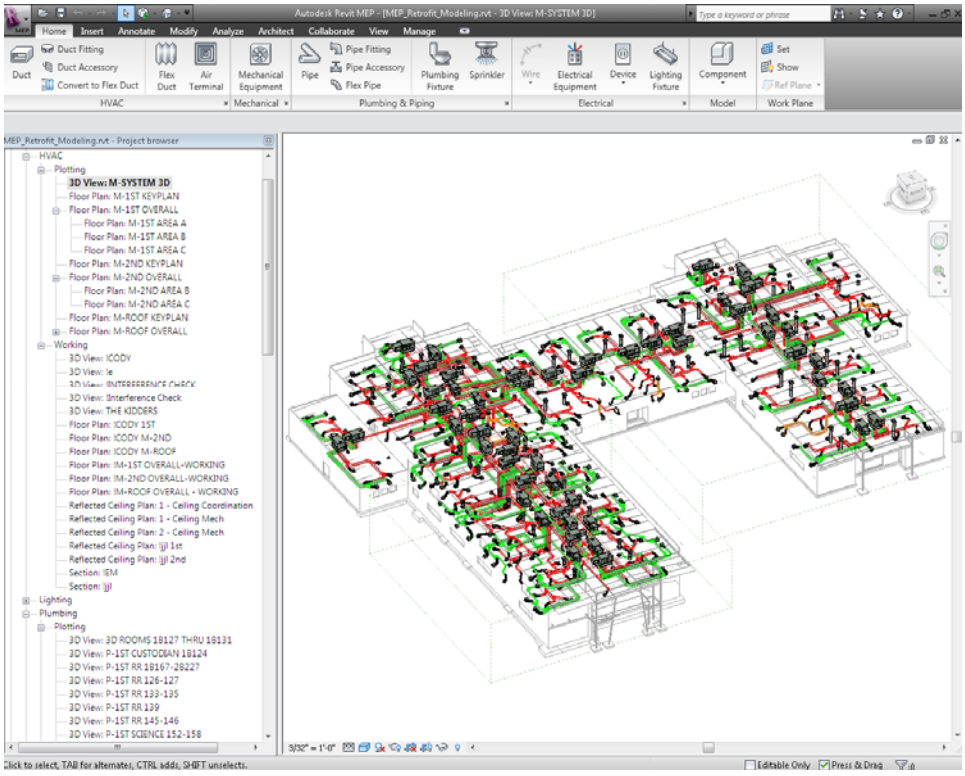

Figure 1:

Autodesk products are capable of capturing existing conditions from a variety of sources, creating a well coordinated model for analysis and measuring the potential for energy conservation using a BIM workflow.

MEP Engineering Case Study

Glumac (*www.glumac.com*) is a mechanical, electrical and plumbing (MEP) consulting engineering firm with over 250 people in eight offices along the western coast of the United States. Founded in 1971, Glumac provides MEP engineering services to its clients in the commercial, healthcare, institutional, and advanced technology market sectors. The firm currently employs more than 80 LEED-accredited professionals and every project the firm undertakes is staffed with sustainable design experts.

With Revit MEP at the core of their design process, Glumac uses building information modeling for building systems design—helping to provide its clients with more cost-effective, sustainable designs. Glumac uses the Revit MEP software in conjunction with Green Building Studio and eQUEST to analyze the potential savings of various green retrofit design approaches. The firm leverages Revit design models to create energy models that can be used for analysis.

"By using Revit MEP we've been able to significantly reduce the time it takes for us to do our analysis. On average we experience a 50 percent time savings," says Aryn Bergman of Glumac. The Glumac designers usually create the building geometry by starting with the architect's Revit model and then modifying that model using Revit MEP to make it suitable for energy analysis.

"Before using Revit MEP we had unconnected design instruments—a set of drawings for the design, an energy model built from scratch for our analysis, another model for CFD analysis, and so on," remarks Skander Spies of Glumac. "But now we have a centralized model that we can all leverage for our own needs: mechanical design, load calculations, CFD analysis, energy modeling, and more."

