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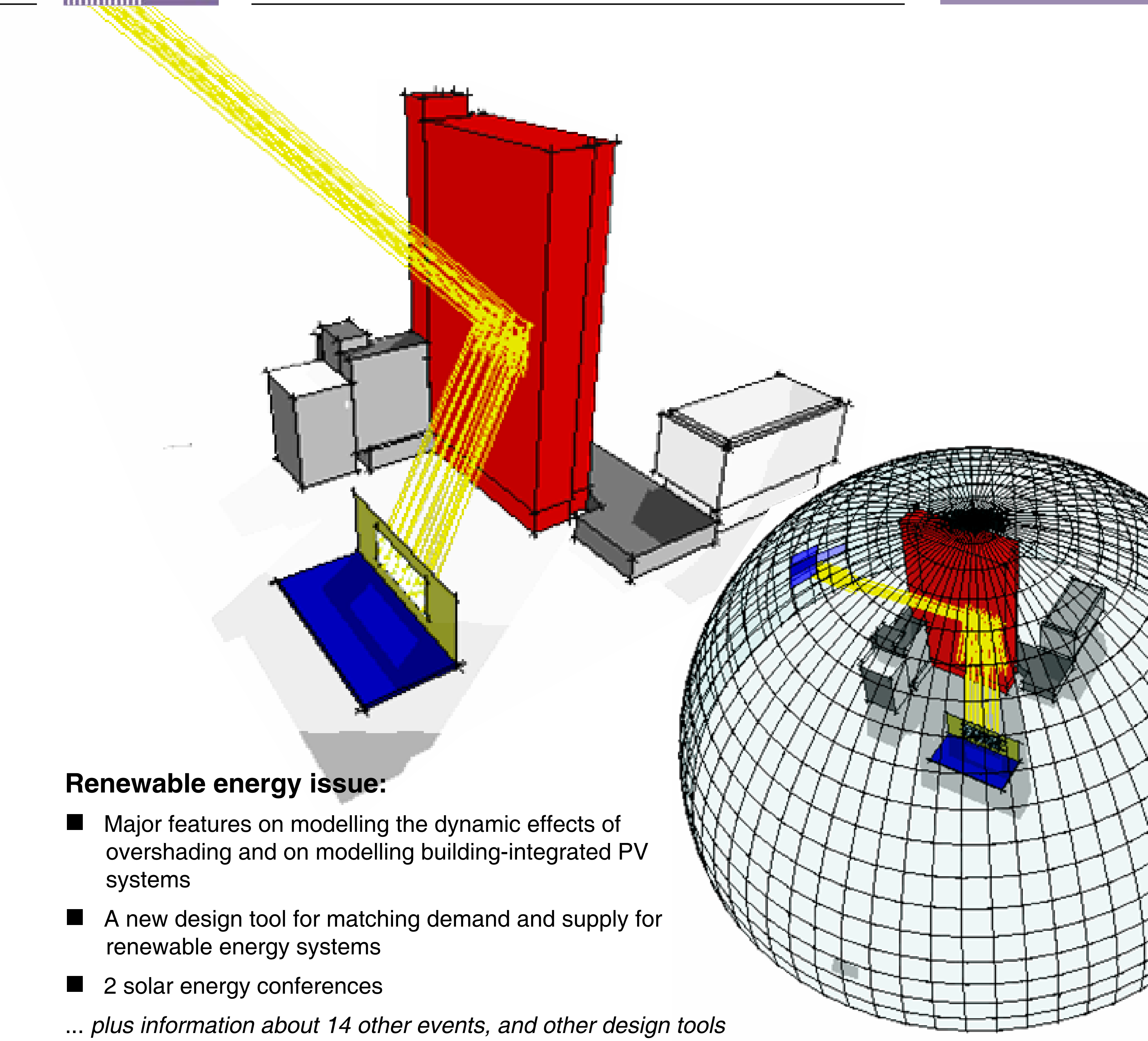

Renewable energy issue:

- Major features on modelling the dynamic effects of overshading and on modelling building-integrated PV systems
- A new design tool for matching demand and supply for renewable energy systems
- 2 solar energy conferences

... *plus information about 14 other events, and other design tools*

The journal of the International Building Performance Simulation Association

Contents

President's message

IBPSA Members and Friends,

It is a real pleasure for me to write an introductory message in this, yet another, great looking issue of IBPSA News. It contains lots of information from a growing and very active society. I would like to take the opportunity of thanking all contributors and especially our Newsletter chairman Larry Degelman, and producer Marion Bartholomew for a fantastic job!

