Oct 2007

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Inside:

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President's message

IBPSA Members and Friends,

Welcome to this issue of IBPSA News. In the previous issue, you have read that 2007 marks IBPSA's 20th anniversary. In this issue you will be able to read about how this milestone was celebrated.

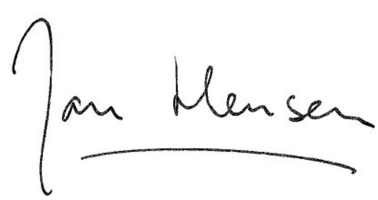
The main event was of course IBPSA's 10th international conference, Building Simulation 2007, which was held on 3 - 6 September in Beijing. With around 300 papers it was IBPSA's largest conference ever. The total number of papers presented at Building Simulation conferences is now about 1500 — visit www.ibpsa.org for the on-line repository of these papers.

I would like to take this opportunity to **thank Prof Yi Jiang and his whole team from Tsinghua University** for a job well done! From personal experience and the feedback I've heard, Building Simulation 2007 was a big success. If you attended the conference, then don't forget to complete the post-conference survey. IBPSA needs that sort of information to help organizers of conferences to come.

Other exiting news — and fitting for a 20th anniversary — is that at its meeting in Beijing the IBPSA Board of Directors took the decision to accept a proposal from Taylor & Francis to launch the **Journal of Building Performance Simulation**. This will be the **official journal of IBPSA** and will be launched in the beginning of 2008. The formal announcement will follow, however if you want to submit a high quality paper for this scientific journal which aims to achieve a high ISI rating soon, please don't hesitate to contact Ian Beausoleil-Morrison (ibeausol@mae.carleton.ca) or myself.

This issue of IBPSA News contains again a lot of interesting updates and news items as well as specifics about the experiences at BS2007. I hope you will enjoy reading it, and I would like to finish by thanking all contributors.

Best wishes,

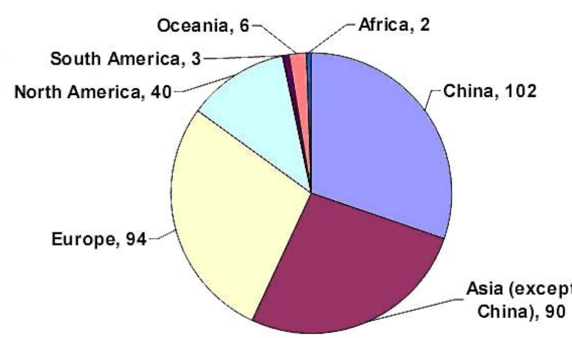


A report on ...

Tenth International IBPSA Conference
Beijing, China, 3-6 September

IBPSA can be proud once again of its biennial Building Simulation conferences. The 10th International Building Simulation conference, BS2007, held in Beijing, China, 3-6 September was a resounding success. This one was larger than any of the previous nine conferences held worldwide. The technical program was jam-packed with rich and rewarding technical sessions. There were 3 keynote speeches, 35 oral sessions, 6 poster sessions, 6 poster discussions, 6 poster awards (see awards section of this Newsletter), 4 plenary sessions, 4 software demonstration sessions of 18 different software packages, and 3 vendor exhibitions.

There were 291 papers presented - 167 in oral format and 124 in poster form. The authors were from 34 different countries. Delegates numbered 337, of which 235 were international and 102 were domestic (China). Representation by continent is shown in the pie chart:



Social events were open to all delegates and accompanying persons and included a welcoming reception, entertainment and dinner, a banquet, three lunches, three technical tours and a number of local social tours.

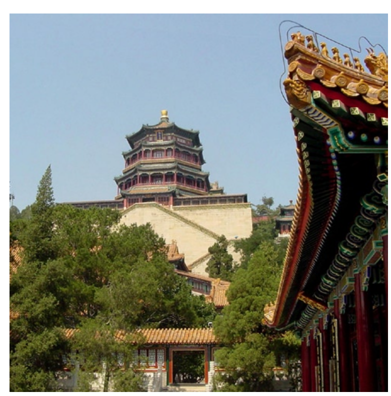
The conference venue was on the beautiful campus of Tsinghua University at the Academy of Arts and Design (AAD), which was rich with wall hangings of art and numerous sculptures. Following the conference, there was a post-conference tour that allowed interested participants to visit near and far cultural attractions. Near the city of Beijing, one could reach the Great Wall of China simply by traveling by taxi cab. The distant tour was to the ancient city of Xi'an where the ancient city wall and the Terracotta Warriors could be experienced.

IBPSA would like to express its sincere gratitude to Tsinghua University for hosting this conference, with a special note of thanks to conference Chair Professor Yi Jiang; conference Co-Chairs: Professors Yingxin Zhu, Xudong Yang, and Xianting Li; conference Secretaries: Drs. Da Yan and Bin Zhao; and some 36 graduate student volunteers from Tsinghua University. Without their organization, reception, and friendly assistance to each of the participants, this conference could not have had such a great success. Many, many thanks again!

Conference Sponsors	
	IBPSA is a non-profit international society of building performance simulation researchers, developers and practitioners, dedicated to improving the built environment. www.ibpsa.org
	IBPSA China is the regional branch of the International Building Performance Simulation Association (www.ibpsa.org) for China. www.ibpsa.cn
	The BS07 conference will be held at Department of Building Science, Tsinghua University. www.tsinghua.edu.cn
	China HVAC&R Society
	American Society of Heating Refrigerating and Airconditioning Engineers. www.ashrae.org
	ECBCS - Energy Conservation In Buildings And Community Systems. www.ecbcs.org
	rehva - Federation of European Heating and Air-conditioning Associations www.rehva.com
	DOE - U.S. Department of Energy www.doe.gov
	Webcasting sponsor: China Meeting Online www.meeting.edu.cn

The Great Wall (photo courtesy Dru Crawley)

The Terracotta warriors in Xi'an

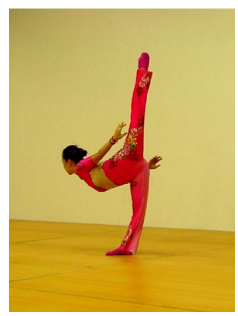


The Summer Palace in Beijing

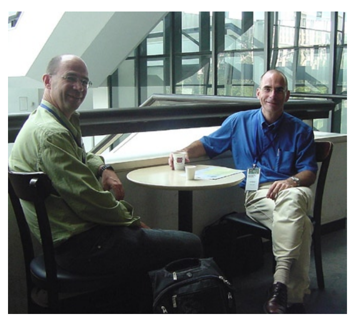
Prof Yi Jiang, Conference Chair, giving an opening keynote address (photos courtesy of Dariusz Heim)

Sculptures near the Arts Academy

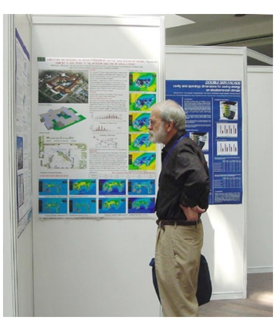
Scenes from BS 07

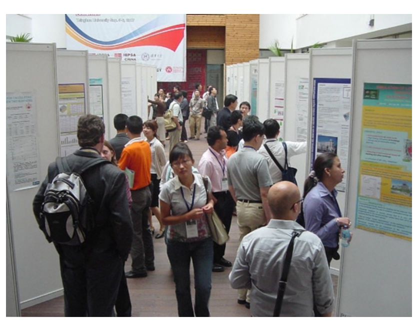


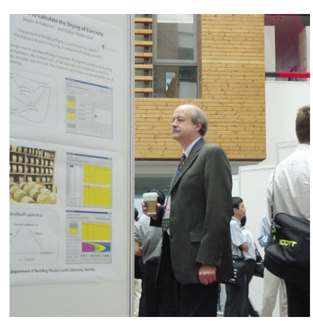
Memorable meals ... and dinner entertainment



Long and serious Board meetings ... with time out for relaxation







Hugely successful and well-attended poster sessions

IBPSA Awards

Yi Jiang receives the IBPSA Distinguished Service Award

Professor Yi Jiang is Vice Dean of the School of Architecture at Tsinghua University and an Academician of the Chinese Academy of Engineering. He received his B.Sc., M.Sc., and Ph.D. degrees in building services engineering from Tsinghua University. Professor Jiang started his academic career in Tsinghua University in 1984 and has since generated more than 130 research publications in journals and international conferences covering a wide range of topics relating to building science. He has also obtained a number of awards from government and associations for his significant achievements in the research and development of building performance simulation. He is the first researcher to apply computer simulation technology into buildings and HVAC systems in China.

Under his leadership, DeST, an integrated building simulation tool, was developed and is now widely used in research, design and education in China. As a major building energy simulation tool in China, DeST has been widely used for building envelope design optimization, building energy conservation assessment and various areas of HVAC scientific research. Up to now, DeST has been used in about 20 million m^2 of building area for design and commissioning, which includes 12 Olympic Games buildings in Beijing, the State Grand Theatre of China, etc.

Professor Jiang was elected as an Academician of the Chinese Academy of Engineering in 2001 and has played an important role in many significant Chinese national research projects for energy saving in buildings. Some projects are supported by the 10th Five-year National Plan Research Project or the 11th Five-year National Plan Research Project in China. He is also the Vice Chairman of the Chinese Association of HVAC Engineers, the Advisor of Beijing Municipality, a member of the Intelligent Building Council of China Ministry of Construction, and a member of the editorial board of the Journal of Ventilation and Building Services Engineering Research and Technology.

Professor Jiang has actively collaborated on a number of IEA Annexes and has published 120 papers in major domestic and international journals.

Outstanding Practice Award goes to Enermodal Engineering Ltd

Enermodal Engineering Ltd, based in Kitchener, Ontario, Canada is a consulting firm committed to improving the energy and resource efficiency of buildings and building products. The company has been actively involved in building performance simulation for more than 25 years, and has made significant contributions in both application and development. Their work has relied on simulation tools such as DOE-2 and eQUEST to analyze building performance and make recommendations for cost effective energy efficiency improvements for more than two hundred buildings.

Most recently, Enermodal has been an active participant in Natural Resources Canada's "Commercial Building Incentive Program" (CBIP), a program which encourages building owners to improve energy efficiency in new construction. CBIP provides financial incentives for buildings that achieve at least 25% annual energy savings (as determined by an energy simulation using EE4/DOE-2) compared to a design that meets the Model National Energy Code of Canada for Buildings (MNECB), which is similar to standard practice.

Enermodal was involved in the development of CBIP, including writing of the original version of the simulation guidelines (i.e. modeling manual) and serving as the primary trainer/instructor in the use of the simulation software (EE4/DOE-2) to architects, engineers, and other design professionals across Canada

Enermodal's involvement with design teams has always included hour-by-hour energy simulations used to identify cost effective energy efficiency measures and make design recommendations to optimize building energy performance. These have included the many notable projects, all of which are among the "leading-edge" of sustainable building design projects in Canada. Examples include the University of Ottawa Biology Building, the Region of Waterloo Emergency Medical Services Fleet Facility (the first building to achieve LEED Canada Gold certification), the Earth Rangers Wildlife Centre, and OMRON Dualtec Inc. (the first industrial building to achieve LEED Canada Silver certification).

Overall, Enermodal has worked to improve the energy performance of buildings totaling more than CAD$3 billion in construction costs, achieving an average reduction of 40% in energy use compared to the Model National Energy Code (i.e. standard practice), and resulting in an estimated annual energy cost savings of approximately CAD$24 million.

Enermodal has also developed a number of software tools for building performance simulation, including tools for analyzing building components and whole building energy use. The company's most significant contributions include its involvement in the development of the software tools "RETScreen" and "FramePlus".

RETScreen is a software tool for performing pre-feasibility assessment studies on renewable energy technologies (e.g. solar, wind, etc). Enermodal was a member of the original design team for RETScreen, and developed two of the original eight analysis modules (Solar Air Heating, and Passive Solar Heating). RETScreen is now one of the most widely used and recognized renewable energy analysis tools in the world. It has nearly 90,000 registered users in more than 200 countries. It has significantly contributed to the development of renewable energy systems throughout the world.

FRAMEPlus is a widely used program for the thermal analysis of windows, doors, and other building envelope products. It was originally developed by Enermodal in the late 1980's. Prior to FRAMEPlus, there were several software tools for analyzing glazing systems only, but none for determining total window performance (i.e. glazing + frame). At that time, total window performance could only be determined by performing expensive laboratory testing. Enermodal developed FRAMEPlus to integrate glazing and frame analysis into one software program. This allowed total window performance of thermal and optical properties to be determined inexpensively by computer modeling (rather than by laboratory testing). The availability of this tool led to the development of standard window rating systems in the U.S., Canada, and Europe. FRAMEPlus was the first software tool officially approved for window performance rating by the U.S. National Fenestration Rating Council (NFRC). Today, nearly all window manufacturers have the performance of their products rated by computer simulation.

Michaël Kummert receives the IBPSA Outstanding Young Contributor Award

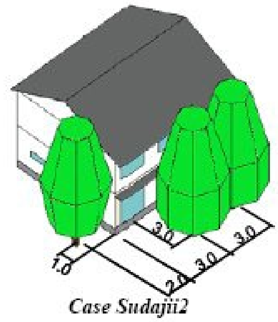
Michaël Kummert made his most significant contribution to building simulation by leading the international TRNSYS developers team between 2001 and 2005. TRNSYS Version 16 was released at the end of his tenure as the TRNSYS Coordinator at the University of Wisconsin Solar Energy Laboratory, setting a new standard for usability, quality assurance and user support. Michaël also played an important role in developing and implementing TRNSYS educational programs and taught numerous energy and building simulation courses to students and practitioners around the world.

In 2005, Michaël joined the École Polytechnique in Montréal, where he took part in software development and taught building energy analysis and simulation to undergraduate and graduate students and to practitioners. He also aided the bringing of simulation to application through an Integrated Design Process (IDP) by his participation in student design charrettes organized by the Canadian Green Building Council and by his involvement in high profile projects. His simulation results and his interaction with architects and engineers proved decisive in selecting the HVAC system design for the Benny Farm Redevelopment project in Montréal. The exemplary outcome of the 15-year IDP in this project received a gold prize in the North American Holcim Awards and a bronze prize in the World Holcim Awards.

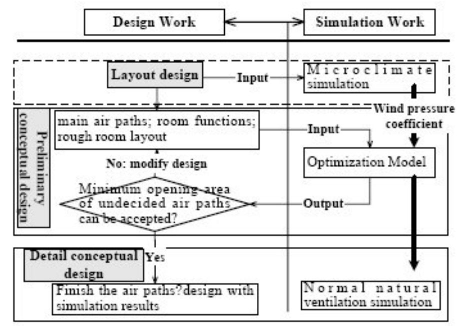
Michaël has attended and/or co-authored papers at the most recent IBPSA world, ESim and SimBuild conferences. He played an active role in the organization of Building Simulation 2005 in Montréal and also proposed and organized post-conference courses on that occasion.

Michaël is currently a Lecturer in the Energy Systems Research Unit at the University of Strathclyde in Glasgow, UK. He is teaching energy systems simulation and building design/analysis to undergraduate and graduate students and he also teaches building simulation training courses on a regular basis. His research interests are: development of energy simulation programs (TRNSYS and ESP-r), analysis and optimization of low-energy buildings and HVAC systems (from passive houses to data centres), and renewable energy systems (solar thermal / PV and ground-source heat pumps).

