EXECUTIVE SUMMARY

RAPID ENERGY MODELING FOR EXISTING BUILDINGS:

Testing the Business and Environmental Potential through an Experiment at Autodesk

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Autodesk®

ICF INTERNATIONAL

1. Executive Summary

Retrofits of existing buildings represent a huge, growing market and an opportunity to achieve some of the most sizable and cost-effective carbon reductions in any sector of the economy. More and more "zero energy" and "carbon neutral" buildings are being conceived every day by combining energy efficiency measures with renewable energy technologies. However, for all the progress, the building industry continues to face major technical and cost challenges in identifying the highest potential candidates for retrofit. This report investigates one potential solution, a technology-driven workflow called "rapid energy modeling," to accelerate and bring to scale the process of energy modeling for existing buildings.

ICF estimates that using software solutions like those tested by Autodesk® and profiled in this report could lead to 90 Mt or more of additional annual CO_2 reductions globally.[1]

1.1. The Environmental Imperative

Implementation of efficiency measures and renewable energy generation in existing buildings is poised to become the global approach to carbon reduction with the largest impact and lowest costs to address climate change.

The magnitude of the climate challenge facing the world today requires scale and speed to address the largest greenhouse gas emitters:

- The International Energy Agency has targeted a reduction of 77 percent in the global carbon footprint by 2050[2] in order to achieve climate stabilization. At roughly 40 percent of global energy consumption[3] and global energy carbon emissions, buildings are the linchpin to achieve that 2050 climate stabilization goal.
- In some places, such as the United States, buildings alone account for 40 percent of national carbon emissions[4] due to the heavy electrical loads from lighting, heating, cooling, computers and appliances.
- In recognition of this, the major economies of the world are producing a drumbeat of national and regional building directives, promoting an aggressive push toward zero energy or carbon neutral buildings.

And yet, our current toolbox will fail us. Even if, for example, 1,000 dedicated energy auditors worked full-time, 365 days a year throughout the United States, it would take them over 13 years to do one-day audits of the entire U.S. commercial building portfolio.[5]

To respond to the climatic challenge at the scale, speed and efficiency required, we will have to be able to quickly and cost effectively prioritize, mobilize and focus our retrofitting efforts. Achieving these goals requires leapfrogging traditional energy modeling methods and building audit techniques.

> *"Rapid energy modeling techniques, like the one I've seen at Autodesk, help users evaluate numerous design alternatives with less time and cost. Such tools are important for enabling better designs that save energy and money and can create competitive advantage for both designers and clients."*
>
> AMORY B. LOVINS, CHAIRMAN AND CHIEF SCIENTIST, ROCKY MOUNTAIN INSTITUTE

1.2. The Business Imperative

We face an unprecedented market opportunity to implement building energy upgrades that serve as an engine for new jobs and capital investment.

- Approximately 75 percent of buildings globally will be either new or have undergone significant renovation by 2035.[6]
- About 150 billion square feet of existing buildings (roughly half of the entire building stock in the United States) will need to be renovated over the next 30 years.[7]
- A recent analysis estimates that green building retrofits in the United States

1. Buildings account for 9Gt of annual CO_2 emissions globally and ICF assumed that uptake of Rapid Energy Modeling could increase by 10 percent the number of buildings retrofitted for energy performance, with an average improvement of 10 percent.
2. International Energy Agency (2008), Energy Technology Perspectives.
3. World Business Council for Sustainable Development (2009), Energy Efficiency in Buildings: Transforming the Market.
4. Energy Information Administration (2008), EIA Annual Energy Outlook.
5. According to the most recent information available to the Energy Information Administration, in 2003, there were nearly 4.9 million commercial buildings accounting for more than 70 billion square feet of floor space in the U.S. alone.
6. http://www.architecture2030.org/ (2009)
7. American Institute of Architects (AIA) COTE (2009), Ecology and Design: Ecological Literacy in Architecture Education.

represent a $400B market[8] in the next 20 years.