IBPSA members come from some thirty countries from around the world, but mainly from the fifteen affiliate organizations. IBPSA is growing. We are very happy that currently in three different regions affiliate organizations are being established. We expect their proposals soon. If there is no affiliate organization in your region, and you would like to know what it involves, don't hesitate to contact our regional affiliate development officer, Karel Kabele (kabele@fsv.cvut.cz).

Not only is IBPSA growing in membership numbers, we also have an increasing number of activities by the regional affiliate organizations as you will be able to read about in this issue of IBPSA News.

I believe that the main driver for the increasing interest in building performance simulation by practitioners, researchers and building related stakeholders around the world is the appreciation and acceptance of the importance of performance-based building design. There are many activities, including government leadership, which form a powerful stimulus for implementation of performance-based design. Building simulation can and should play an important role in this.

In our last issue of IBPSA News, you've seen that Building Simulation 2005 in Montreal was a big success from several points of view. (Check out the post-conference survey results at http://ibpsa.ca/bs2005/survey.asp) There were many high quality papers. Two of the papers are re-printed in this issue of the News. Expanded versions of several other papers will appear in special issues of the prestigious scientific journals International Journal of HVAC&R Research, Building and Environment, and Journal of Building Physics. You will be able to enjoy these later this year or early next year.

The IBPSA Board would like to once more acknowledge the volunteers' review work which is a main ingredient of our recipe for successful conferences. With around one hundred and fifty people volunteering their time, this is not a small undertaking. We hope that the organizers of the next conference can count on your help again.

Preparations for Building Simulation 2007 are well under way. All signs are promising another great conference. Don't miss it, and don't forget to submit an abstract which is due 15 September 2006 (see www.bs2007.org.cn).

The Board is already looking further ahead, currently entertaining two proposals for hosting Building Simulation 2009. If you are interested in hosting an international IBPSA conference further in the future, don't hesitate to contact our Conference Location Coordinator, Jeff Spitler at spitler@okstate.edu.

As of February 1, a new IBPSA board of directors was put in place. Given our type of organization, we have a quite long and laborious voting procedure. I would like to thank Veronica Soebarto for organizing the voting and tallying up all the votes! There was quite a good turnout of 187 votes out of a world-wide membership of around 1150. This 16% is proportionally the same as in 2004, however we have grown considerably since the world-wide membership in 2004 was around half of what we have now.

Immediate past-president of IBPSA, Jeff Spitler, deserves recognition and thanks for his exceptional leadership for the past four years. Seeing the time stamp on his emails, I know that Jeff works far beyond the normal workday taking care of Board business, and under his leadership the Board has made significant progress on initiatives that will have long-term impact for what we stand for. Thank you, Jeff!

Best wishes,

Jan Hensen

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Karel Kabele chair

To register yourself on the IBPSA mailing list go to the IBPSA home page **www.ibpsa.org** and click on Mailing Lists for instructions, or go directly to **www.ibpsa.org/m_lists.asp**. For additional information about IBPSA, visit:

- About IBPSA: **www.ibpsa.org/m_about.asp**
- Conferences and papers online: **www.ibpsa.org/m_events.asp**
- Regional affiliate web sites and contact persons: **www.ibpsa.org/m_affiliates.asp**
- Downloads/links: **www.ibpsa.org/m_downloads.asp**

For information on joining IBPSA please contact your nearest regional affiliate. If there is no affiliate in your region, use the Central membership form from the IBPSA web site at **www.ibpsa.org/m_membership.asp.**

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(continued on next page)

IBPSA Board of Directors (continued)

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IBPSA Sustaining Members

Sustaining members of IBPSA are those individuals or organizations that provide financial support to IBPSA at the level of US$500 or more per year. To learn about sustaining membership, please contact one of the IBPSA officers shown in this newsletter.

US - DOE United States Department of Energy **1985-2007**	ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers **2003-2007**
rehva europe REHVA Federation of European Heating and Air-Conditioning Associations **2003-2007**	Agence de l'efficacité énergétique Québec Vous économisez. L'environnement y gagne aussi. **2005-2007**
Montréal Chapter **2005-2007**	CMHC SCHL **2005-2007**
Concordia University Real education for the real world **2005-2007**	École Polytechnique Montréal **2005-2007**
Université du Québec École de technologie supérieure **2005-2007**	Natural Resources Canada / Ressources naturelles Canada **2005-2007**
iRC Institute for Research in Construction **2005-2007**	Itron **2005-2007**
International Energy Agency Energy Conservation in Buildings and Community Systems Programme **2005-2007**	