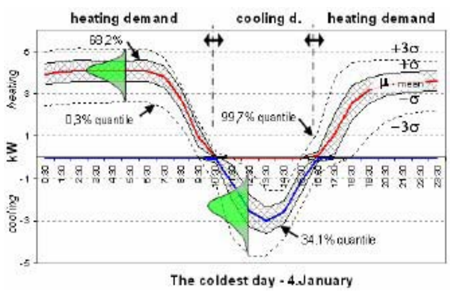
IBPSA Best Poster Awards to six recipients



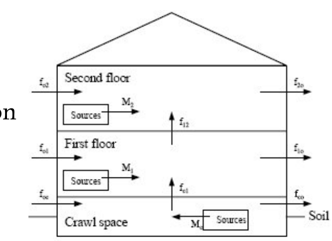
Paper 538, Effects of trees on the room temperature and heat load of residential building, by Yoshiki Higuchi and Mitsuhiro Udagawa, Department of Architecture, Kogakuin University, Tokyo, Japan



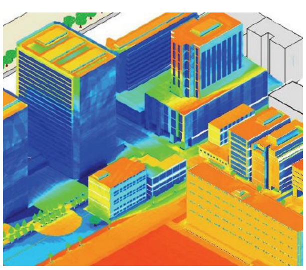
Paper 845, Discussion on methodology of applying building thermal simulation in conceptual design, by Yingxin Zhu, Chunhai Xia, and Borong Lin, Tsinghua University, Beijing, China.



Paper 609, Technique of uncertainty and sensitivity analysis for sustainable building energy systems performance calculations, by Petr Kotek, Filip Jordán and Karel Kabele, CTU Technical University in Prague, Czech Republic, and Jan Hensen, Technische Universiteit Eindhoven, Netherlands.



Paper 619, Human health damages due to indoor sources of radon in life cycle assessment of dwellings, by Arjen Meijer, Delft University of Technology, Delft, the Netherlands.



Paper 582, Development of support tool for outdoor thermal environmental design of urban/building using numerical analysis, by Kazuaki Nakaohkubo and Akira Hoyano, Tokyo Institute of Technology, Yokohama, Japan, and Takashi Asawa, A&A, Co., Ltd., Japan.

Paper 835, Life cycle green cost assessment method for green building design, by Lijing Gu, Daojin Gu, Borong Lin, Mingxing Huang and Yingxin Zhu, Tsinghua University, Beijing, China, and Jiazi Gai, National University of Singapore, Singapore. *This paper appears in full on page 39*.

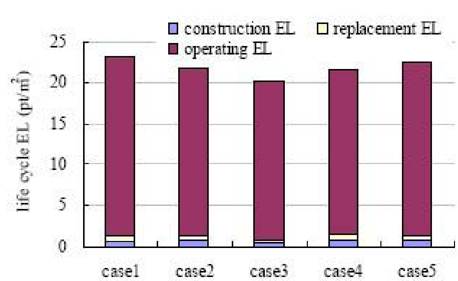


Fig.3 Building life cycle environmental load

IBPSA Student Travel Awards to BS2007

Six students were honored with a significant IBPSA student travel scholarship to attend BS2007. These are competitive awards made to those students who have written and presented scholarly papers of high quality. The six awardees for 2007 were:

Jun Hong, University of Strathclyde, Glasgow, UK, Paper 513, The role of demand side control to facilitate the integration of renewable energy and low carbon energy technologies within buildings

Henrik Karlsson, Chalmers University of Technology, Goteborg, Sweden, Paper 375, Integrated modelling of radiant floor heating systems

Georgios Kokogianakis, University of Strathclyde, Glasgow, UK, Paper 160, Impact of using different models in practice — a case study of the simplified methods of ISO 13790 and detailed modelling tools

Rong Li, University of Sheffield, UK, Paper 094, Buoyancy driven ventilation in a room with large openings

Luis Prazeres, University of Strathclyde, Glasgow, UK, Paper 401, Delivering Building Simulation Information via new Information and Communication Media

Ravi Srinivasan, University of Pennsylvania, Philadelphia, USA, Paper 769, Energy Based Decision Support System for Facilities Management: Integration of Data/Web mining, Knowledge Base and Thermal Simulation

Building Simulation 2011: Call for Proposals

The board of IBPSA is pleased to issue the following call for proposals from parties interested in hosting Building Simulation 2011. A complete proposal, in PDF format, should be sent to the Conference Location Coordinator, Jeff Spitler (spitler@okstate.edu), no later than February 15, 2008. Discussions with Jeff of potential proposals prior to the due date are strongly encouraged. The proposal should address the following items:

- proposed venue
- dates
- details of conference secretariat
- organization time line
- detailed budget in local currency and in US dollars
- discussion of possibilities for sponsorship
- details of the conference presentation schedule (e.g. number of parallel and plenary sessions), publication of proceedings etc.
- details of accommodation, including costs, for delegates
- social events
- options for pre and post conference tours
- options for program for accompanying persons
- plans for organization of an IBPSA Regional Affiliate Organization, if applicable
- involvement of existing or planned IBPSA Regional Affiliate(s)
- experience of organizing committee with IBPSA and with organizing similar conferences

To assist your decision there are several documents available for your review:

- **www.ibpsa.org/IBPSA-Regionalization-Guide.pdf** describes IBPSA's regionalization plans: we schedule all of the Building Simulation conferences in regions with existing affiliates or regions that are starting a new affiliate organization. In a region currently without an affiliate, we will only consider holding the conference there if a regional affiliate organization will be in place by the time of the conference.
- **www.ibpsa.org/BSRFP/BS2003_final_report.pdf** is the final report of Building Simulation '03 in Eindhoven. This report contains several appendices with organizational and financial information (e.g. planned budget and real expenses) useful for organizers of future Building Simulation conferences. It also contains the original proposal from IBPSA-NVL as Appendix 1.
- **www.ibpsa.org/BSRFP/BS2005_final_report.pdf** is the final report of Building Simulation '05 in Montreal. In addition to containing organizational and financial information (e.g. planned budget and real expenses), it also includes results from the post-conference survey.

- **www.ibpsa.org/BSRFP/Sponsor_Exposure.pdf** contains suggestions regarding the exposure and benefits of Building Simulation sponsors.
- **www.ibpsa.org/BSRFP/BS_05_MOA.pdf** serves as an example for the contract which will be agreed between IBPSA and the organizers of Building Simulation '11.

Proposals will be evaluated using the following criteria:

- Attractiveness and accessibility of location - is this location likely to attract delegates from around the world? (10%)
- Affordability of venue - is the combination of registration fee and accommodation costs likely to not be a hurdle to potential delegates? (In this respect, a range of accommodation types including student dorms or the like is a benefit.) (10%)
- Quality of conference plan and facilities - are the facilities and conference plan conducive to a well-run conference? (10%)
- Likelihood of financial success - will the conference financial plan likely lead to breaking even (at least.)? A financial plan that does not rely on unconfirmed sponsorships to break even is strongly preferred. (30%)
- Support of IBPSA goals - will choosing this proposal help draw new members into IBPSA (in new regions) or support membership in existing regions? (10%)
- Diversity of location - is this location sufficiently distant from recent conferences? (10%)
- Regional participation - is the proposal well-supported by volunteer effort from the regional affiliate and/or nearby regional affiliates? (10%)
- Experience of members of the organizing committee with IBPSA and with organizing IBPSA affiliate conferences or conferences similar to Building Simulation. (10%)

The final decision regarding the location of Building Simulation 2011 resides with the IBPSA Board of Directors and will be made following a thorough evaluation of all submitted proposals.

Forthcoming events calendar

Date(s)	Event	Information
2007		
29-30 October 2007	**VisualDOE training seminar** San Francisco, USA	www.archenergy.com/products/visualdoe/training/
16 November 2007	**IBPSA England symposium** on building simulation in the South-West, Plymouth, UK	www.ibpsa-england.org
2008		
21-22 May 2008	**eSim 2008** Québec, Canada	www.esim.ca
30 July - 01 August 2008	**SimBuild 2008** Berkeley, California, USA	http://gaia.lbl.gov/ocs/index.php/simbuild/2008

29-30 October 2007
San Francisco, USA
www.archenergy.com/products/visualdoe/training/

VisualDOE Training Seminar
Architectural Energy Corporation

Architectural Energy Corporation (AEC) is pleased to announce a VisualDOE training seminar on 29 and 30 October at AEC's San Francisco office - 142 Minna Street, San Francisco, CA 94105. Each day of the workshop begins at 8:30 am and ends at 5:30 pm.

VisualDOE is a whole building energy simulation tool covering building envelope, lighting and daylighting, water heating, HVAC systems, and central plant. VisualDOE version 4.1 build 0002 is approved as an energy analysis tool for the IRS Tax Deduction for commercial buildings (EPACT 2005).

The seminar includes two full days focus on DOE-2, the VisualDOE interface, general energy simulation skills, and LEED-NC 2.2 energy savings calculations for green buildings. Attendees are welcome to bring their projects for discussion in class. No prior energy modeling experience is required, but a good understanding of building systems and energy performance issues is very helpful.

VisualDOE 4 is available at a discount to training attendees. However a free one-month license for VisualDOE 4 is included with the training. Attendees should bring their own laptop computers to participate in class exercises.

The cost for the two-day program is $900. Morning coffee/danish and afternoon soft drinks will be provided each day. Lunch will be on your own - 60 minutes each day.

SPACE IS LIMITED - to register or get more training information, please go to VisualDOE training page at **www.archenergy.com/products/visualdoe/training/**.

A free demo version of VisualDOE 4 can be downloaded at **www.visualdoe.com**.

For questions, please contact us via email **vdoetraining@archenergy.com** or phone (415) 957-1977 ext 111.

VisualDOE Training Team
Architectural Energy Corporation
142 Minna Street, Second Floor
San Francisco, CA 94105
Voice: (415) 957-1977
Fax: (415) 957-1381

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16 November 2007
Plymouth, England
www.ibpsa-england.org

IBPSA England symposium on Building Performance

IBPSA-England

IBPSA-England will be holding a one-day symposium on building performance simulation in the Southwest on Friday, 16 November 2007, starting at 8.30 am. The event is jointly organised by the Universities of Plymouth, Exeter, West of England and Bath, and will take place on the campus of the University of Plymouth.

It will be followed in the evening by a seminar organised by the Environmental Building Group, comprising presentations by guest speakers who have close relations with the environmental building surveying and construction management courses taught at the University of Plymouth.

The main topics to be covered are the application of, and education and R&D on, building performance simulation in the region. Papers are invited on the following themes:

- the application of building performance simulation in construction projects in the Southwest, both from an engineering and end-user (client, architect) point of view
- education in building performance simulation in the region
- simulation software development and research furthering the state-of-the art of building performance simulation in or specifically related to the Southwest.

Contributions will be peer-reviewed before acceptance, and will be published on a CD-ROM with symposium proceedings. All accepted papers will be presented orally.

Guest speakers and visitors from other regions will ensure a tie-in with the national state-of-the-art.

For a detailed programme of the event, download **www.ibpsa-england.org/download/plymouth-final-programme.pdf**.

21-22 May 2008
Québec, Canada
www.esim.ca

eSim 2008
IBPSA-Canada

The biennial conference of IBPSA-Canada is being organized to bring together professionals, academics and students interested in building performance simulation issues and applications. It will be held in Québec City, Canada on 21 and 22 May 2008 (pre-conference workshops 20 May 2008). The conference will be hosted by l'École d'architecture de l'Université Laval in Québec City, in collaboration with the National Research Council of Canada.

L'École d'architecture, part of the Faculté d'aménagement, d'architecture et des arts visuels de l'Université Laval, is located within the fortifications of the historic district of Québec City. The nearby Musée de la civilisation, located in the city's old port district — well-known for its hotels and restaurants — will serve as the main conference venue (**www.mcq.org**). 2008 will be a landmark year for Québec as the city will be celebrating the 400th anniversary of its founding in 1608. Although most celebrations will be held from June to August, the end of May is expected to be a festive — and busy — time of year in this part of the city (**www.monquebec2008.com**).

Please visit the conference web site **www.esim.ca** for more information.

The themes for the conference are:

- Recent developments for modelling the physical processes relevant to buildings (thermal, air flow, moisture, lighting)
- Algorithms for modelling conventional and innovative HVAC systems
- Methods for modelling the whole-building performance, including integrated resource management, renewable energy sources and combined heating, cooling and power generation
- Building simulation software development and quality control approaches
- Use of building simulation tools in code compliance and incentive programmes
- Moving simulation into practice. Case studies of innovative simulation approaches
- Validation of building simulation software
- User interface and software interoperability issues
- Architectural and engineering data visualization and animation
- Optimization approaches in building design.

IMPORTANT DEADLINES

17 September 2007	Call for abstracts (500 words max.), English or French
22 October 2007	Deadline for submission of abstracts (500 words max.), English or French

27 November 2007	Deadline for indicating interest for presenting software
27 November 2007	Deadline for Scientific Committee to finish reviews
04 December 2007	Abstract acceptance/rejection
22 January 2008	Paper submission deadline for manuscripts, English and French
19 February 2008	Comments on papers from review committee
04 March 2008	Student Travel Awards submission deadline
18 March 2008	Final paper submissions
21 March 2008	Deadline for early registration

The Conference Chair is Dr. Denis Bourgeois, Université Laval (**denis.bourgeois@arc.ulaval.ca**) and the Chair of the Scientific Committee is Dr. Christoph Reinhart, National Research Council Canada (**christoph.reinhart@nrc-cnrc.gc.ca**).

photos courtesy Claudel Huot (above) and Luc-Antoine Couturier (right)

30 July - 01 August 2008
University of California, Berkeley, California, USA
http://gaia.lbl.gov/ocs/index.php/simbuild/2008

SimBuild 2008
IBPSA-USA

IBPSA-USA will hold its third national conference from 30 July to 01 August 2008 on the campus of the University of California at Berkeley. The format will be similar to the two previous SimBuild conferences held at the University of Colorado at Boulder in 2004 and at the Massachusetts Institute of Technology in 2006.

The conference organizers are limiting the number of peer-reviewed oral presentations in order to maintain a high level of quality in the papers. Submissions will therefore be rigorously peer-reviewed. Abstracts are due by 1 December 2007 (firm deadline) and may be on a variety of building and environmental simulation topics, such as: system or component modeling, simulation algorithm development, CFD applications, IAQ, acoustics, energy, lighting, life safety, weather, city-scale environmental simulations, or case studies that exhibit in-depth use of simulation software. Authors should indicate a preference for poster or oral presentation. In addition, a limited number of non-peer-reviewed oral presentations are sought in order to enable practitioners and researchers to address simulation-related issues of strong current interest — please contact Philip Haves **phaves@lbl.gov** (510) 486 6512.