- In fact, six of the world's largest economic regions (Brazil, China, European Union (EU), India, Japan and USA) could reduce their energy and carbon footprints by 40 percent by investing US$150 billion, with a payback period of only five years.[9]

National economic stimulus programs throughout the world are investing billions of dollars combined in energy efficiency programs over the next few years. In the United States, approximately 86 percent of building construction expenditures is now being directed to renovation of existing buildings, as opposed to new construction.[10] But these massive resources must be channeled into the most cost-effective and scalable of approaches to building upgrades.

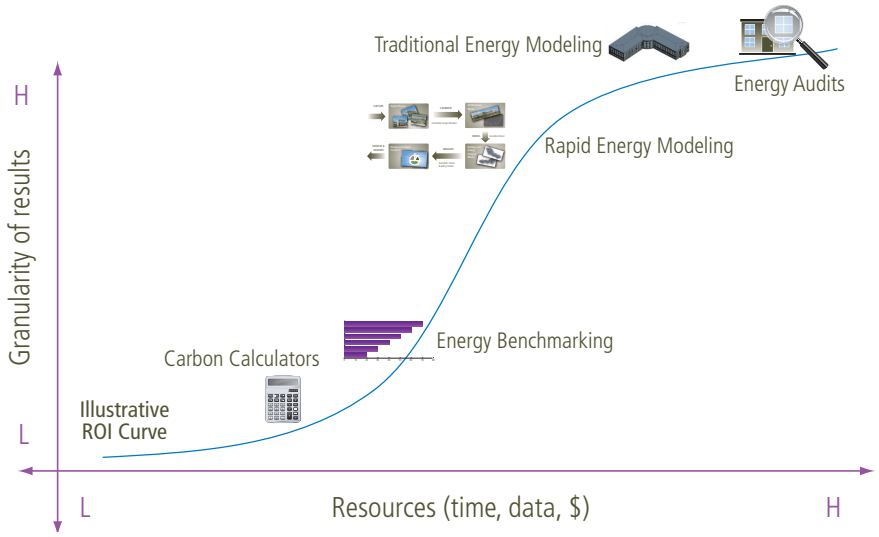
Each of the above solutions provides a unique value by addressing a specific market demand. **However, cost, time, effort, lack of expertise and lack of scale in existing energy modeling will thwart the widespread application of building energy analysis, which is so clearly demanded by the environmental and business imperatives described earlier.**

1.3. The Challenge: Time, Tools and Techniques

Through our discussions with leading green architecture and engineering firms, we have found that:

- *Energy benchmarking* is useful but needs to be supplemented with the ability to model, choose and test the energy and cost savings of different design measures and alternatives.

THE SPECTRUM OF ENERGY REDUCTION TOOLS AND APPROACHES



- *Traditional energy modeling* capabilities often require weeks to months to construct before they can provide the information necessary to guide the design and retrofit process, and are therefore often restricted to only high-budget projects. Their results too often do not accurately represent the measured energy use once buildings are operating. For these reasons, traditional energy models have not penetrated the market sufficiently to meet carbon reduction goals for buildings.
- *Building audits* can provide crucial perspectives on the unique operational details of a building, but they are time consuming, expensive, and require travel and significant investment of time on the part of auditors and their clients. So they only provide optimal value if targeted at buildings with known high potential for improved energy performance.

1.4. The Solution: Rapid Energy Modeling

To address this challenge, this report explores rapid energy modeling as a way to help commercial and residential property owners identify buildings with the greatest potential for energy and carbon emissions savings at the lowest cost and in the shortest time. **Rapid energy modeling is a streamlined process that involves moving rapidly, and with minimal data, from image capture of building exteriors through simplified simulation to building energy analysis.** It offers the capability to:

- Supplement energy benchmarking by providing numerous design alternatives to users.
- Democratize the energy and carbon footprinting process by making it accessible to a wider audience of practitioners.
- Make modeling faster, cheaper, and more likely to be used.

8. Pike Research (2009), "Energy Efficiency Retrofits for Commercial and Public Buildings," Executive Summary.
9. World Business Council for Sustainable Development (2009), Energy Efficiency in Buildings: Transforming the Market.
10. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Journal (2008), http://findarticles.com/p/articles/mi_m5PRB/is_1_50/ai_n25376330/

- Augment, refine, and focus traditional on-site building energy audits.