Forthcoming events calendar

Date(s)	Event	Information
2006		
3-5 May 2006	**eSim 2006**, Toronto, Canada	www.esim.ca
5 May 2006 (Also 8-9 June, 10-11 July, 11-12 September)	**ESP-r Training Course**, Glasgow, UK	www.esru.strath.ac.uk
9 May 2006	**Scottish Energy Systems Group Software Fair**, Glasgow, UK	www.sesg.strath.ac.uk
18-19 May 2006 (Also New York July or August, Boulder 13-14 November)	**Visual DOE Training Seminar**, San Francisco, USA	www.archenergy.com/products/visualdoe/training/
5-7 June 2006	**ISC-2006**, Palermo, Italy	http://biomath.ugent.be/~eurosis/conf/isc/isc2006/index.html
May or June (dates tba) (Also Atlanta 15-16 June, Cambridge 1 August)	**EnergyPlus Training Workshop**, West Coast, USA (specific venue tba)	www.gard.com/training.htm
8-13 July 2006	**Solar2006**, Denver, USA	www.solar2006.org
2-4 August 2006	**SimBuild 2006**, Boston, USA	www.ibpsa.us
20-24 August 2006	**Canadian Solar Buildings Conference**, Montréal, Canada	www.solarbuildings.ca
28-30 August 2006	**MESM 2006**, Alexandria, Egypt	http://biomath.ugent.be/~eurosis/conf/mesm/mesm2006/index.html
6-8 September 2006	**PLEA 2006**, Geneva, Switzerland	www.plea2006.org
11-13 September 2006	**Low Energy Buildings Session at PEA 2006**, Gaborone, Botswana	www.iasted.com/conferences/2006/Botswana/pea-specsess3.htm
14 September 2006	**IBPSA Netherlands+Flanders Symposium**, Eindhoven, Netherlands	www.ibpsa-nvl.org
9-11 October 2006	**BauSIM 2006**, Munich, Germany	www.ibpsa-germany.org/bausim2006
23-25 October 2006	**ESM 2006**, Toulouse, France	www.eurosis.org
20-21 November 2006	**IBPSA Australasia 2006 conference**, Adelaide, Australia	www.adelaide.edu.au/ibpsa2006

And next year ...
Building Simulation 2007,
3-6 September 2007,
Beijing, China
www.bs2007.org.cn

3-5 May 2006
Toronto, Canada
www.esim.ca

eSim 2006
IBPSA-Canada

The bi-annual conference of IBPSA-Canada aims to bring together professionals, academics and students interested in building performance simulation issues and applications. It will be held in Toronto, Canada on 4 and 5 May 2006 at the Faculty of Architecture, Landscape, and Design (al&d) located within the downtown campus of the University of Toronto. Pre-conference workshops will be held on May 3, 2006 at Ryerson University, featuring eQuest the Quick Energy Simulation Tool, and RETScreen Combined Heat & Power (CHP) Project Model.

The themes of 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 heat, cool 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

For more information, please visit **www.esim.ca**.

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5 May 2006
8-9 June 2006
10-11 July 2006
11-12 September 2006
Glasgow, UK
www.esru.strath.ac.uk

Training courses on ESP-r
Strathclyde University

Strathclyde University in Glasgow, UK is offering a series of training courses on different aspects of ESP-R:

5 May	Quality assurance of simulation models course
8-9 June	Advanced IAQ course - focusing on mass flow networks, computational fluid dynamics and contaminant tracking
10-11 July	Introductory course
11-12 September	Advanced systems course focusing on the transition from ideal representations of environmental systems to detailed component based models

Full details can be found at **www.esru.strath.ac.uk**.

9 May 2006
Glasgow, UK
www.sesg.strath.ac.uk

Scottish Energy Systems Group Software Fair

Strathclyde University

A one-day Software Fair will take place at Strathclyde University, Glasgow on 9 May 2006. We will have a rolling programme of presentations from software vendors from the building energy systems design and modelling arena. In the demo area, visitors can try out different packages for themselves, or challenge the vendors to demonstrate how they would tackle real problems brought along to the event. Further details will be published in due course. This event is free of charge, and open to anyone who has an interest in this subject area.

Full details can be found at **www.sesg.strath.ac.uk**.