The meeting is open to all, world-wide. Being near San Francisco, Berkeley is a convenient destination for travelers from major cities in the U.S. and in many other countries. U.C. Berkeley is the oldest campus of the University of California system, which also operates the well-known Lawrence Berkeley National Laboratory, the Lawrence Hall of Science, the Space Sciences Laboratory, and the U.C. Botanical Garden. The city of Berkeley contains a variety of neighborhoods with diverse character and excellent restaurants. The "Bay Area" is full of visitor attractions accessible within 20 minutes, such as the city of San Francisco, scenic mountains, and rich architecture (including the Frank Lloyd Wright Civic Center). Numerous wineries are within one hour travel to the Napa and Sonoma valleys, where wine-tasting tours are available.

KEY DATES

15 Sep 2007	Call for abstracts
01 December 2007	Abstracts due (firm deadline)
20 December 2007	Abstract acceptance
15 February 2008	Papers due (firm deadline)
20 March 2008	Paper reviews provided to authors
30 April 2008	Revised papers due
01 June 2008	Final decisions on all papers
30 July - 01 August 2008	SimBuild 2008 conference

The conference registration fees are:

Full registration	$400
Student registration	$200

Conference housing will be offered on campus in dormitories and in nearby hotels. Single- and double-occupancy dormitory rooms will range in price from about $39 to $68 per night. Student bursaries will again be available.

Abstracts are now being accepted at the SimBuild 2008 website at **http://gaia.lbl.gov/ocs/index.php/simbuild/2008**

Please note that 01 Dec 2007 is a firm deadline for all abstracts.

We look forward to welcoming you to Berkeley!

Philip Haves, Conference Chair
Larry Degelman, Scientific Committee Co-Chair
Michael Wetter, Scientific Committee Co-Chair

Various dates and venues
www.gard.com/training.htm

EnergyPlus Training

Gard Analytics

Three two-day training workshops for EnergyPlus were recently held in China and India in September and October. These workshops provided a combination of lecture and hands-on exercises:

- 30 August - 01 September in the Low Energy Building at Tsinghua University in Beijing, China. More than 40 individuals participated in the workshop from 8 countries. This workshop was held just prior to the Building Simulation 2007 conference at Tsinghua University.
- 01-03 October, CEPT University, Ahmedabad, Gujarat, India. More than 20 individuals from throughout India participated.
- 05-06 October, Bureau for Energy Efficiency, New Delhi, India. More than 20 individuals from throughout India participated.

For information about future EnergyPlus training workshops, visit **www.gard.com/training.htm.**

Software news

EnergyPlus version 2.1 and Design Plugin v1.0 now available

Dru Crawley, DOE

The latest release of the EnergyPlus building energy simulation program, Version 2.1, became available in early October. A few key new features include new packaged terminal air conditioner, multi-speed heat pump, and additional controls for modeling hybrid ventilation systems. We have updated and extended capabilities throughout the existing building envelope, daylighting, and HVAC equipment and systems portions of the program.

EnergyPlus v2.1 is available at no cost from the EnergyPlus web site **www.energyplus.gov**. Other new EnergyPlus features include:

DATA SETS

- Color schemes for DXF. (original and default)

DESIGN DAY

- User now can choose between ASHRAE Clear Sky and Zhang-Huang solar radiation models for use in design day calculations

INPUT

- Example input files created for all new features (More than 225 example input files now available)

GEOMETRY/WINDOW/WALLS/SHADING

- Surface Surround Subsurface error detection more robust (fewer false errors)
- Autocalculate now allowed for shading surfaces (number of vertices)

NATURAL AND MECHANICAL VENTILATION

- Added new system availability manager to allow system-level control of hybrid ventilation systems

HVAC

- Added water-cooled condenser capability to refrigeration compressor racks for useful heat recovery
- Chilled and hot-water coils can now be used in the outside air system to preheat or precool outside air
- New desiccant dehumidifier with additional capabilities and flexibility compared to the existing solid desiccant dehumidifier model
- Water side economizer (including simulation of integrated and non-integrated water side economizers)

- Packaged terminal air conditioner (PTAC) added to model a fan, DX cooling coil, and a gas, electric, hydronic or steam heating coil serving a single zone
- Multispeed heat pump with up to four discrete speeds for both cooling and heating
- Heat losses (and gains) from plant piping
- New and updated Compact HVAC objects:
  - Compact HVAC chilled water coils now use the COIL:WATER:COOLING model by default, COIL:Water:DetailedFlatCooling can be selected as an option
  - Compact HVAC unitary system now supports the draw-thru fan placement option, and allows a schedule for the supply fan operating mode (continuous or cycling)
  - New Compact HVAC options for dehumidification and humidification controls for unitary and VAV system types
  - New primary-secondary loop options for Compact HVAC chilled water loops.
  - Compact HVAC expanded to support specification of outside air as a combination of flow/person, flow/area and flow/zone
  - Compact HVAC baseboard heat option added for unitary and VAV zones.
  - New Compact HVAC objects for unitary heat pump, unitary VAV, packaged terminal air conditioner, and packaged terminal heat pump

OUTPUT

- New tabular reports for surface shadowing, shading, lighting, HVAC sizing, system and component sizing, and outside air
- New Report:SurfaceColorScheme allow users to select their own colors for building elements in the DXF output

UTILITIES

- WeatherConverter now produces KML output (for Google Earth) of latitude, longitude, elevation, and a few climate statistics for locations in a list processing run
- Add comma delimited form of CLM (ESP-r Ascii files) conversion to WeatherConverter
- WinEPDraw produces in new default colors

DOCUMENTATION AND GUIDES

- New Basics manual replaces Getting Started
- Input/Output Reference and Engineering Reference updated and extended for all new features and updates. Total documentation now exceeds 3500 pages.

And many other enhancements and speed improvements throughout.

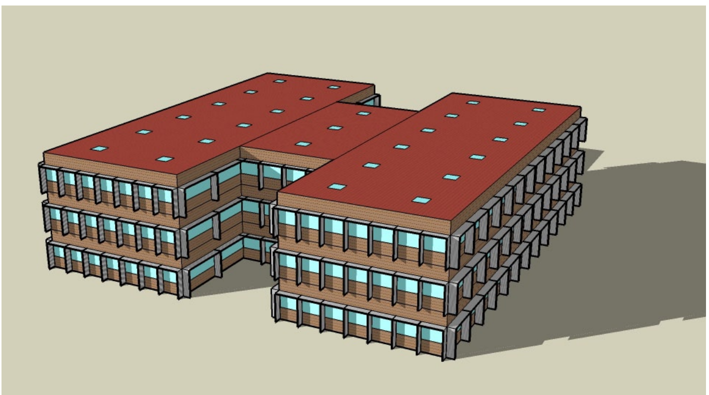
More information on these and other new features in this version is available on the EnergyPlus web site, **www.energyplus.gov**.

Also coming soon…

The EnergyPlus plugin for Google SketchUp. The plugin makes it easy to create and edit the building geometry in your EnergyPlus input files, and allows you to launch EnergyPlus simulations and view results—all within SketchUp.

EnergyPlus Example File Generator

DOE and NREL are pleased to announce the update of the EnergyPlus Example File Generator. The goal of the Example File Generator is to provide input files for building models that serve as a starting point for using and learning EnergyPlus. This service is free and available at the EnergyPlus web site (**www.energyplus.gov**) under Interfaces & Other Tools.



Web-based forms allow you to input some general information about the building you want to model. The service then automatically creates a complete EnergyPlus input file, runs an annual simulation on NREL's computers, and then sends you an email with the EnergyPlus input file along with a summary of the annual energy results (and a dxf image file). The DXF of an EnergyPlus example file (left) was generated in just a few minutes.

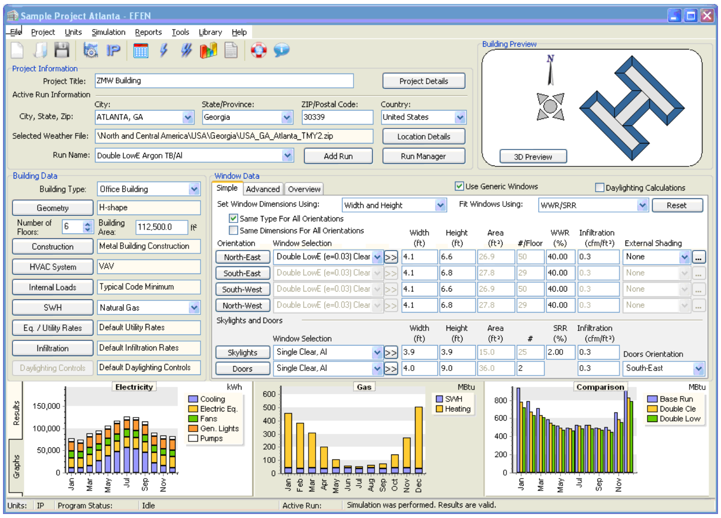
Assumptions should be carefully reviewed. There is no guarantee that the models are fully compliant with the energy performance Standards used to generate model details.

The new version has many new capabilities:

- Generates input file for EnergyPlus version 2.0.
- The input files are now completely annotated with the descriptions of the fields for each object.
- Added input boxes on the web page for
  - New footprints for geometry including
    - Rectangle
    - Courtyard
    - L-Shape
    - H-Shape
    - T-Shape
    - U-Shape
  - Gas appliances
  - Fins
  - Continuous daylighting
  - Addition of over 50 HVAC systems
  - Ventilation rates by people and/or area
  - Service Water Heating inputs

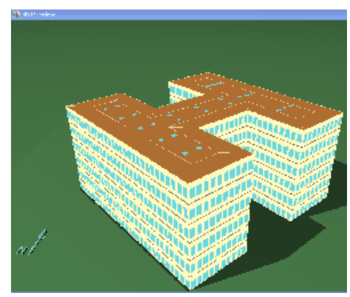
If you have questions or feedback, contact **ewi_support@nrel.gov**.

DesignBuilder release new software for evaluating fenestration options



DesignBuilder Software is pleased to announce the release of EFEN, a user friendly energy analysis program for evaluating fenestration options in commercial buildings.

EFEN is a next generation energy analysis tool incorporating the latest in technological advances, such as the EnergyPlus simulation engine and intelligent building generator, packaged in a user friendly program that is suitable for quick analysis in early stages of design, comparative energy analysis of different fenestration options, sophisticated analysis and prediction of the whole building energy use, and prediction of the size of HVAC equipment.



The program is suitable for use by the fenestration industry, code officials, engineers, architects, utilities, academia, etc. It provides both annual energy use and peak loads that can be used for equipment sizing. The analysis can be completed in as little as 10 minutes.

The main features of the program are:

- Latest EnergyPlus, v2.0 simulation engine
- Intelligent Building Creator — automated generation of commercial buildings
- Choice of 7 building types/uses and 6 geometries — a total of 42 different buildings
- 3-D building preview in real time
- Automated download of weather data files for locations in United States (zip, city/state choice) and internationally
- Automated insulation levels based on the climate zone, worldwide
- Automated HVAC system generation
- Choice of temperature setback and economizer
- Multiple runs with parametric analysis for different fenestration products
- Advanced fenestration placement, allowing more freedom in placing fenestration products on individual walls
- Generic windows library, with more than 500 standard fenestration configurations
- Flexible user defined window libraries - fenestration products are imported from WINDOW program
- Daylighting controls choice
- Energy, cost and first year cost savings (capital equipment cost savings) calculation and presentation
- Automated program updates over the web.

DesignBuilder
SOFTWARE

Visit the web site at **www.designbuildersoftware.com** for more details and downloading the Demo version.

Building Energy Tools Directory

Dru Crawley, DOE

The web-based Building Energy Tools Directory at **www.energytoolsdirectory.gov** contains information on more than 345 building-related software tools from more than 20 countries around the world. Haven't visited lately? Since April 2007, more tools have been added including Daylight 1-2-3, Demand Response Quick Assessment Tool, METEONORM 6, and Overhang Annual Analysis.

For each tool in the directory, a short description is provided along with information about technical expertise required, users, audience, input, output, validation, computer platforms, programming language, strengths, weaknesses, technical contact, availability and cost. A link is also provided for directly translating the web pages into more than 8 languages.

If you know of a tool (yours?) that isn't in the directory, send the information shown here: **www.energytoolsdirectory.gov/submit.cfm** in an email message to Dru Crawley at **Drury.Crawley@ee.doe.gov**.

Announcements

Job opportunity at Transsolar

Engineer for Dynamic Thermal Simulation with TRNSYS

Transsolar is a German-based climate engineering firm, and one of the premier such offices in the world. We are seeking a talented, highly motivated engineer for our New York office.

Our work is to develop and validate concepts for high quality environments that require minimal energy use. To achieve this we work collaboratively within the design team from the start of the design process, considering each step from the standpoint of fundamental thermodynamics. This generates a climate concept in which form, material, and mechanical systems are synergistic components of a well-orchestrated climate control system; and conversely, an environmental control strategy that is integral to the architectural concept. We use dynamic thermal simulation on TRNSYS to develop and validate appropriate, reliable concepts in relationship to the complex set of factors that is unique to each project.

The qualifications required, in order of importance, are:

- Education related to building energy flows: newtonian physics, thermodynamics, fluid mechanics, solar geometry and daylighting, etc. Ideal is a degree in mechanical engineering
- Education/professional experience with architectural and mechanical systems for building climate control
- Experience with dynamic thermal simulation, preferably TRNSYS
- Computer-based drawing skills (e.g. Corel Draw, Adobe Illustrator, etc)
- Excellent oral and written communication skills

Transsolar engineers are often specialized in their work, but all carry out a broad range of tasks. Responsibilities may include but are not limited to:

- Design and validation of ongoing projects via TRNSYS simulation
- Collaboration with German Transsolar offices
- Project coordination
- Participation in meetings and design charrettes
- Graphical representation of climate and energy concepts
- Writing reports and correspondence.

If interested, please send a resume and samples of work to Peter Voit at:

Transsolar Inc.
145 Hudson Street
New York City, NY 10013 or email **voit@transsolar.com.**

Feature articles

Simulation Quality Assurance - Challenges for the simulation community

Michael Donn, Centre for Building Performance Research, Victoria University School of Architecture, PO Box 600 Wellington Michael.donn@vuw.ac.nz

WHAT IS QA?

Imagine a world where: *"The changes in the predictions of a simulation program following changes in building design are always of the same scale and nature as those perturbations in performance observed in reality"*. This obvious "truth" is one that most involved in building would agree is necessary for trust to be placed in the predictions of building performance. Putting systems in place to guarantee that what you imagine is the performance is in fact the reality is **Quality Assurance**. Most experienced simulationists would agree that this is also the hardest aspect of simulation to guarantee.

Recent proposals for web-based information tools for the simulation community[1,2] offer the possibility that this goal may be achievable in the not too distant future.

Background

In 1999 I wrote in a keynote address for IBPSA Kyoto *"Not only for senior partners in architecture firms but for all users of performance prediction software, the greatest single need right now is for Quality Assurance mechanisms. The interviews described above have shown that all users require some means of ensuring that the model they have created with a design tool represents the real building. If performance prediction programs contained good Quality Assurance tools, then architects' interest in the environmental quality of their buildings would naturally drive the use of this software. The problem for these architects is that there is no independent measure, no benchmark to legitimise the output. We can measure something as simple as an R-value calculation against a benchmark in a code or standard. Yet even for this R-value calculation guaranteeing quality is difficult. No systems exist for independently verifying the calculation, apart from repeating it carefully and comparing the results of the two calculations. The issue is not the precision of each number but the accuracy of the relationship between the numbers and the reality they represent."*

Quality Assurance often degenerates into a process of **checking and rechecking the numbers entered** into the calculation against their "book" values - a necessary but not sufficient component of Quality Assurance. **Validation** is another necessary component: it should be the role of the writers of the program, and only needs to be done once, each time the tool is compiled. **Calibration** is required when the software is first set up in an analyst or an architect's office - ensuring the user(s) reproduce the simulation predictions of other users of the same software. **QA processes** in simulation software should allow the user to check the relationship between the performance predictions and the actual building design.