As retrofit projects on existing buildings become more prevalent, MEP firms such as Glumac are in a prime position to capture these opportunities. Glumac's approach of using existing building design information to create a centralized, digital model is an ideal workflow for retrofit projects. If possible, an MEP firm should start with an existing model of the building (such as an AutoCAD or Revit model).

[Note: In lieu of digital models, firms can also use existing floor plans by scanning them into AutoCAD® Raster Design software to create a DWG file and export those DWG files to Revit MEP for modeling and design using BIM. They can also use that 2D data to perform some of their schematic design within AutoCAD® software.]

From within Revit MEP, Glumac engineers can perform heating and cooling load analysis on their model to determine the amount of energy required to heat and cool the building. This type of analysis is critical to determining the appropriateness of existing systems as well as modeling new systems to meet the energy requirements of the space.

Once the model is created in Revit MEP, Glumac uses sustainable design analysis tools such as Green Building Studio and eQuest to better predict the behavior of the building with the new systems in place. To complete the workflow, Autodesk® Navisworks® Manage software can be used for cross-discipline project coordination, visualization, and clash detection.

Structural Engineers: Seismic and Structural Rehabilitation

Structural engineers face retrofit opportunities in various forms and, like MEP engineers, the opportunities are more prevalent today based on: economic stimulus packages; more stringent building codes being implemented throughout the world; and the increasing reuse of older buildings based on the rising costs of new construction.

Typical retrofitting opportunities for structural engineers include precautionary seismic retrofitting, the repair or restoration of existing structures, and the support of new HVAC equipment for energy retrofit projects. Regardless of the type of retrofit, there are consistent themes and obstacles that engineers face on these projects: investigation of existing building conditions, determination of code requirements, and the design of the retrofitted structure.

Existing structures require extensive field investigation to determine the layout and type of vertical and lateral structural systems, as well as any existing deterioration and deficiencies that need to be addressed. Depending on the type of building and when it was built, existing documents might be available to aid this investigative work. Even if drawings *are* available, verifying as-built conditions is a critical task in retrofit projects.

Along with the investigation and documentation of the existing building, these projects require extensive code analysis based on updated codes, seismic provisions, or new building use requirements. In most countries, for instance, buildings that were constructed before the 1960s and 1970s were not designed to withstand the seismic forces prescribed by modern building codes. These codes include updated seismic provisions based on extensive research and the severe impact on structures due to recent earthquake events such as Northridge (in 1994) and Kobe (in 1995).

For example, the International Existing Building Code (IEBC), which is widely adopted in the United States for the alteration of existing buildings, defers to the requirements of the building code used for new construction with regards to structural safety and seismic design requirements. So many building retrofits—whether they involve new construction, or new systems or sometimes even just a tenant fit out—will trigger seismic upgrades and the need for structural analysis calculations.

When new HVAC equipment is specified by MEP engineers during energy retrofit projects, structural engineers have to evaluate several conditions. First, they need to analyze the existing structural systems to determine if they can adequately support the new equipment. Secondly, the equipment itself may not be the governing factor for retrofitting the structure, but rather the requirements of current building codes.

For example, in areas that are prone to snow loads, buildings must be designed to support additional load due to the accumulation of drifting snow. HVAC equipment on a roof can cause snow to drift and accumulate against the equipment—enough so to cause additional load that can be more than twice as large as the standard snow load. It is this additional load that requires structural engineers to retrofit the structural systems to accommodate the new equipment.

In addition, certain municipalities have specific code requirements for the repair, addition, or change of use to an existing building—codes that may be more stringent than the IEBC or other national codes used for building retrofits. For example, the Massachusetts State Building Code has specific sections for the structural requirements of existing structures that are unique to Massachusetts[9]. These requirements may prompt the engineer to analyze the existing structures systems, and in many cases upgrade them to meet the current code requirements.

Once the building is investigated, documented, and the codes have been analyzed, the structural engineer has to determine the best means for retrofitting the structure. As with most structural designs, there is no single way to design a structure. Numerous factors need to be considered such as material and labor costs, accessibility within the existing structure, and schedule.