This type of workflow will benefit a number of constituencies as illustrated by the picture below.

1.5. Autodesk's Rapid Energy Modeling Workflow

This report summarizes the results of an in-house experiment at Autodesk, where three Autodesk products (Autodesk® ImageModeler™, the Autodesk® Revit® platform and Autodesk® Green Building Studio web service) were applied to Autodesk's own facilities.

ICF and Autodesk worked together over the span of three months to test solutions for rapid energy modeling on six Autodesk facilities and investigate the application of Autodesk tools in the wider architecture community. While the rapid energy modeling workflow can be applied to both new and existing building projects, we chose to focus this study on existing buildings, both to address a much needed demand described in Section 1.2 and to validate the models using actual energy consumption data. Autodesk's software products provide the ability to deliver a detailed energy and carbon report, beginning with pictures of building exteriors taken with a digital camera.

We took a two-pronged approach to help validate our hypotheses:

- Interview leading architecture firms to help understand their experience with, and perspective on, the potential value of such a workflow.
- Apply this workflow to a selection of Autodesk's own facilities and compare the modeling results with data from existing carbon footprint and energy audit reports.

1.6. Key Conclusions

Adoption of rapid energy modeling techniques can significantly increase the number of existing buildings that undergo energy assessments and subsequent upgrades within a smaller budget and shorter time frame.

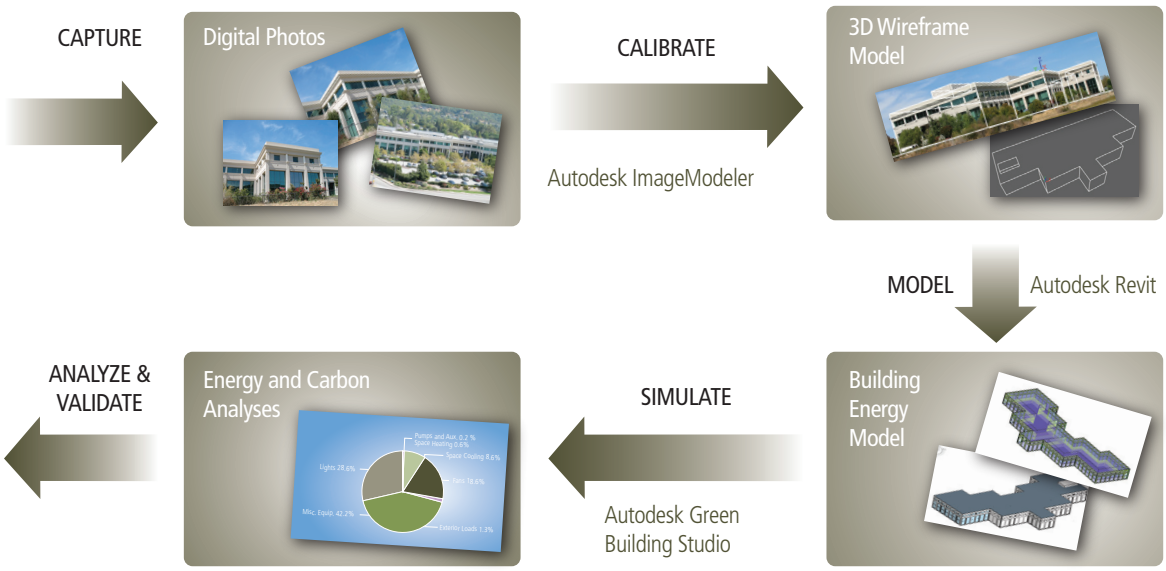
There is considerable interest in the building community to streamline the modeling process. Property managers, tenants, home buyers, design teams, public policy advocates and energy consultants are expected to benefit from such a workflow in the following ways:

A. Shortcut to estimating actual energy use: Applying a set of standard parameters to all facilities,[11] we found that for three of the six Autodesk buildings, the energy intensity (kWh/square foot) predicted by the model fell within 6 percent of actual energy data, one facility was 12 percent off, and two others showed higher deviations. Given that we constructed the initial models without knowing anything about the facilities' operations, and applied the same set of modeling assumptions to facilities that were diverse in geographies, weather zones, operational schedules and power efficiencies, we were pleased by the results' proximity to actual consumption data.