The QA 'test'

I proposed at the time " …a test for the output from a simulation program like the Turing Test20 for the "existence" of computer-based intelligence. Alan M. Turing introduced the Turing Test as 'the imitation game' in his 1950 article where he considered the question "Can machines think?" In the 'modern' version of the test we connect an interrogator to one person and one machine via a terminal. The interrogator's task is to find out which of the two candidates is the machine, and which is human, only by asking them questions. If the interrogator cannot decide within a certain time then we deem that the computer is 'intelligent'. In the proposed QA test the user must ask whether the data in front of them representing a building's performance is from a real building. Like the Turing Test, this test requires a minimum of three 'players'. Player A asks questions; players B and C answer from their data. B has data on a real building. C has simulation results. If the interrogator A cannot distinguish simulation from real then the simulation quality is assured."

As I noted at the time, "The problem with this QA idea is the same problem as affects the Turing 'Test': how to operationalise it".

Semantic Web

In 1999 I suggested a system by which people might use the then new 'Semantic Web' concepts to develop an operational QA system. In the intervening 7 years the 'Semantic Web' has become talked about as Web 3.0 - where the web might go over the next five years. In the meantime, we have in place a series of Web 2.0 technologies that allow a beginning to be made to this QA concept.

COMPONENTS OF A QA WEB SITE/SERVICE

The web site **www.aecsimqa.net** has been built around the daylight design roadmap investigations of the IEA Solar Heating and Cooling Programme Research Task 31 'Daylight for the 21st Century'. The web site proposes a system of Simulation Quality Assurance that comprises a number of necessary components:

Definitions of Appropriate External Environments

The question is how to characterise the 'typical' external environment. Is it an average day/week/year? What might the risk to the building owner or operator be if the normally expected variations around the average occur from year to year? Stochastically valid risk analysis is essential in all Quality Assurance procedures related to building performance simulation. In an era where overheating is becoming more prevalent - what is the risk of overheating in a 'typical warm year'? What might the consequences of Climate Change be for the designed building performance?

Definitions of Appropriate Operational Environments

The designer needs to know just how vulnerable the simulated performance will be to variations in the way we occupy or operate the building. If we no longer operate the building as we assumed it would be, what might the performance consequences be?

Data on Actual Performance of Real Buildings Evaluated Against Their Predicted Performance

Guidance about how to move forward in improving a design comes best from the informed user looking backwards at how an existing design performs. Post Occupancy Evaluation (POE) contributions to an Internet performance database could provide a rich set of performance data. It could be used to generate initial design ideas based on successful precedents.

Software Test Suites

Publicly available suites of test data exist for lighting (CIE TC3.33)[3] and thermal[4] (ASHRAE 140) simulation software. Articles comparing or describing the performance and features of individual software packages appear regularly in the lighting press, computer graphics publications and architectural journals. These seldom are able to rate the software quantitatively in the ways that the TC 3.33 or ASHRAE 140 tests do. No single reviewer can be sufficient an expert in the use of all at a level to run them 'through their paces'. Use of the TC 3.33 suite or ASHRAE-140 offers the potential to score software in a manner that is fair, independent and repeatable.

Software Suitability Indices

Looking at published software reviews, users are looking for guidance on more than just calculation accuracy. The TC3.33 and ASHRAE 140 tests are just a part of the guidance they seek on the suitability of different software for different applications (e.g. daylighting vs electric lighting - building solar design vs building services optimisation). Also, they want up-to-date indices of software suitability. Tests that are published in journals are inevitably out-of-date almost as soon as they are published. Some rendering software has a less than 12 month version cycle. Web based databases permit the updating of the software reviews with each new release of the software. The suitability of simulation software for particular tasks can be reduced to a suitability index so long as the index is based on the following suitability dimensions:

Modelling

Modelling in the tool itself - For quick analysis of simple designs in-tool modelling ability is essential. Importing other geometry - It should be straightforward to import models from a wide range of CAD sources. Portability of model - Models should be easy to move about between computer programs.

Materials Library available

Inclusion of a basic materials library would be useful to most users. Accurate material properties are often difficult to obtain.

Provenance of material properties guaranteed

The software needs to be compatible with quality systems for the publication of material information. A quality system for distributing material information does not just publish properties for a range of materials. It includes in the data file format itself a record of the authors of the material properties, the type(s) of test apparatus used, and the trustworthiness of their laboratory. With such meta-data appended - the provenance of the material information - the simulation software can produce reliability scores for its output.

Customising in language that is normal in construction

Material descriptions in the software should be simple to understand and enter into the software.

Mapping scaling / uvw coordinates

Simple mapping techniques in lighting modelling and simple geometric placement in thermal modelling can be useful to users wishing to define materials and surfaces in relation to each other and the geometric 'world coordinates' of the model.

Equipment data for luminaries or HVAC should be in industry standard formats

Photometric data is essentially numeric, but to be useful it should be available not just as numeric values, but a 3D array on a predefined grid of points, compacted into isoluminance contour maps. HVAC data should not just comprise an efficiency number but a load / efficiency relationship, and of course for both the provenance of the data is of paramount importance.

Models or records of the external environment

A wide variety of sky conditions for daylighting and weather conditions for thermal modelling should be supported. More than the standard CIE or IES models of clear and overcast skies must be able to be included in lighting models. More than the standard Reference Year of data should be able to be used in thermal modelling. A database of external sky or climate data for specific locations would be useful. As with material properties, the provenance of sky models and external weather files is essential documentation. For both daylight and thermal simulation the basic standard is hour by hour simulation of performance. What is needed in addition to this is tests of the statistical validity of the 'typical' year daylight or weather data.

Simulation setting up

Render and thermal simulation settings should be easy to set up. Those controls that are there should be easily understandable in terms that communicate the implications for render accuracy, not the details of the mathematics used to solve the GI problem.

Output: display of illuminance / luminance or temperature / energy use

It is desirable to be able to scale the output in terms that make sense outside of the world of simulation. Benchmarks for the light levels or the energy use or the thermal comfort should be available as part of the output to enable simple scaling of the output against some realistic data.

Guides / roadmaps to sensible use of simulation

What users of building performance software need most is guidance on the state of the art in practice. For example, it is no longer acceptable to do a daylight simulation for five or six 'representative' times of the day and year. What is absolutely essential is to ensure that the newly developed systems of usage that have become available over the past two years - enabling hour by hour simulation of daylight for a full year - are made common practice.

Accuracy

There are currently two functions for tests of the accuracy of simulation software: validation and calibration. For the developer of software, and standards authorities, there is the requirement to be sure that the physics of the lighting or thermal energy balances are modelled correctly. For the practitioner who wishes to ensure that the software they are using is being used correctly, there is the calibration of the office practices and the office simulation staff against established test cases. If independent data is available on the match of the software to the 'truth' established by these tests, then there is also a third function: to provide a compound index of the accuracy of the software in different physical situations.

CIE TC 3.33 and ASHRAE 140 analytical tests

These tests individually rate the software's ability to model light or energy. They are primitive abstractions of particular modelling issues designed to interrogate the software and reveal its fundamental light simulation properties, item by item. Reducing these to a single score - e.g. a weighted rating such as is often used in rating computers or in consumer software reviews - could be attempted, but would hide these individual scores.

CIE TC 3.33 and ASHRAE 140 empirical tests

Each set of measured data provides a single benchmark. In the case of the TC3.33 tests, they only measure the ability of the software to model a single artificially lit room. But they are at least a 'touchstone' in reality - a first step towards empirically testing the software.

Automating the benchmark scoring process

What is needed for any review web site to be used and trusted is a process of peer review and cross checking of the software evaluations. Using the CIE TC 3.33 or ASHRAE 140 suites and the other performance criteria listed above to develop a database of software performance scores produced only by the software developers is not likely to produce trusted information. Following the model of the peer reviewed journal article, one needs evidence of the degree to which the reviewer can be trusted, and a means of cross checking their results.

The aecsimqa.net web site proposes a system whereby several independent reviewers contribute the benchmarks. The database requires more than one complete set of tests. The IEA Task 31 experience of an online uploading system for software test results is that very little uploading occurs if the uploading process requires reporting about the process of test. However, the ability to upload numbers from a spreadsheet in order to generate web reports automatically is increasingly possible with Web 2.0 applications.

In addition, the proposal requires that the provenance of the data must be documented and scored. Criteria for the scoring process are: who is the author of the tests; what is their relationship to the software developer; what are others' reliability assessments of this person (this is equivalent in traditional publishing, to ranking reliability by Citation scores and relevant refereed publications). In Web 2.0 applications it is very much like the e-bay vendor trust scores.

The Future?

With a reliable and trusted tool scoring system available, the next step is for training institutes and for offices to use the suite to calibrate users. Automated uploading of the results at the end of this user calibration exercise begins the certification of the user's trustworthiness but also adds to the database. With a web server of this type, the next logical step would be to develop a means of assessing real simulations of buildings. Software on the client and server would determine the best set of tests and comparisons to perform on the model. Simulations would be examined against indexed results assembled from previous users. Completed simulations would be uploaded with a single click. An analysis of the simulation model would be returned to the user. Software on the local client computer would present this data in the most comprehensible form for the user - probably bands of acceptability / trust. These results would in turn act as a reference for further comparisons. Again, submissions would be graded on the credibility of the simulation's creator. Experienced technicians would receive a higher credibility rating than the first time novice.

The most important feature of web services / Web 2.0 systems is that they are database linked and they are therefore linkable as intelligent objects reporting more than the basics of an individual web report because of the links provided by the individual user. Thus it is possible to link into the software evaluation process simupedia information: (**http://129.187.44.165/index.php/Simupedia/en**) This site offers guidance to simulation software users ("Representing not only theory but also practical advise, Simupedia shows the benefits and limitations of simulations") and therefore these wiki entries on appropriate software use can be linked in and used as the multi-contributor software evaluation.

REFERENCES

[1] Christoph van Treeck, Martin Egger and Gunter Pültz *Simupedia – the new IBPSA-Germany MediaWiki* **www.ibpsa.org/Newsletter/IBPSANews-17-1.pdf** (Last accessed Sept 24 2007)

[2] Michael Donn, Dan Xu, David Harrison, Fawaz Maamariz *Using Simulation Software Calibration Tests As A Consumer Guide – A Feasibility Study Using Lighting Simulation Software*

[3] Maamari, Fawaz et al. *Test Cases to Assess the Accuracy of Lighting Computer Programs* Publication CIE 171:2006 ISBN 3 901 906 47 9

[4] ANSI/ASHRAE 2004. Standard 140-2004 *Standard Method of Test for the evaluation of Building Energy Analysis Computer Programs*

Contrasting the capabilities of building energy performance simulation programs

Drury B. Crawley, Jon W. Hand, Michaël Kummert, and Brent T. Griffith

ABSTRACT

This is an abridged version of a 59-page paper of the same title, which can be found at **www.energytoolsdirectory.gov/pdfs/comparative_paper.pdf**. The report compares the features and capabilities of twenty major building energy simulation programs. Comparisons are based on information provided by the program developers, and these are categorized in 14 separate tables in the report: (1) general modeling features; (2) zone loads; (3) building envelope and daylighting and solar; (4) infiltration, ventilation and multizone airflow; (5) renewable energy systems; (6) electrical systems and equipment; (7) HVAC systems; (8) HVAC equipment; (9) environmental emissions; (10) economic evaluation; (11) climate data availability, (12) results reporting; (13) validation; and (14) user interface, links to other programs, and availability.

INTRODUCTION

Over the past 50 years, literally hundreds of building energy programs have been developed, enhanced and are in use. The core tools in the building energy field are the whole-building energy simulation programs which provide users with key building performance indicators such as energy use and demand, temperature, humidity, and costs.

The report references at least 20 separate comparative surveys of energy programs that have been published. However, the recent study found that no comprehensive comparative survey of tools had been conducted in the past ten years.

This paper provides a small excerpt from the much longer report which compares the features of twenty major building energy simulation programs: BLAST, BSim, DeST, DOE-2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, EnergyPlus, eQUEST, ESP-r, IDA ICE, IES<VE>, HAP, HEED, PowerDomus, SUNREL, Tas, TRACE and TRNSYS. The developers of these programs provided initial detailed information about their tools.

Readers are reminded that the information collected was based on vendor-supplied information and only a limited peer review has been undertaken to verify the information supplied. Some of the descriptions within the tables that are contained in the full report employ vendor specific jargon and thus is somewhat opaque to the broader simulation community. One of the authors' findings was that the simulation community is a long way from having a clear language to describe the facilities offered by tools and the entities that are used to define simulation models. As a result, the tables are not yet uniform in their treatment of topics. Some vendors included components as separate entries and others preferred a general description of component types. Clearly there is considerable scope for improvement in both the layout of the table and in the clarity of the entries.

It is the authors' hope that this will become a living document that will evolve over time to reflect the evolution of tools and an evolution of the language the community uses to discuss the facilities within tools. This task is beyond the resources of three or four authors. It requires community input that not only holds vendors to account for the veracity of their entries, but injects additional methodologies into the task of tool comparison. To access any of the vendor descriptions of their software products, click on the web links following each title.

BRIEF VIEW OF THE TWENTY PROGRAMS

BLAST Version 3.0 Level 334

The Building Loads Analysis and System Thermodynamics (BLAST) system predicts energy consumption and energy system performance and cost in buildings. BLAST contains three major subprograms: Space Loads Prediction, Air System Simulation, and Central Plant. Space Loads Prediction computes hourly space loads given hourly weather data and building construction and operation details using a radiant, convective, and conductive heat balance for all surfaces and a heat balance of the room air. This includes transmission loads, solar loads, internal heat gains, infiltration loads, and the temperature control strategy used to maintain the space temperature. BLAST can be used to investigate the energy performance of new or retrofit building design options of almost any type and size.

BSim2002 www.bsim.dk

BSim provides user-friendly simulation of detailed, combined hygrothermal simulations of buildings and constructions. The package comprise several modules: SimView (graphic editor), tsbi5 (building simulation), SimLight (daylight), XSun (direct sunlight and shadowing), SimPV (photovoltaic power), NatVent (natural ventilation) and SimDxf (import from CAD). BSim has been used extensively over the past 20 years, previously under the name tsbi3. Today BSim is the most commonly used tool in Denmark, and with increasing interest abroad, for energy design of buildings and for moisture analysis.

DeST Version 2.0 (Chinese version only) www.dest.com.cn

DeST (Designer's Simulation Toolkits) allows detailed analysis of building thermal processes and HVAC system performance. DeST comprises a number of different modules for handling different functions: Medpha (weather data), VentPlus (natural ventilation), Bshadow (external shading), Lighting (lighting), and CABD (CAD interface). BAS (Building Analysis & Simulation) performs hourly calculations for indoor air temperatures and cooling/heating loads for buildings, including complicated buildings of up to 1000 rooms.