In projects that include new HVAC equipment, structural engineers need to determine whether the additional loads can be supported by locally strengthening elements or adding supplementary supports. In cases where snow drift is a concern, structural engineers design steel structures (dunnage) built up from main structural supports in order to support the new equipment and prevent snow from drifting on the existing beams and deck.

For seismic retrofitting, there are several techniques and strategies that are used by structural engineers. Some retrofit strategies involve strengthening the overall capacity of the lateral resisting system (such as adding shear walls or braced frames) while others focus on strengthening the capacity of individual elements. Other options for seismic retrofit include reduction of seismic demand through the use of supplementary damping systems or base isolation.

Structural engineering firms working on retrofit projects can benefit greatly by using a BIM workflow. Autodesk® Revit® Structure software is Autodesk's building information modeling (BIM) solution for structural engineers. Revit Structure integrates a multi-material physical and analytical model, providing concurrent structural modeling for analysis, design and documentation.

The analytical model in Revit Structure is bidirectionally linked with Autodesk® Robot™ Structural Analysis software, so analysis results more accurately and automatically update the Revit Structure model if any member size has changed. Revit Structure also links to many third party structural analysis and design programs, enabling the sharing of structural analytical information such as release and boundary conditions, loads and load combinations, and material and section properties.

[9] *The Massachusetts State Building Code (780 CMR – Seventh Edition), 3408.0 Structural Requirements for Existing Buildings*

During a retrofit project, structural engineers investigate the existing structural condition of the building, determine the building code requirements for updating the structure, and redesign and document the retrofitted structure. Typically, the structural engineer on a retrofit project will:

- *Assess and document the condition of the existing structure to determine if they are meeting building codes for structural safety and seismic requirements.*
- *Model the retrofitted structure and use that model to simulate and analyze structures against new load requirements.*
- *Coordinate with the architect and MEP engineer to ensure that clashes are minimized and that there are no interferences between the MEP, structural and architectural design.*
- *Document and certify the newly designed structure.*

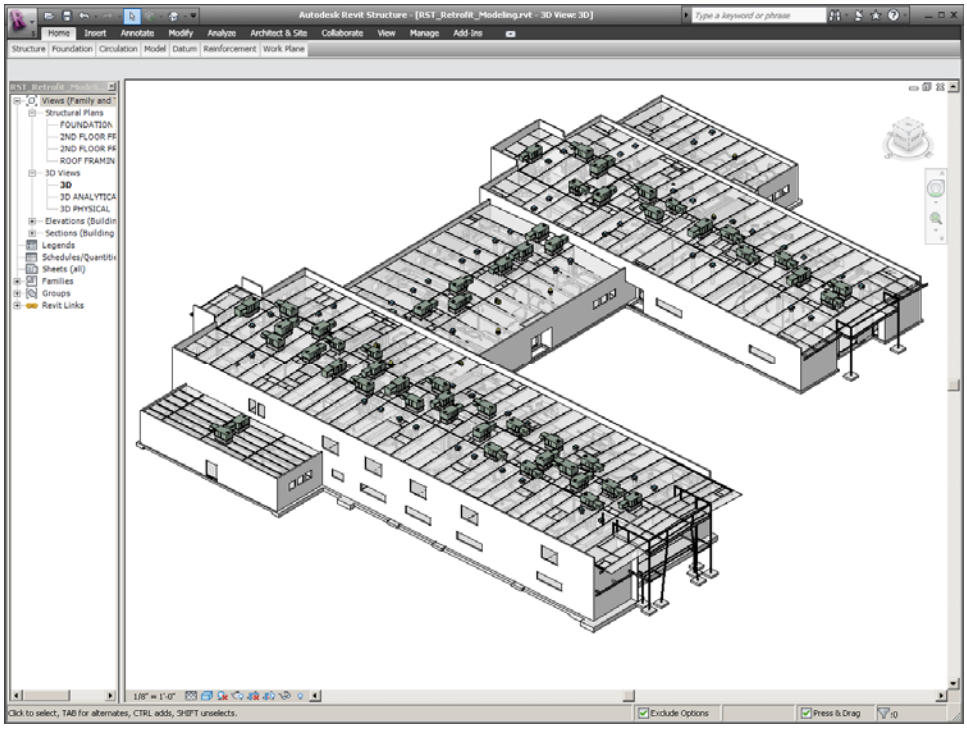

Figure 2:

Revit Structure helps structural engineers to document existing structures, design the retrofitted structure, and then use that design model to simulate and analyze the structure under new load requirements.