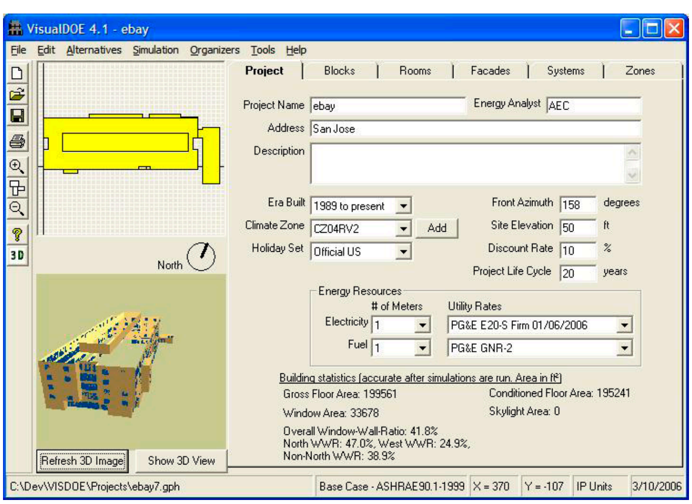
18-19 May 2006
San Francisco, USA
July or August (dates tba)
New York, USA
13-14 November 2006
Boulder, USA
www.archenergy.com/ products/ visualdoe/ training/

VisualDOE training seminars

Architectural Energy Corporation

Architectural Energy Corporation is pleased to announce three VisualDOE training seminars in 2006. The first is on May 18 and 19 in San Francisco. The second will be held in July or August in New York City, details will be available soon. The third is on November 13 and 14 in Boulder.

Each seminar includes two days (total 16 hours) focused on DOE-2, the VisualDOE interface, VisualDOE 4 new features, general energy simulation skills, and LEED-NC 2.1 and 2.2 energy savings calculations for green buildings. Attendees are welcome to bring their projects for discussions in class.



No prior energy modeling experience is required, but a good understanding of building systems 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.

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

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

5-7 June 2006
Palermo, Italy
http://biomath.ugent.be/~eurosis/conf/isc/isc2006/index.html

ISC-2006 Industrial Simulation Conference 2006

The Industrial Simulation Conference 2006 (ISC-2006) is the fourth annual international Simulation conference, which aims to give a complete overview of industrial simulation related research and to provide an annual status report on present day industrial simulation research within the European Community and the rest of the world. The exchange of techniques and ideas among the different disciplines, universities and industry, which support the integration of simulation in the everyday workplace, is the basic premise at the heart of ISC-2006. ISC'2006 consists of four major parts. A part concerns itself with simulation methodology, another with simulation applications, then there are the workshops, the exhibition and last but not least the poster sessions for students.

The conference covers:

- Modelling Methodology
- Analysis Methodology
- Discrete Simulation Languages and Tools
- Simulation in Manufacturing
- Simulation in Automotive Systems
- Simulation in Robotics
- Simulation in Electronics, Computers and Telecom
- Simulation in Electronics Manufacturing
- Simulation in Logistics, and Transport Simulation
- Complex Systems Modelling
- Simulation in Aerospace
- Marine Simulation
- Simulation in Industrial and Product Design
- Simulation in Engineering Processes
- Simulation in Energy and Power Systems
- Simulation in Multibody Systems
- Simulation in Chemical and Petroleum Engineering
- Simulation in Military and Defense
- Verification, Validation and Accreditation
- Simulation and Training
- Virtual Reality and Graphical Simulations in Industrial Applications
- The Future of Simulation Roundtable
- Workshop on Modelling and Simulation in the Textile Industry
- Workshop on Intelligent Transport Systems
- Workshop NANOSIM
- Multi-agent Systems and Simulation
- Augmented reality and Pervasive Systems in Factories
- Lean Manufacturing Simulation

More information can be found at **http://biomath.ugent.be/~eurosis/conf/isc/isc2006/index.html.**

May or June (dates tba)
West Coast, USA
15-16 June 2006
Atlanta, USA
1 August 2006
Cambridge, Mass., USA
www.gard.com/training.htm

EnergyPlus training workshops

Gard Analytics

There are three EnergyPlus training workshops scheduled for this year:

May or June (tba)	West Coast (San Francisco, Portland, or Seattle), USA, May or June 2006. Specific dates and location to be determined.
15-16 June	Atlanta, Georgia, USA, Early registration deadline is May 10, 2006 Registration closes after June 7, 2006
1 August	Cambridge, Massachusetts, USA, immediately before the IBPSA-USA SimBuild Conference at MIT. Early registration deadline is June 28, 2006. Registration closes after July 24, 2006

For more details and to register on-line go to **www.gard.com/training.htm**.

For more information about EnergyPlus go to **www.energyplus.gov**.

8-13 July 2006
Denver, USA
www.solar2006.org

Solar2006

American Solar Energy Society and other organisations

The 14-day Solar2006 conference and exhibition offers a packed programme of workshops, technical sessions, forums, posters and tours on a wide range of topics. These include — amongst many others — building sustainable communities, climate change, jobs in solar energy, modelling, codes of practice, markets, solar cells and materials, hydrogen, and daylighting.