There are five versions in the DeST family: DeST-h (residences), DeST-c (commercial), DeST-e (building evaluation), DeST-r (building ratings) and DeST-s (solar buildings). DeST has been widely used in China for various prestige large structures such as the State Grand Theatre and the State Swimming Centre.

DOE-2.1E Version 121 simulationresearch.lbl.gov

DOE-2.1E predicts the hourly energy use and energy cost of a building given hourly weather information, a building geometric and HVAC description, and utility rate structure. DOE-2.1E has one subprogram for translation of input (BDL Processor), and four simulation subprograms (LOADS, SYSTEMS, PLANT and ECON). LOADS, SYSTEMS and PLANT are executed in sequence, with the output of LOADS becoming the input of SYSTEMS, etc. The output then becomes the input to ECONOMICS. Each of the simulation subprograms also produces printed reports of the results of its calculations.

DOE-2.1E has been used extensively for more than 25 years for both building design studies, analysis of retrofit opportunities, and for developing and testing building energy standards in the U.S. and around the world. The private sector has adopted DOE-2.1E by creating more than 20 interfaces that make the program easier to use.

ECOTECT Version 5.50 www.ecotect.com

Ecotect is a highly visual architectural design and analysis tool that links a comprehensive 3D modeller with a wide range of performance analysis functions covering thermal, energy, lighting, shading, acoustics and cost aspects. Whilst its modelling and analysis capabilities can handle geometry of any size and complexity, its main advantage is a focus on feedback at the earliest stages of the building design process.

In addition to standard graph and table-based reports, analysis results can be mapped over building surfaces or displayed directly within the spaces. This includes visualisation of volumetric and spatial analysis results, including imported 3D CFD data. Real-time animation features are provided along with interactive acoustic and solar raytracing that updates in real time with changes to building geometry and material properties.

Ener-Win Version EC http://pages.suddenlink.net/enerwin

Ener-Win, originally developed at Texas A&M University, simulates hourly energy consumption in buildings, including annual and monthly energy consumption, peak demand charges, peak heating and cooling loads, solar heating fraction through glazing, daylighting contribution, and a life-cycle cost analysis. Design data, tabulated by zones, also show duct sizes and electric power requirements.

The Ener-Win software is composed of several modules - an interface module, a weather data retrieval module, a sketching module, and an energy simulation module. The interface module includes a rudimentary building sketching interface. Ener-Win requires only three basic inputs: (1) the building type, (2) the building's location, and (3) the building's geometrical data.

Energy Express, Version 1.0 www.ee.hearne.com.au

Energy Express is a design tool, created by CSIRO, for estimating energy consumption and cost at the design stage. The user interface allows fast and accurate model creation and manipulation. Energy Express includes a dynamic multi-zone heat transfer model coupled to an integrated HVAC model so that zone temperatures are impacted by any HVAC shortcomings.

Energy Express for Architects provides graphic geometry input and editing, multiple report viewing, comparison of alternative designs and results, simplified HVAC model, and detailed online help. Energy Express for Engineers provides those capabilities along with peak load estimating, and detailed HVAC model, graphic editing of air handling system and thermal plant layouts.

Energy-10 Version 1.8 www.nrel.gov/buildings/energy10

Energy-10 was designed to facilitate the analysis of buildings early in the design process with a focus on providing a comprehensive tool suited to the design-team environment for smaller buildings. Rapid presentation of reference and low-energy cases is the hallmarks of Energy-10. Since Energy-10 evaluates one or two thermal zones, it is most suitable for smaller, 10,000 ft2 (1000 m2) or less, simpler, commercial and residential buildings.

Energy-10 takes a baseline simulation and automatically applies a number of predefined strategies ranging from building envelope (insulation, glazing, shading, thermal mass, etc.) and system efficiency options (HVAC, lighting, daylighting, solar service hot water and integrated photovoltaic electricity generation). Full life-cycle costing is an integral part of the software.

EnergyPlus Version 2.0.0 www.energyplus.gov

EnergyPlus is a modular, structured code based on the most popular features and capabilities of BLAST and DOE-2.1E. It is a simulation engine with input and output of text files. Loads calculated (by a heat balance engine) at a user-specified time step (15-minute default) are passed to the building systems simulation module at the same time step. The EnergyPlus building systems simulation module, with a variable time step, calculates heating and cooling system and plant and electrical system response. This integrated solution provides more accurate space temperature prediction — crucial for system and plant sizing, occupant comfort and occupant health calculations. Integrated simulation also allows users to evaluate realistic system controls, moisture adsorption and desorption in building elements, radiant heating and cooling systems, and interzone air flow.

eQUEST Version 3.55 www.doe2.com/equest

eQUEST is an easy to use building energy use analysis tool which provides high quality results by combining a building creation wizard, an energy efficiency measure (EEM) wizard and a graphical results display module with an enhanced DOE-2.2-derived building energy use simulation program.

The building creation wizard walks a user through the process of creating a building model. Within eQUEST, DOE-2.2 performs an hourly simulation of the building based on walls, windows, glass, people, plug loads, and ventilation. DOE-2.2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices. eQUEST allows users to create multiple simulations and view the alternative results in side-by-side graphics. It offers energy cost estimating, daylighting and lighting system control, and automatic implementation of energy efficiency measures (by selecting preferred measures from a list).

ESP-r Version 10.1 www.esru.strath.ac.uk/Programs/ESP-r.htm

ESP is a general purpose, multi-domain-building thermal, inter-zone air flow, intra-zone air movement, HVAC systems and electrical power flow-simulation environment which has been under development for more than 25 years. It follows the pattern of `simulation follows description` where additional technical domain solvers are invoked as the building and system description evolves. Users control the complexity of the geometric, environmental control and operations to match the requirements of particular projects. It supports an explicit energy balance in each zone and at each surface. ESP-r is distributed under a GPL license. The web site also includes an extensive publications list, example models, source code, tutorials and resources for developers.

HAP Version 4.20a www.commercial.carrier.com

Hourly Analysis Program (HAP) provides two tools in one package: sizing commercial HVAC systems and simulating hourly building energy performance to derive annual energy use and energy costs. Input data and results from system design calculations can be used directly in energy studies.

HAP is designed for the practicing engineer, to facilitate the efficient day-to-day work of estimating loads, designing systems and evaluating energy performance. Tabular and graphical output reports provide both summaries of and detailed information about building, system and equipment performance.

HAP is suitable for a wide range of new design and retrofit applications. It provides extensive features for configuring and controlling air-side HVAC systems and terminal equipment. Part-load performance models are provided for split DX units, packaged DX units, heat pumps, chillers and cooling towers. Hydronic loops can be simulated with primary-only and primary/secondary configurations, using constant speed or variable speed pumps.

HEED Version 1.2 www.aud.ucla.edu/heed

The objective of HEED is to combine a single-zone simulation engine with a user-friendly interface. It is intended for use at the very beginning of the design process, when most of the decisions are made that ultimately impact the energy performance of envelope-dominated buildings.

HEED requires just four project inputs: floor area, number of stories, location (zip code), and building type. An expert system uses this information to design two base case buildings: scheme 1 meets California's Title 24 Energy Code, and a scheme 2 which is 30% more energy efficient. HEED automatically manages up to 9 schemes for up to 25 different projects.

HEED's strengths are ease of use, simplicity of input data, a wide array of graphic output displays, computational speed, and the ability to quickly compare multiple design alternatives. Context specific Help, Advice, and a FAQ file are included. A full Spanish language version is also included. HEED is free, and can be downloaded from **www.aud.ucla.edu/heed**.

IDA ICE Version 3.0, build 15 www.equa.se/ice

IDA Indoor Climate and Energy (IDA ICE) is based on a general simulation platform for modular systems, IDA Simulation Environment. Physical systems from several domains are described in IDA using symbolic equations, stated in either or both of the simulation languages Neutral Model Format (NMF) or Modelica. IDA ICE offers separated but integrated user interfaces to different user categories:

- Wizard interfaces lead the user through the steps of building a model for a specific type of study. The Internet browser based IDA Room wizard calculates cooling and heating load.
- Standard interface for users to formulate a simulation model using domain specific concepts and objects, such as zones, radiators and windows.
- Advanced level interface - where the user is able to browse and edit the mathematical model of the system.
- NMF and/or Modelica programming - for developers.

IES <VE> Version 5.2 www.iesve.com

The IES <Virtual Environment> (IES <VE>) is an integrated suite of applications linked by a common user interface and a single integrated data model. <Virtual Environment> modules include:

- ModelIT - geometry creation and editing
- ApacheCalc - loads analysis
- ApacheSim - thermal
- MacroFlo - natural ventilation
- Apache HVAC - component based HVAC
- SunCast - shading visualisation and analysis
- MicroFlo - 3D computational fluid dynamics
- FlucsPro/Radiance - lighting design
- DEFT - model optimisation
- LifeCycle - life-cycle energy and cost analysis
- Simulex - building evacuation

The program provides an environment for the detailed evaluation of building and system designs, allowing them to be optimized with regard to comfort criteria and energy use.

PowerDomus Version 1.5 www.pucpr.br/lst

PowerDomus is a whole-building simulation tool for analysis of both thermal comfort and energy use. It has been developed to model coupled heat and moisture transfer in buildings when subjected to any kind of climate conditions, i.e., considering both vapor diffusion and capillary migration. Its models predict temperature and moisture content profiles within multi-layer walls for any time step and temperature and relative humidity for each zone.

PowerDomus allows users to visualize the sun path and inter-buildings shading effects and provides reports with graphical results of zone temperature and relative humidity, PMV and PPD, thermal loads statistics, temperature and moisture content within user-selectable walls/roofs, surface vapor fluxes and daily-integrated moisture sorption/ desorption capacity.

SUNREL Version 1.14 www.nrel.gov/buildings/sunrel

SUNREL is an hourly building energy simulation program that aids in the design of small energy-efficient buildings where the loads are dominated by the dynamic interactions between the building's envelope, its environment, and its occupants.

SUNREL has a simplified multizone nodal airflow algorithm that can be used to calculate infiltration and natural ventilation. Windows can be modeled by one of two methods. Users can enter exact optical interactions of windows with identical layers of clear or tinted glass and no coatings on the layers. Thermal properties are modeled with a fixed U-value and fixed surface coefficients. For the second method, a user imports data from Window 4 or 5. SUNREL only models idealized HVAC equipment. The equipment and loads calculations are solved simultaneously, and the equipment capacities can be set to unlimited. Fans move a schedulable fixed amount of air between zones or from outside.

Tas Version 9.0.7 www.edsl.net

Tas is a suite of software products, which simulate the dynamic thermal performance of buildings and their systems. The main module is Tas Building Designer, which performs dynamic building simulation with integrated natural and forced airflow. It has a 3D graphics based geometry input that includes a CAD link. Tas Systems is an HVAC systems/controls simulator, which may be directly coupled with the building simulator. It performs automatic airflow and plant sizing and total energy demand. The third module, Tas Ambiens, is a robust and simple to use 2D CFD package which produces a cross section of micro climate variation in a space.

Tas combines dynamic thermal simulation of the building structure with natural ventilation calculations which include advanced control functions on aperture opening and the ability to simulate complex mixed mode systems. The software has heating and cooling plant sizing procedures, which include optimum start. Tas has 20 years of commercial use in the UK and around the world.

TRACE 700 Version 4.1.10 www.tranecds.com

TRACE is divided into four distinct calculation phases: Design, System, Equipment and Economics. During the Design Phase the program first calculates building heat gains for conduction through building surfaces as well as heat gains from people, lights, and appliances and impact of ventilation and infiltration. Finally, the program sizes all coils and air handlers based on these maximum loads.

During the System Phase, the dynamic response of the building is simulated for an 8760-hour (or reduced) year by combining room load profiles with the characteristics of the selected airside system to predict the load imposed on the equipment. The Equipment Phase uses the hourly coil loads from the System Phase to determine how the cooling, heating, and air moving equipment will consume energy. The Economic Phase combines economic input supplied by the user with the energy usage from the Equipment Phase to calculate each alternative's utility cost, installed cost, maintenance cost and life cycle cost.

TRNSYS Version 16.0.37 http://sel.me.wisc.edu/trnsys

TRNSYS is a transient system simulation program with a modular structure that implements a component-based approach. TRNSYS components (referred to as "Types") may be as simple as a pump or pipe, or as complex as a multi-zone building model.

The components are configured and assembled using a fully integrated visual interface known as the TRNSYS Simulation Studio, while building input data is entered through a dedicated visual interface (TRNBuild). The simulation engine then solves the system of algebraic and differential equations that represent the whole energy system. In building simulations, all HVAC-system components are solved simultaneously with the building envelope thermal balance and the air network at each time step. In addition to a detailed multizone building model, the TRNSYS library includes components for solar thermal and photovoltaic systems, low energy buildings and HVAC systems, renewable energy systems, cogeneration, fuel cells, etc.

The modular nature of TRNSYS facilitates the addition of new mathematical models to the program. New components can be developed in any programming language and modules implemented using other software (e.g. Matlab/Simulink, Excel/VBA, and EES) can also be directly embedded in a simulation. TRNSYS can generate redistributable applications that allow non-expert users to run simulations and parametric studies.

COMPARISON AMONG THE TOOLS

Readers of the report who have specific simulation tasks or technologies in mind should be able to quickly identify likely candidate tools. The web sites and detailed references and footnotes included in the report would then allow a potential user to confirm that the programs indeed have the capabilities.

From our experience, many users are relying on a single simulation tool when they might be more productive having a suite of tools from which to choose. Early design decisions may not require a detailed simulation program to deal with massing or other early design problems. We encourage users to consider adopting a suite of tools which would support the range of simulation needs they usually see in their practice.

Because the 14 tables comprise 30 pages with more than 250 footnotes in the full comparison report, only a glimpse was provided here. Readers can access the full report at **www.energytoolsdirectory.gov/pdfs/comparative_paper.pdf**.

LIFE CYCLE GREEN COST ASSESSMENT METHOD FOR GREEN BUILDING DESIGN

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ABSTRACT

Life cycle green cost assessment (LCGCA) method, which can evaluate building environmental load and economic performance throughout its life cycle comprehensively, is propounded in this paper in order to guide green building design. In LCGCA, environmental load (EL) cost is proposed based on concept of environmental tax and counted into general building initial cost and operating cost, and then green payback time (GPT) could be worked out. With this method, an office building in Beijing is studied. The operating energy consumption, life cycle EL, life cycle cost (LCC) and GPT of different envelope schemes have been compared. The results indicate GPT is obviously shorter than the general payback time when EL cost is considered. Especially, the exterior shading scheme changes to be economically feasible through GPT evaluation. This assessment method is more suitable to guide green building design practice because environmental performance and economical performance are considered together.