Structural Engineering Case Study

Odeh Engineers Inc. (*www.odehengineers.com*) is a full-service structural engineering consulting firm headquartered in Providence, RI. With its staff of 25 engineers, the firm has developed a BIM workflow, based on Revit Structure, specifically for its retrofit projects.

This workflow starts with investigating and documenting the existing structure as well as all structural deficiencies. Most retrofit projects are existing buildings that were built more than 40 or 50 years ago and construction documents are often hard to come by. When available, Odeh uses existing construction documents to start documenting the structure.

[Note: Even if only paper drawings are available, firms can use them to start creating their digital model—employing AutoCAD Raster Design to scan the existing paper drawings and converting the raster images into working AutoCAD files. The images can then be converted into editable polylines and text that can be used as the baseline of the project. These AutoCAD files are used to document existing conditions and also to create a Revit Structure model—without the need to redraw or recreate the existing information.]

As stated earlier, even with existing documentation, it's vital to document as-built conditions for retrofit projects. Odeh uses a team of field engineers and a combination of AutoCAD and Revit Structure to create a 3D model of the structure and as-built conditions. This model serves as the basis for all other aspects of the retrofit project.

"The use of a BIM approach and the Revit Structure software has been invaluable in terms of our project coordination and quality control," reports David J. Odeh, Principal at Odeh Engineers. "We rely on the Revit model as our single source of data and use it for documentation, coordination between disciplines, design visualization and simulation, analysis and optimization, sometimes even for fabrication and construction."

Accurately documenting structural deficiencies in retrofit projects is critical to the success of the project. Deficiencies that are not caught, or ones that are not evaluated to the fullest extent, can cause major repercussions for the entire project. Odeh's in-house software development team has designed a tool that leverages the BIM model and more clearly identifies structural deficiencies using annotations in AutoCAD. Once identified, these deficiencies are imported back into the Revit Structure model for documentation purposes. When the investigation of deficiencies and as-built conditions is complete, the result is a comprehensive Revit Structure model of existing conditions, which is used as the basis for the retrofit design.

Many retrofit projects—especially energy retrofit projects—require new HVAC equipment, resulting in new rooftop units (RTU) installed on the existing roof structure. In order to determine the capacity of the existing roof's structural elements and their adequacy of supporting the new loads, Odeh uses the Revit Structure model and the Autodesk® Revit® Extensions to simulate the loads and analyze the supports of the structure.

Engineers are able to perform Load Takedown simulation using the Revit Extensions to simulate the additional loads of the new units and the new load requirements of the local building code. The Extension more clearly identifies the load path and distribution of these required loads, all the way to the foundations. This type of analysis and simulation allows structural engineers to perform analysis earlier in the process without having to recreate any additional structural models.

By performing this analysis inside of Revit Structure using the Revit Extensions, Odeh's engineers are able to more quickly and dynamically explore different design alternatives to provide feedback to the entire team on the feasibility of different options.

Finally, the same Revit Structure model is used to complete the construction documentation and can also be used in Autodesk Navisworks Manage to help coordinate and collaborate with the HVAC engineer and/or the rest of the extended project team.

Summary

MEP and structural engineers are in a prime position to help engineer a sustainable future. Our existing buildings pose an environmental challenge, but also represent an exciting opportunity for engineers—giving us the chance to revitalize our building infrastructure from the ground up, capitalize on new revenue streams, and minimize the environmental impact of our built environment.

With technologies that support a more sustainable future, Autodesk strives to provide more cost-effective, advanced technical solutions that support the entire lifecycle of a more sustainable infrastructure from planning and design, retrofitting and construction, through to operation and maintenance.

For more information about Autodesk Revit MEP or Autodesk Revit Structure, please visit *http://www.autodesk.com/revitmep* or *http://www.autodesk.com/revitstructure*. For additional information about sustainable building design, please visit http://*www.autodesk.com/sustainabledesignguide*.

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