RAPID ENERGY MODELING BENEFITS

11. A 12-hour/7-day (12/7) operation schedule, a lighting power density of 1.5 W/sf, equipment power density of 1.65 W/sf.

RAPID ENERGY MODELING WITH AUTODESK TOOLS



B. Stepping stone between quick benchmarking and detailed audits: Rapid energy modeling alone is not yet sufficient in capturing unique operational details that can only be captured through discussions with on-site personnel or through in-person building audits. However, rapid energy modeling does provide a quick, sophisticated way of going beyond carbon footprinting and energy benchmarking to look at tangible energy reduction opportunities. It provides useful data points to prompt tangible dialogue with the facility manager, a useful outcome in and of itself.

For example, the two outliers mentioned above prompted U.S. to have conversations with facilities managers, which led to further insights by identifying:

- Gaps in the model's assumptions that could be subsequently addressed to improve accuracy of the model.
- Operational inefficiencies that were previously unknown and could be addressed through efficiency investments.

C. Screen for high potential buildings: Rapid energy modeling represents a prioritization screen to determine how to focus on-site building audits and renewables assessments, which can be very time- and resource-intensive. Through rapid energy modeling, we were able to determine the following:

- Autodesk's six facilities had relatively similar energy intensities, with the exception of Shanghai, which had a lower intensity. As a result, it was also important to look at the buildings' carbon intensities to prioritize targets for energy reductions.
- Autodesk's Novi facility had the highest carbon intensity of all modeled facilities, due in part to more carbon-intensive electricity sources, potentially making this facility the highest priority for carbon reduction activities.
- Autodesk's Farnborough and Toronto facilities had the highest wind energy potential.
- Autodesk's San Rafael office had the highest natural ventilation and photovoltaic potential.

These findings will help Autodesk prioritize its energy and carbon reduction efforts, focusing on facilities that have the most potential in each relevant area.

D. Communicate Return on Investments for priority buildings: Rapid energy modeling can increase the ability to evaluate the potential financial and environmental values of an energy efficiency project, as well as those of specific green building measures including day-lighting, natural ventilation, and solar photovoltaic and solar thermal applications.

- Assuming a rough electricity reduction estimate of 10 percent,[12] the reduction potential

12. 10% reduction is a conservative estimate based on ICF's extensive experience with building retrofit projects. We find that most buildings have a significantly higher cost-effective energy reduction potential.

across the six modeled Autodesk facilities is equal to approximately $122,000 in annual cost savings.[13]

E. **Achieve economies of scale across a portfolio:** The rapidity of the process and its ability to point to a subset of high potential buildings allows property owners to achieve economies of scale when investing in efficiency measures or renewable energy technologies.

Autodesk and ICF personnel, with no previous experience with Autodesk tools, completed the rapid energy modeling process for the six Autodesk facilities on three continents in a matter of days for each one, and in some cases, hours, without any travel to the building sites. We estimate that with two dedicated modelers with little or no training and with access to basic facility information and photographs, Autodesk could have completed rapid energy modeling of all 72 of its corporate facilities in under two months,[14] and immediately have a workflow to test the value of a variety of energy and carbon reduction measures, as well as a prioritized list of facilities with high photovoltaic, wind, and natural ventilation potential.

F. **Stimulate creation of skilled green jobs:** The growth of rapid energy modeling could lead to an increased number of green jobs, as entry-level professionals could quickly learn the skills necessary to seamlessly create energy models. Implementing a rapid energy modeling process for the 4.9 million commercial buildings in the United States alone could employ 20,000 new entry-level energy modelers in a year.[15]

13. Based on energy spend data taken from Autodesk Green Building Studio model results.
14. Assumed 2 modelers working 21 days a month, averaging eight hours per model.
15. Assuming modelers working 21 days a month, 12 months a year, averaging eight hours per model.