KEYWORDS

Green building design, Environmental load, Green payback time, Life cycle cost analysis

BACKGROUND

Green buildings have got rapid development around the world in recent 10 years. Then how to evaluate green performance and determine green level of buildings becomes one of the research emphases. In China, green building design is still at beginning stage. Recently, domestic scholars begin to pay attention to building environmental impact and use life cycle assessment (LCA) method to quantify it in order to get evaluation index of green building. Moreover, some scholars try to use this method to guide building cooling and heating resources selection and envelope design (Li 2005, Lin 2004, Gu 2007), but researches like these are just a few part. However, when real projects in practice are designed, the research conclusion will not be considered, because economic performance is most important in market and better environmental performance sometimes leads to higher initial construction cost. To promote energy saving and environment protection in practice, national policy is needed. In some foreign counties, environmental tax has been is imposed to lead some industry to control and reduce pollution. Chinese government also has issued notification of beginning to study environmental tax imposition (Anon.) not long before. Although most environmental tax aims at energy production and use now, buildings will be involved in the future for its high energy and resources consumption. Then a comprehensive assessment method that can evaluate both environmental and economic performance of building is urgently needed. But there is no corresponding study in China yet. Some results of foreign study (Gluch and Baumann 2004) may not be used directly because of different status of China. Therefore, life cycle green cost assessment (LCGCA) method is propounded in this paper as an attempt to solve this problem.

LCGCA METHOD

LCGCA involves two indexes: building environmental load (EL) and building green cost (GC). EL (unit: point and pt for short) can be calculated with LCA method by Building Environmental Load Evaluation System (BELES) developed by Department of Building Science in Tsinghua University (Gu 2006). GC can be calculated according to life cycle cost analysis (LCCA) method. GC is different from the general cost which mainly includes initial cost (IC) and operating cost (OC). It also includes environmental load cost (ELC) which is the economic value of EL. The price of unit EL can be determined according to CO_2 price. Influenced by Clean Development Mechanism of Kyoto protocol, international carbon trade is very active at present, the general price of CO_2 is about 80RMB/t (trade in China) (Anon A). BELES analysis result shows EL of CO_2 is 0.463pt/t, so price of unit EL is 173 RMB/pt. Then ELC of building construction phase plus general IC comes to be green initial cost (GIC), and ELC of operation phase plus general OC comes to be green operating cost (GOC). With above calculation and redefinition, building environmental performance and economic performance are connected together. Finally the integrated evaluation index of LCGCA, green payback time (GPT), can be calculated with equations (1)-(6).

$$ELC = EL \cdot V_{pt} \quad (1)$$

$$GIC = ELC_c + IC \quad (2)$$

$$GOC = ELC_o + OC \quad (3)$$

$$-(GIC - GIC_0) = (OC - OC_0) \cdot P_G + (ELC_o - ELC_{o0}) \cdot P_{EL}$$

namely $-\Delta GIC = \Delta OC \cdot P_G + \Delta ELC_o \cdot P_{EL}$ (4)

$$P_G = (\frac{1+e}{1+i} - (\frac{1+e}{1+i})^{N_G})/(1-\frac{1+e}{1+i}) \quad (5)$$

$$P_{EL} = (\frac{1+e_{EL}}{1+i} - (\frac{1+e_{EL}}{1+i})^{N_G})/(1-\frac{1+e_{EL}}{1+i}) \quad (6)$$

Where EL is building EL per unit floor area (pt/m^2), V_{pt} is price of unit EL (RMB/pt); ELC_c is ELC of construction phase per unit floor area (RMB/m^2) (all the other cost parameters in this paper refers to the cost of per unit area, no statement is made in the following text except special condition), ELC_o is ELC of operation phase (RMB/m^2); IC is general IC (RMB/m^2), OC is general annual OC (RMB/yr/m^2) GIC is GIC (RMB/m^2), GOC is annual GOC (RMB/yr/m^2), subscript "0" refers to GIC and annual GOC of base case; N_G is GPT (yr); P_G is discount coefficient of total OC in N_G years, it is a function of energy price growth rate e and bank rate i; P_{EL} is discount coefficient of total ELC in N_G years, it is a function of CO_2 price growth rate e_{EL} and bank rate i.

The difference value is used to calculate N_G, so there is no need to consider the same part of each scheme, only comparison of different part is enough to get results. The calculation workload can be simplified. The results of case study in this paper are all carried out with comparison of only different part of schemes.

Green building design can be optimized through comparison of GPT of each design scheme. If $GIC>GIC_0$ and $GOC>GOC_0$, it means the scheme not only increases GIC but also increases GOC, it is less green than the base case and should not be chosen; If $GIC<GIC_0$ and $GOC<GOC_0$, it means the scheme not only decreases GIC but also decreases GOC, it is more green and economic than the base scheme. There is no payback time for above two conditions in theory. If $GIC>GIC_0$ and $GOC<GOC_0$, N_G may be worked out, the greater it is, the longer the GPT is. When N_G is in an acceptable range, the scheme is greener than the base case and economically feasible in life cycle.

CASE STUDY

Investigation data show that energy consumption per unit floor area of commercial buildings is much more than that of residential buildings, besides, facade designs of commercial buildings are always complicated than that of residential buildings. Therefore, an office building in Beijing is taken as a study case in this paper. Several schemes of envelope design and energy saving strategy of it are analyzed. Energy consumption, life cycle environmental load (LCEL), life cycle cost (LCC) and GPT are compared respectively. In addition, the difference between GPT and general payback time (PT) are analyzed too.

The building has 30 floors with total area 49445m^2, and the first four floors are designed as annex. HVAC system of it is fan-coil unit plus fresh air system, centrifugal water chillers for cooling in summer and gas-fired boiler for heating in winter. The original envelope scheme is all-glass curtain wall and is taken as base case. All the schemes are described in table 1.

Table1 List of design schemes

	DESIGN SCHEME
case1	all-glass curtain wall, base case
case2	ARWW* 0.65 & aluminum curtain wall
case3	ARWW 0.45 & aerated concrete block
case4	glass curtain wall with louver and ventilation adjustable double-skin facade for south facade
case5	glass curtain wall with fixed exterior louver (500mm wide) for south facade, 4 layers for floor 1 and 4, 3 layers for the other floors

**ARWW is the area ratio of window over wall*

Building operating energy consumption analysis

1. Building load simulation

Building load is hourly simulated by an energy simulation software DeST (Designer's Simulation Toolkits) (Yan etc. 2004), which is also developed by Department of Building Science in Tsinghua University. According to the local design standard of public buildings (Ministry of Construction P.R.China 2005), different window thermal performance is required for different building ARWW scheme. Double skin facade and exterior louver shading schemes are designed for energy efficiency and better comfort based on the original scheme. Envelope thermal parameters of each scheme are shown in Table 2, and simulation results of building load are shown in Table 3.

Table2 Envelope performance of each scheme

	K* of WALL	K of ROOF	WINDOW	
			K	SC*
case1	0.80	0.54	1.6	0.45
case2	0.78	0.54	2.0	0.45
case3	0.75	0.54	2.3	0.55
case4	0.80	0.54	s*1.4/w*1.33	s0.11/w0.47
case5	0.80	0.54	1.6	hourly different

**K is heat transfer coefficient, W/(m^2·K),*
SC is shading coefficient of glass,
"s" stands for summer, "w" for winter

Table3 Results of building load simulation

	MAX HEATING LOAD	MAX HEATING LOAD	TOTAL HEATING LOAD	TOTAL COOLING LOAD
	(W/m^2)	(W/m^2)	(kWh)	(kWh)
case1	87.7	137.8	568575	3990996
case2	88.3	130.5	773416	3521657

case3	87.2	126.9	805122	3318760
case4	84.4	132.3	532965	3644480
case5	89.0	134.9	624631	3778845

2. Operating energy consumption

Different envelope scheme has different cooling and heating load, as well as different operating electricity and gas consumption. Building load affect not only energy consumption of cooling or heating units, but also electricity consumption of supply system (including pumps, fans etc.). A concept of TCOP (total coefficient of performance) is proposed to describe the total energy efficiency of cooling system. TCOP is the ratio of total cooling load in summer over total electricity consumption of cooling system. TCOP is quite difficult to be calculated precisely, it is greatly depend on the type of distribution system and equipment speciality. As for this building, it is estimated to be 2.5 according to energy consumption measurement and investigation to many office buildings in Beijing by our department. Because heating load of this building is much less than cooling load and the difference of heating pump electricity consumption among schemes is small, so it is not counted in the total electricity consumption of HVAC system. Then annual operating electricity and gas consumption can be worked out with equation (7)-(8). Where *TCOP* is TCOP of cooling system; CON_e is annual operating electricity consumption per unit floor area (kWh/yr/m^2); CON_g is annual operating gas consumption per unit floor area (m^3/yr/m^2); η_{boiler} is gas-fired boiler efficiency, is assumed to be 0.89 according to the local standard; r is heat value of natural gas, 8500kcal/m^3; Q_c and Q_h is the total cooling load in summer and heating load in winter respectively (kWh/m^2). The results are shown in Fig.1 and Fig.2.

$$CONe = \frac{Q_c}{TCOP} \quad (7)$$

$$CONg = \frac{Q_h}{\eta_{boiler} \times r} \quad (8)$$

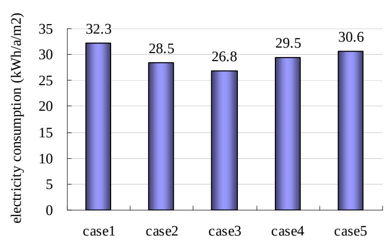

Fig.1 Operating electricity consumption

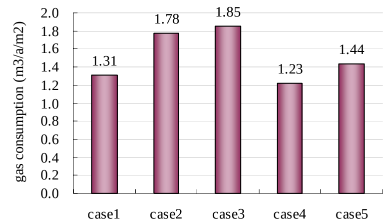

Fig.2 Operating gas consumption

It shows the smaller the ARWW (case2, case3) is, the less the electricity consumption is and the more gas consumption is. Energy consumption of double skin facade scheme (case4) is less than that of base case both in summer and in winter. Electricity consumption of exterior shading scheme (case5) is less than that of base case, but gas consumption is a little bigger since the fixed louver decrease solar heat gain in winter and makes heating load higher. Case3 has the least electricity consumption for its smallest ARWW, and case4 has the least gas consumption for its largest ARWW and higher SC of glass.

LCEL analysis

Each scheme is different only in exterior envelope design, so only EL of exterior walls and windows are considered when calculating building construction EL. There are many kinds of materials in envelop, but consumption of some kinds are just a little, so only consumption of main materials are counted for comparison. Besides, some building materials have shorter life-span than building, so they need to be replaced during building use life. Building lifespan is assumed to be 50 years, and curtain walls, double skin facade, exterior louver are assumed to be 40 years (IBEC 2004). Operating EL mainly comes from energy use of cooling and heating system. According to building materials consumption and building load, EL of construction, replacement and operation can be worked out with BELES. Then building LCEL of each scheme can be calculated. The results are shown in Table 4 and Fig.3.

Table 4 Building life cycle environmental load

	EL_c* (pt/m^2)	EL_r* (pt/m^2)	EL_o* (pt/yr/m^2)	LCEL (pt/m^2)
case1	0.656	0.656	0.439	23.2
case2	0.700	0.700	0.406	21.7
case3	0.375	0.295	0.388	20.0
case4	0.775	0.775	0.402	21.6
case5	0.701	0.701	0.421	22.5

**The subscript "c" stands for construction phase, "r" for replacement and "o" for annual operation.*

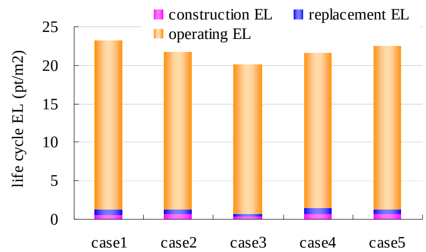

Fig.3 Building life cycle environmental load

It is found that, construction and replacement EL of case4 is highest, operating EL of base case is highest, and ELs of all phases of case3 are lowest. Although construction EL of case2, case4 and case5 are higher than that of base case, LCEL of them are all lower than that of base case. This means the increased construction and replacement EL of optimized strategy can be balanced out by the decreased operating EL, and the total life cycle environmental performance of these optimized schemes are better than that of base case.

LCC analysis

LCC of building contains many kinds of cost, such as IC, OC, maintenance and replacement cost and so on. In this case, IC, OC and replacement cost (RC) are considered. Cost for maintenance is not included because the type and amount of maintenance is difficult to estimate. Besides, there is just a little difference between the max heating and cooling load of each scheme, so the cost difference of cooling and heating source equipment is very small (the largest equipment cost difference is 3.3RMB/m^2) and can be ignored. Since there is only difference of exterior envelope among cases, IC calculation only includes this part. The total area of building facade is 19991m^2. The total length of aluminum louvers of case5 is 4729m. According to current cost analysis from curtain wall company, the cost of concealed-frame double-layer glass curtain wall is 1011.9 RMB/m^2; the cost of aluminum curtain wall of case2 is 642.9 RMB/m^2; the cost of aerated concrete block of case3 is 39.5 RMB/m^2; the cost of double skin facade of case4 is 2500 RMB/m^2; the cost of aluminum louvers of case5 is 600 RMB/m. Then IC and RC can be worked out. OC mainly is energy use cost. Electricity cost for cooling is calculated hourly according to time-differentiated electricity price in Beijing (Anon B), and natural gas cost for heating is calculated according to gas price 1.9 RMB/m^3 in Beijing.

LCC results of each scheme can be figured out with equation (9)-(11), where *LCC* is the LCC of building (RMB/m^2); N_r is the life-span of curtain wall and louver (yr), which is assumed to be 40 in this paper as stated before; *RC* is the RC of building materials (RMB/m^2); e_m is the growth rate of building materials price, is assumed to be 3% according to statistic data (Anon C); P_l is discount coefficient of total OC in building 50-year lifespan, it is a function of energy price growth rate *e* and bank rate *i*. *e* is assumed to be 5% according to the growth tend of electricity and gas price in Beijing in recent years, and *i* is assumed to be 6.12% according to the general bank rate in China in 2006 (Anon D). Then general payback time (PT) can be calculated with equations (12)-(13), where *N* is PT of scheme (yr); *P* is discount coefficient of total OC in *N* years. All the results are shown in table 5.

$$LCC = IC + RC \cdot \left(\frac{1+e_m}{1+i}\right)^{N_r} + OC \cdot P_l \tag{9}$$

$$P_l = \left(\frac{1+e}{1+i} - \left(\frac{1+e}{1+i}\right)^{50}\right) / \left(1 - \frac{1+e}{1+i}\right) \tag{10}$$

$$-(IC - IC_0) = (OC - OC_0) \cdot P \tag{11}$$

$$P = \left(\frac{1+e}{1+i} - \left(\frac{1+e}{1+i}\right)^{N}\right) / \left(1 - \frac{1+e}{1+i}\right) \tag{12}$$

Table 5 Life cycle cost analysis

	IC	***RC***	***OC***	***LCC***	**PT**
	(RMB/m^2)	(RMB/m^2)	(RMB/yr/m^2)	(RMB/m^2)	(yr)
case1	409.1	409.1	34.0	1826.3	/
case2	355.9	355.9	31.2	1650.7	/
case3	192.2	183.4	29.8	1378.9	/
case4	593.1	593.1	31.1	1955.7	108
case5	466.5	466.5	32.6	1846.2	54

It shows that, both IC and OC of case2 are lower than that of base case, so does that of case3. Therefore there is no PT for these two cases in theory. LCC of these two cases are lower than that of base case. they have better economic performance. Case4 and case5 pay much in construction phase to get lower OC. But the PTs of them are all longer than 50-year building life-span and LCC of them are higher than that of base case, so in terms of economic performance with general meaning they are worse than the base case.

GPT analysis

As stated above, ELC is included in GC. According to the EL results, ELC of construction and operation phase of each scheme can be calculated, and then GIC and GOC can be worked out, consequently GPT, N_G, can be calculated with equation (4)-(6). Considering the uncertainty of CO_2 price growth rate e_{EL}, it is assumed to be 0 in calculation. The results are shown in Table 6.

Table 6 Green payback time analysis

	ELC$_C$	***GIC***	***ELC$_O$***	***GOC***	**GPT**
	(RMB/m^2)	(RMB/m^2)	(RMB /yr/m^2)	(RMB /yr/m^2)	(yr)
case1	113.4	522.5	75.8	109.8	/
case2	121.0	476.9	70.1	101.3	/
case3	64.7	257.0	67.0	96.7	/
case4	134.0	727.1	69.4	100.5	48
case5	121.1	587.6	72.8	105.4	24

It is found that, GIC and annual GOC of both case2 and case3 are lower than that of base case, so there is no PT for these two cases in theory, they are better schemes than base case in comprehensive performance of environment and economy. GPTs of case4 and case5 are obviously shorter than PTs of them when ELC is counted in. GPT of case5 turns to be 24 years, which means the exterior shading scheme is better than base case in comprehensive performance of environment and economy. GPT of case4 turns to be 48 years, however, it is longer than the life-span of curtain wall and louvers, so the double skin facade scheme is still economically unfeasible. This is because the double skin façade technique is very expensive under the current situation of China.

CONCLUSION

To evaluate environmental and economic performance of green building design comprehensively, a new assessment method, LCGCA, is proposed in this paper, which takes ELC into account and use GPT as an integrated evaluation index.

Based on the new method, a real office building in Beijing is studied. Several different schemes of envelope design have been compared from aspects of building operating energy consumption, LCEL, LCC and GPT. And different results can be obtained from different evaluation aspect.

1. Operating energy consumption: all the optional schemes (case2-5) have less operating energy consumption than initial scheme (base case).
2. LCEL: both construction and operation EL of case3 are lower than that of base case. Although construction EL of case2, case4 and case5 are higher than that of base case, LCEL of them are all lower. So all the optional schemes perform better in life cycle environmental impact than base case does.
3. LCC: case2 and case3 have lower LCC than base case, but case4 and case5 have higher. There is not PT for case2 and case3 in theory. PTs of case4 and case5 are longer than building life-span. So as general economy analysis is concerned, both double skin facade scheme and fixed exterior shading scheme are economically worse than base case.
4. LCGCA: GPTs of case4 and case5 are obviously shorter than PTs of them. GPT of case5 is 24 years, which indicates the fixed exterior shading scheme is better than base case in comprehensive performance of environment and economy. GPT of case4 is 48 years, however, is still longer than lifespan of curtain wall and louvers, which indicates double skin facade scheme is still economically worse than base case. As for case2 and case3, both GIC and GOC of them are lower than that of base case, there are no GPTs for them, they are better than base case in comprehensive performance of environment and economy.

It can be concluded, comparison results may be different from that of general economy analysis when ELC is considered. Since energy and pollution problem become more and more serious and environmental tax imposition is upcoming, environmental and economic performance of green building design should be evaluated comprehensively. Therefore LCGCA, which can meets this need, is worth being recommended to be the evaluation and guide tool for green building design in China.

What need to be explained is the conclusions in this paper are obtained from this special case, they may not suitable for other cases, and so special case needs special analysis. But LCGCA is a universal method. Besides construction EL and ELC only include the exterior envelope part, which is only a small part of the total construction system. So the value in this paper is not the total EL and ELC of the whole construction system. Consequently LCEL and LCC value in this paper is not the real value of the whole building either. Although this will not affect any of the conclusion for exterior envelopes is the only different part between each scheme, we will try our best to get more detailed data about the building and give total value of the whole building in future study. In addition, changing of energy price growth rate, building material price or bank rate will all affect the results of ELC, LCC, PT and GPT and further affect the conclusion, so sensitivity analysis of these affecting factors may be studied in our future work.

NOMENCLATURE

Abbreviation

EL	environmental load
ELC	environmental load cost
GC	green cost
GIC	green initial cost
GOC	green operating cost
GPT	green payback time
IC	initial cost
LCA	life cycle assessment
LCC	life cycle cost
LCCA	life cycle cost analysis
LCEL	life cycle environmental load
LCGCA	life cycle green cost assessment
OC	operating cost
PT	general payback time
RC	replacement cost
TCOP	total coefficient of performance

Symbol

CON_e	annual operating electricity consumption per unit floor area (kWh/yr/m^2)
CON_g	annual operating gas consumption per unit floor area (m^3/yr/m^2)
e	energy price growth rate

e_{EL} — CO_2 price growth rate

e_m — growth rate of building materials price

EL — building environmental load per unit floor area (pt/m^2)

ELC_c — environmental load cost of construction phase per unit floor area (RMB/m^2)

ELC_o — environmental load cost of operation phase per unit floor area (RMB/m^2)

GIC — green initial cost per unit floor area (RMB/m^2)

GIC_0 — green initial cost per unit floor area of base case (RMB/m^2)

GOC — annual green operating cost per unit floor area ($RMB/yr/m^2$)

GOC_0 — annual green operating cost per unit floor area of base case ($RMB/yr/m^2$)

i — bank rate

IC — general initial cost per unit floor area (RMB/m^2)

IC_0 — general initial cost per unit floor area of base case (RMB/m^2)

LCC — life cycle cost of building per unit floor area (RMB/m^2)

N — general payback time (yr)

N_G — green payback time (yr)

N_r — life-span of curtain wall and louver (yr)

OC — general annual operating cost per unit floor area ($RMB/yr/ m^2$)

OC_0 — general annual operating cost per unit floor area of base case ($RMB/yr/m^2$)

P — discount coefficient of total operating cost in N years

P_{EL} — discount coefficient of total environmental load cost in N_G years

P_G — discount coefficient of total operating cost in N_G years

P_l — discount coefficient of total operating cost in building 50-year lifespan

Q_c — total cooling load in summer per unit floor area (kWh/m^2)

Q_h — total heating load in winter per unit floor area (kWh/m^2)

r — heat value of natural gas, $8500 kcal/m^3$

RC — replacement cost of building materials per unit floor area (RMB/m^2)

$TCOP$ — total coefficient of performance of cooling system

V_{pt} — price of unit EL (RMB/pt)

η_{boiler} — gas-fired boiler efficiency

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INTEROPERABILITY OF BUILDING INFORMATION MODEL AND ENERGY SIMULATION TO IMPROVE ENERGY EFFICIENT AND SUSTAINABLE DESIGN PROCESS

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Abstract

The paper describes the significance of novel interoperability and parametric modeling technology to improve building energy performance simulation and sustainable design through Virtual Model Environment (VME) and Virtual Model System (VMS). Interoperability through VME and VMS establish a seamless link between building information, parametrics, and energy simulation model for detailed thermal and day light simulation and analysis during the design and construction process. Application Program Interface (API) in VME and VMS provide bidirectional data exchange capabilities, which may significantly reduce time and effort spent in data regeneration and duplication, for example regenerate building geometries. Lack of interoperability and parametric relationship between building model and energy simulation is one of the major obstacles that limit the application of building design and performance integration. A proposed new model mapping engine can alleviate the problems of abstraction and representation to phenomenal real life experience that building simulation professionals face nowadays, substantially reducing time, cost and labor spending to simulate sophisticated building materials and climate responsive building, complexity of building systems and control, and many unknown building parameters.

1. INTRODUCTION

This paper presents the new approach that allows bidirectional data extraction and synchronization data mapping of drawings, model, schedule simulation, extraction of analysis of graphical and numerical data, and reports, and more ultimately, enabling design professionals to have better informed design decisions, which describe different aspects of building design, concept, aesthetic, function, safety, energy performance, and sustainability.

During the last four decades, building designers have utilized information and communication technologies for creating environmental representations in order to communicate spatial concepts or designs and for enhancing spaces. Most architectural firms still rely on hand labor, working from drafted drawings, generating construction documents, specifications, schedules, and work plans in traditional means. Three-dimensional modeling has been used primarily as a rendering tool, not as the actual representation of the project.

Nowadays, the Architecture, Engineering, and Construction (AEC) industry appears to be moving toward adopting building information model (BIM) as the next generation of CAD and over standard computerized drafting. Already many governments are adopting BIM technology. In the U.S., for example, the General Services Administration and other agencies are embarking on initiatives that will require the use of BIM solutions for work done on their buildings and complexes. BIM is a different and more productive way of working for all AEC professionals, from the architect or designer, through the structural and MEP engineers to the contractor, and finally to the owner.

1.1. CAD 3D Model and Energy Simulation Tools

Since the early 1960, the use of computer modeling and simulation tools with in the building industry has steadily increased. These tools have progressed from simple, single tasks applicationss weith limited input and output requirements (Howard 1960), to quite sophisticated modeling system that can simultaneously analyze a range of performance parameters. In 1973, there was the energy crisis that leads to the development in computation energy analysis tools. Some focus of development in this area has long been on the accurate simulation of fundamental physical process such as mechanisms of heat flow through materials and the transmission of light. Adequate description of boundary conditions for such calculation usually requires very detailed mathematical models (Manning, 1987). To understand how air flows and heat transfers around the building, architects and engineers need a very sophisticated modeling technique. Computer modeling help solves equations that govern fluid flow, and the transferring of momentum, energy and mass. The data can be entered and translated to resolve into easy to read graphics.

The original premise of a Computer Assisted Design and Drawing (CAD) system was to automate the task of drafting. As such, the original focus of CAD applications was to represent 2D geometry via graphical elements, such as lines, arcs, symbols, et al. In this context, walls, for example, are merely represented as parallel lines. To establish some meaning behind these graphical elements, the concept of layering was introduced to group related elements, such as the lines used to represent walls on a given 'wall layer.' By doing so, discrete 2D drawing files could be generated and plotted from CAD, but more complex information, such as the relationships between elements could not be represented. The emergence of 3D CAD initially focused almost entirely on creating geometry in support of visualization, and subsequent advances concentrated on creating realistic rendering and lighting effects.

Until recently object-oriented building systems replaced 2D symbols with building elements (objects), capable of representing the behavior of common building elements. These building elements can be displayed in multiple views, as well as having non-graphic attributes assigned to them. The inclusion of parametric 3D geometry, with variable dimensions and assigned rules, adds "intelligence" to these objects, permitting the representation of complex geometric and functional relationships between building elements. In this paradigm, walls are objects which can be stretched, joined, have height, be of a specific cross-section type, and "own" associated properties, such as a fire rating or insulation value. Similarly, doors and windows are represented as objects, capable of representing their relationship to the walls in which they are placed and behaving accordingly. More importantly, abstract objects, such as a space, can be defined by the relationships between physical building elements, identified (e.g. room number, room name, etc.), described (e.g. area, volume, use, occupancy, etc.), and referenced (e.g. listed in a room schedule, counted to calculate total floor area, etc.). Capturing these relationships and behaviors and the richness of the intelligence are just not possible in the previous CAD paradigm. Traditional approaches to sharing and linking project information via file exchange using formats such as .dxf, .dwf, .dwg, .pdf or ascii, do not transfer the appropriate levels of object-event procedure intelligence from one model to another. New approaches which strive to address the need to exchange more intelligent project data include IFC-based model exchange (i.e. to transfer objects, their relationships and associated property sets), 3D DWF from Autodesk and 3D support in PDF from Adobe, and XML Software vendor such as Geopraxis or Green Building Studio, developed Green Building XML (gbXML) schema that provides a standard exchange mechanism between sources of building model and CAD information (including Architectural Desktop, REVIT, and ArchiCAD), and energy analysis and simulation products (including Energy Plus, and TRACE). GbXML has grown to support six different sources of BIM data and nine different energy analysis/simulation products.

The International Alliance for Interoperability (IAI) is an alliance of organizations dedicated to bring about a coordinated change for the improvement of productivity and efficiency in the construction and facilities management (AECFM) industry (Building Smart). It was initiated by twelve companies in May 1996. The mission of IAI can be seen as to define, promote, and publish a specification for sharing data throughout project life cycle, globally across disciplines and across technical applications. Industrial Foundation Classes (IFC) is data model developed by IAI since 1995, now endorsed as a draft ISO (International Standards Organization) standard, to provide data exchange capabilities for the AECFM industry. IFC represent the parts of buildings or elements of the processes, IAI defines IFC specifications and six releases have been published. IFC specifications provide common attributes and data structure of shared objects in various domains for modeling. (The International Alliance for Interoperability (http://www.iai-international.org/, 2007)

1.2. Remaining Unresolved Issue of Interoperability and Data Exchange

For almost twenty years that design computing of virtual environment has been developed, and nowadays, there is still an attempt to have BIM model replacing CAD model. But most of energy simualtion software is still tied strongly with the CAD model. Up to now linking or exchanging data are still inefficiencies and lost in the process, due to the different algorithm and data structure between CAD model and energy simulation. Building simulations have taken a long time because of the nature to re-use of the project data and the iterative nature of the design process. could be calculated. Lack of integrity, consistent, and well coordinated of the model and clash these different models – is critical to the success of our profession and industry. Demanding support for open data and library standards and non-proprietary access to data is increasing. To define a single building model as one authoritative semantic definition of building elements or parts, and to coordinate every building element in one database and to encapsulate information and characteristics of different building parts or processes are still remaining unresolved issues.

The correct data format and work flow between building and energy model is also another remaining unsolved issue. Energy simulation is an event process model, while building model is used to store and provide data extraction or mapping of the parametric elements. Event model is used in illustrating the timing and action and show how messages are passed between various objects or elements. Once the data is in the correct format of shared across discipline, it can eliminate the duplicated shared data model. Each adaptable parts or modules within the building object and energy simulation allows learning of design characteristic throughout the design cycle. Each parts or modules recognize their subsystem and automatically connect.

Building design optimization is an iterative process, which architects, engineers and planners have to go through a series of iterations with simulation, evaluation and adaptation to achieve the best results. Up to now the time to prepare, run and interpret simulations limits the number of iterations and thus the possible quality of the design. Especially in the architectural practice, simulations are not integrated into the usual workflow. After an initial design, engineers work on the simulations, interpret the results and return recommendations to the architects. Then changes are made and sometimes a second or even third iteration of the simulation is run. However this time consuming process is very limiting to find the best possible solution.

A proposed model mapping and data exchange through VME and VMS is aim to accomplish the integrity, consistent, well coordinated, correct data format and work flow between building and energy model, and to address the implementation issues of decreasing the time for these iterations, reducing possible interpretation errors and giving immediate inform design feedback.

2. Proposed VME & VMS and the Data modeling for Simulation

2.1. Objective and Approach

The objective of using data modeling through Virtual Model Environment (VME) and Virtual Model System (VMS) is to investigate the data mapping model and software interoperability between BIM software (e.g. Autodesk Revit), thermal simulation software (e.g. DOE2.1E) and day light simulation software (e.g. IES, Radiance), to decrease architects' and engineers' time consuming in the design process from implementing simulation iterations, and have more time to think of design alternatives and solutions, and to have the best possible accurate simulation results while give the immediate feedback. The approach of VME and VMS can be explained through (1) object representation model, (2) operation of the object model or method, (3) and process model. Object representation model has the capabilities to store data in both instance and building type parameters, and can inherit or refer to other object model in other class, attain through a method of improving traditonal design, model, drawings and construction documents. The method includes preparing a virtual representation of the plan and model; extracting graphical and attribute; information from the plan and model through VMS application program interface (API) and storing data in the database; creating an energy simulation input and displaying an energy simulation results through a VMS application user interface (AUI).

VME Framework and VMS integrate building object model with energy performance simulation based on the concept that building can be represented as a central repository for many real world components throughout the building life cycle, and energy simulation is represented as an event procedure of the work flow process. As design decision are made, the object model and event procedure acquire further definition and gaining mutual charateristics that relate them to an energy efficient performance and sustainable design. VME and VMS implement the operation of the object model by using the new operator, which is a method to send, receive, or cast data been building model and energy simulation program. They extract data in and out of building geometries, coordinates, parameters, properties, materials, schedules, system and equipments, and provide a modular structure to the model and a framework for sharing information between different disciplines, and enable information, model components and software to be reused.

Figure 1 illustrates Virtual Model Environment (VME) and VMS work flow by providing ongoing framework and set of tools in acquiring information from building geometries, coordinates, climate location, thermal zones and sufaces, construction and materials properties etc.

2.2. VME Framework Application Program Interface

VME Framework API is to enable the most efficient interoperability of information model between Autodesk Revit and DOE2.1E. Virtual Model Sysem (VMS) uses a framework API from VME to extract infornation from BIM model, store in the database, and prepare input data file format and parameters for energy simulation as designated in the namespaces. This process allows the reusability of components or parts as a library that can be called from multiple areas of the applications. VMS uses basic terminology and concepts such as tags, schemas, database, and transforms to perform data exchange, data mapping, data retrieval, and data binding through database relation and queriy sysem to create DOE2.1E energy input file format corresponding to the simulation engine parameters of DOE2.1E.

2.3. Data and work Flow System

The strength of VMS API is the ability to link both graphical and numerical data and coordinate every building element in one database, thus providing users the ability to immediately see the results of any design revisions made in the model, have them reflected in the associated views (drawings), as well as to detect any coordination issues. The database is used to create a logical relationship between the structure information. Database retrieves and queries information that has been extract through API, and performs data mapping and organizes data relationship. Database ranges from a single data table in the dataset to entities relationship database of information model. Database provides functionality for connecting to a data source in VME Framework, executing commands, and retrieving results. Those results can be processed directly, or placed in an dataset for further processing while in a disconnected state. There are some database features that have been designed to use in this paper, such as data mapping and data binding, which binds the graphic and non-graphic information from building information model and allows establishing a correspondence between data in 3D model Data binding uses information read from building information model and creates data relationship for looking at related data.

3. Case Study

3.1. Genesis Project

The objective of this project is to explore a prototype urban housing that is affordable, energy efficient, and sustainable, with healthy construction. Figure 2 shows the BIM model, which was created in the context by using Autodesk Revit Architecture and MEP Building System 2008. The integrity, consistent, and well coordinated of the model is critical in order to create spatial high performance contexts for energy simulation, which includes geometric representation context for information to be exchanged, record and analysis of existing building's environments, visualizations of the design process and/or the designed space, new representations that integrate architectural design and the construction process. Computing and simulations can be speed up, thus to allow a maximum number of iterations to be calculated. Interoperability will allow the re-use of project data which has already been created and thus ensure the support of faster revision cycles and the iterative nature of the design process. The true values of the model is intended to enable architects to directly interact with their architectural models and get instant feedback from the simulation.

3.2. Site, Climate Location and Weather Data Model

The site location is determined by the project site, location, climate location and weather data to match with energy simulation weather data. The site was situated in 44th Street and Vincennes, north of the down town Chicago (the LOOP).Chicago climate is in Latitude of 41.98, Longitude of -87.9, and Altitude of 658.136 feet above sea level, time zone (6) and provide necessary weather data, with very fluctuated in day and night temperature.

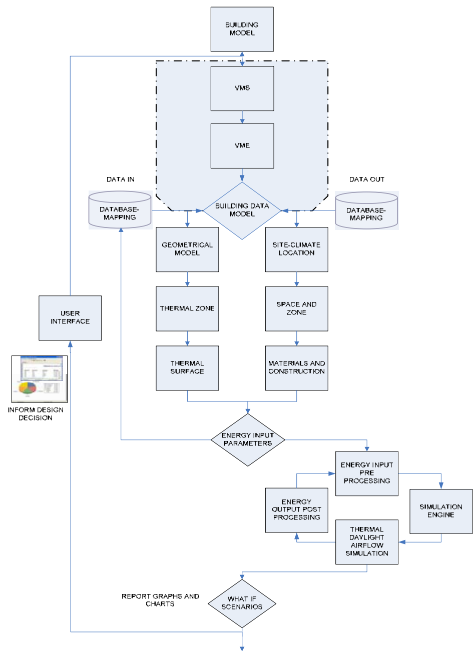


Figure 1: Proposed VME, VMS Work Flow

Figure 2 Genesis Project

3.3. Geometric Model and generation (generation of a 3D surface model)

A geometrical 3D model serves as the basis for establishing an energy model. It is equipped with attributes such as boundary conditions, an initial surface mesh, and a volume mesh. Interpret the relevant geometrical, topological and numerical data for any given building model, we identify a structural component graph, a graph of room faces, a room graph and a relational data object graph as aids and explain algorithms to derive these relations. Figure 3 shows the building model, which was created by transferring its geometrical, topological and coordinates data into a volume model, decomposing the latter into a so-called connection model and then extracting volume bodies. The technique is demonstrated within the scope of building energy simulation. The algorithm is basically applicable to any building energy simulation tool. Air flow and thermal energy model are derived from building geometric model, and Figure shows knowledge of linkage between model hierarchies where the coupling strategies are implemented. In order to interpret the relevant geometrical and topological data mapping for a given building model, the model is identified as a triangulation area, zone and space component graph, a graph of room faces, a room graph and a relational object graph as and explain algorithms to derive these relations. Building model is **translated its geometrical and topological data into a volume model**, and then **extracting all volume bodies into elements and components**. The technique is demonstrated within the scope of building energy simulation by deriving those required for setting up a thermal multizone model and a geometrical model. The algorithm is basically applicable to any building energy simulation software tool

3.4. Volume Space Body Extraction

The space boundary information can be acquired by space boundary, where r and a is the radius of the arc and the angle of the arc correspondingly. A coordinate system is determined by its origin and three orthographic unit vectors, termed as X, Y, and Z direction. Point X, Y, and Z represent X, Y, Z values of a point to be transformed.

The calculation proof for each room/area is illustrated by a figure. A figure 6 shows the original boundary of the room/area, newly introduced sectors, if any, and figure 7 shows a triangulation of the adjusted room/area border. Room boundaries, sectors located inside/outside the original boundary, triangulation lines are displayed in different, user-defined colors. All triangles in the triangulation are right-angled and their areas is calculated as 0.5 * c1 * c2 Eqn _(1) Where c1, c2 are catets of the triangle. Areas of sectors is calculated as 0.5 * r * r * (a – sin (a)) Eqn_(2).

The calculation proof for each room/area is illustrated by a figure. Figure ___shows the original boundary of the room/area, newly introduced sectors, if any, and triangulation of the adjusted room/area border. Room boundaries, sectors located inside/outside the original boundary, triangulation lines are displayed in different, user-defined colors. All triangles in the triangulation are right-angled and their areas is calculated as 0.5 * c1 * c2, where c1, c2 are catets of the triangle. Areas of sectors is calculated as 0.5 * r * r * (a - sin(a)), where r and a is the radius of the arc and the angle of the arc correspondingly.

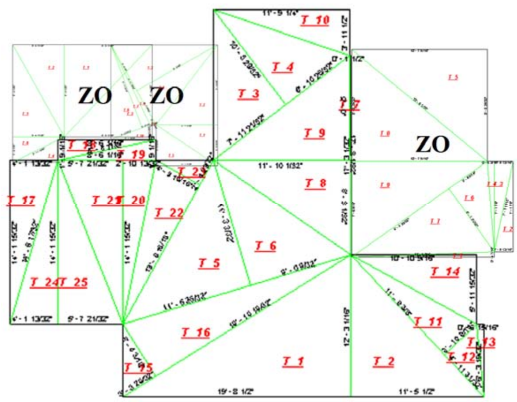


Figure 3 Triangulation of the adjusted room/area border is a volume space body of the building first floor.

3.5. *Thermal Zone Model*

Thermal zone model in turn is a dimensionally reduced model. It can be described by an object model that represents the building structure in a hierarchical manner, i.e. the model is organized in building level, rooms, building components, layers, materials, etc., in order to automatically set up both models— starting from a unique building model—model and a geometrical (B-rep) model, the prerequisites for establishing a numerical coupling between both approaches are incidence matrices relating models and components. In other words, a CFD and HVAC simulation requires volume bodies of air volumes together with boundary conditions while a thermal multizone simulation basically needs a collection of building or plant components with information on their interconnections.

3.6. *Data Mapping of Thermal Surfaces*

Thermal surfaces refer to heat transfer surfaces to describe the thermal representations of building elements, such as walls, roof, windows, doors, ceiling, and floor. Each surface has some attributes to determine its interaction between internal and external environment. A surface in figure 8 may have interaction with another surface to represent inter zone heat transfer. Thermal surfaces are the basic ingredients of the thermal simulation. A simulation project aggregates a number of zones, where the latter aggregate one or more air volumes. Air volume objects are aware of the corresponding set of adjacent bodies and their semantics. Structural elements themselves are composed of a multilayered structure with respective individual materials. Although they form part of the geometric model, we also store the surface geometry and vertex coordinates.

3.7. *Mapping of Building Construction and Materials*

One of the great capabilities of data mapping in VME Framework is directly acquired building element construction and materials properties from BIM model, and retrieved and queried directly to create DOE-2 INPUT for energy simulation. Figure 4 shows materials data mapping of building's components (wall, windows, roof skylight).

3.8. Create Energy Input Model

DOE-2 is an up-to-date, unbiased computer program that predicts the hourly energy use and energy cost of a building given hourly weather information and a description of the building and its HVAC equipment and utility rate structure. Using DOE-2, designers can determine the choice of building parameters that improve energy efficiency while maintaining thermal comfort and cost-effectiveness. The purpose of DOE-2 is to aid in the analysis of energy usage in buildings; it is not intended to be the sole source of information relied upon for the design of buildings: The judgment and experience of the architect/engineer still remain the most important elements of building design. Basically, DOE-2 has one subprogram for translation of your input (BDL Processor), and four simulation subprograms (LOADS, SYSTEMS, PLANT and ECON). LOADS, SYSTEMS and PLANT are executed in sequence, with the output of LOADS becoming the input of SYSTEMS, etc. The output then becomes the input to ECON. Each of the simulation subprograms also produces printed reports of the results of its calculations.

Reusability of components as a library that can be called from multiple areas of the applications and application interface allows the model to interact with the simulation data and match with the simulation parameters in DOE2.

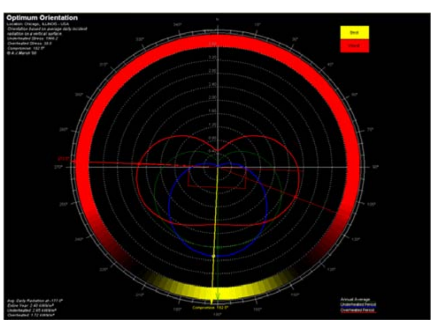
4. Analysis, Simulation Results and discussion

Post processing simulation and analysis (interpret the results e.g. on a screen or the web browser) are the output reults in the simulation process, which interface and interact with the architects or design professionals in the design decision. The followings are some of the analysis and results, which consist of the following graphical data and information;

1. Optimum orientation based on design day and annual Chicago weather data.
2. Shadow study
3. Daylight study
4. Thermal simulation model
5. Annual zone air requirement of each room space.
6. Annual cooling and heating demand for each zone
7. LEED NC 2.2 Credit 8.1 Daylight simulation model data:

Energy simulations can assist architects and engineers in optimizing their design and in minimizing its environmental impact. By adjusting the “What if scenarios” or “Informed design decision” strategies according to simulation results, and running further simulations based on the adjusted design, an iterative process can help to increase the design quality.

The simulation results, which are in the form of reports and graphs, will be displayed in Virtual Model User Interface’s web browser.



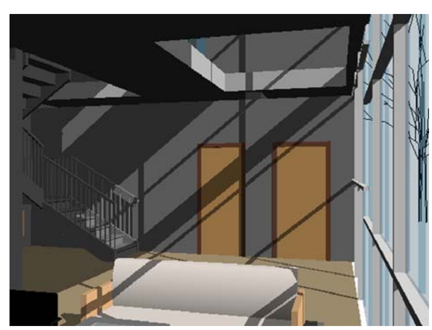


Figure 4 Left: Optimum orientation based on design day and annual Chicago weather data. Right: Daylight study

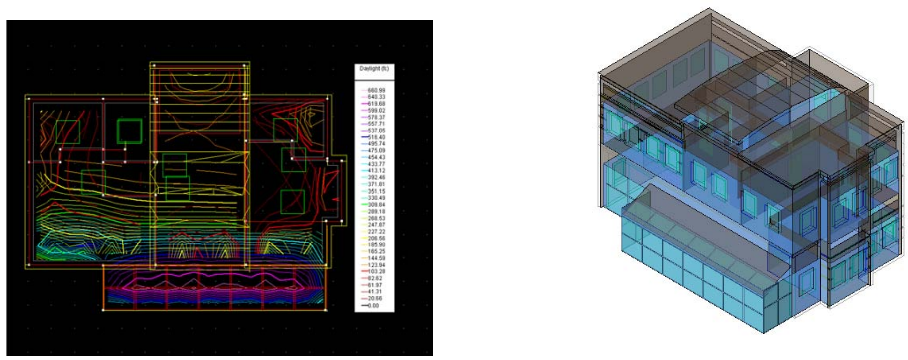


Figure 5 Left: LEED NC 2.2 Credit 8.1 Daylight simulation model data Right: Thermal simulation model

5. Conclusion

Virtual Model Environment Framework (VME) and Virtual Model System (VMS) is an enabling technology allowing for software interoperability through shared information models and data modeling. VME and VMS updating, and reusing were reviewed. The innovative specifications and ability to link and share object-based model in BIM with performance-based model in energy simulation were introduced. The benefits of adopting VME Framework and VMS are the significant reduced time and effort spent in creating energy efficient building and sustainable design. A data model can be expanded to any other CAD application and energy simulation software.

The paper aims to present an innovative framework, tool and system that map between building information models, using Autodesk Revit Arhitecture and Building System with thermal simulation software using DOE-2.1E. Using data modeling and application framework API specifications for mapping data of building geometry, thermal zone, construction and material properties, and thermal design parameters, were discussed. A data mapping engine in VME Framework Server has been developed to accomplish the task of fully converting building information model to energy performance model. The work flow and the implementation of model mapping were presented, and the process of data mapping was demonstrated with the illustrative examples.

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