The attendance fee for all the plenaries, forums and technical sessions is $500 (members of *any* of the participating organisations)/$575 (non-members)/$125 (students) for bookings before 1 June and $575/$675/$150 for later bookings. One and two day tickets are also available. Fees include proceedings on CD-ROM, but workshops, special events and tours are extra.

It is impossible to do justice to it in the space available here; for full details, including provisional lists of speakers and their paper titles, visit the conference at **www.solar2006.org**.

2-4 August 2006
Boston, USA
www.ibpsa.us

SimBuild 2006
IBPSA-USA

The second national SimBuild conference hosted by IBPSA-USA will be held on 2-4 August 2006 at the campus of the Massachusetts Institute of Technology. The format will be similar to the very successful 2004 conference held at the University of Colorado, Boulder. Technical sessions over two days will feature presentations on a wide range of topics related to the simulation of HVAC equipment, airflow in buildings, energy usage, and the visual and acoustic environment in buildings, as well as demonstrations of simulation software and of hardware and software needed to emulate or measure the performance of buildings. Friday will be a practitioner day, offering case studies, hands-on software demonstrations and other presentations, aimed at giving practicing architects and engineers the information they need to be more informed collaborators with simulation experts. The practitioner day will be coordinated with local US Green Building Council chapters and affiliates.

Conference housing will be offered on campus in dormitories and in nearby hotels. MIT has a growing number of architecturally significant buildings that participants can visit, including recent work by Frank Gehry, Steven Holl, and Kevin Roche, and earlier projects by I.M. Pei, Eero Saarinen, and Finnish master Alvar Aalto. Harvard University and Harvard Square are a short distance away.

The meeting is open to all, world-wide. Boston is a convenient destination for travelers from major cities in the U.S. and in many other countries. It is a historic and compact city, easily explored on foot and via public transportation. Conference participants may want to stay longer and explore New England's mountains and Atlantic coast, including Cape Cod, Martha's Vineyard and Nantucket. Abstracts were accepted by 15 February and final papers were due by 31 March 2006. More information is available on the IBPSA-USA web site, **www.ibpsa.us**.

20-24 August 2006
Montréal, Canada
www.solarbuildings.ca

Canadian Solar Buildings Conference
Solar Energy Society of Canada & the Canadian Solar Buildings Research Network

CONFERENCE FOCUS

Buildings account for approximately 30% of Canada's energy consumption, 50% of its electricity consumption and 28% of its greenhouse gas (GHG) emissions. The available solar energy incident on the building envelope far exceeds building energy needs, particularly when solar energy utilization systems and energy efficiency measures are optimally integrated. The energy consumption and GHG emissions, which are associated with heating, cooling and lighting buildings, have the potential to be substantially reduced if the incident solar energy on the façades and roofs of buildings is utilized. This 31st Annual Conference of the Solar Energy Society of Canada is held jointly with the 1st Conference of the newly formed Solar Buildings Research Network that brings together top researchers from 10 Canadian Universities to develop the solar-optimized building of the 21st century. This conference will be a cornerstone of Canadian efforts to promote innovative research and development in solar energy utilization. It will foster a culture of excellence in an area that significantly affects two major sectors of the Canadian economy — energy and construction.

TOPICS

The conference addresses all topics related to solar energy and buildings, innovative technologies, experimental studies, simulation applications, design tools and methods, case studies and practical applications. These include:

Topic 1: Photovoltaic Systems, Applications and Manufacturing
- 1.1. Photovoltaic Applications
- 1.2. Hybrid Systems Applications
- 1.3. Photovoltaic Cell Materials and Manufacturing
- 1.4. Balance-of-System Components and Manufacturing

Topic 2: Solar Thermal Systems
- 2.1. Solar Thermal Applications
- 2.2. Hybrid Systems Applications
- 2.3. Solar Collector Technologies
- 2.4. Thermal Storage

Topic 3: Integration of Solar Energy Systems into Buildings
- 3.1. Passive Solar Design
- 3.2. Building Integrated Photovoltaics
- 3.3. Building Integrated Solar Thermal
- 3.4. Daylighting, Shading and Fenestration

Topic 4: Solar Electricity Generation in Buildings
- 4.1. Power Conversion Systems for Buildings
- 4.2. System Integration for PV Systems in Buildings

Topic 5: Design Tools, Policy, and Regulatory Issues
- 5.1. Simulation Tools for Buildings
- 5.3. Solar Resource Analysis
- 5.4. Policy, Marketing, Legislation, Regulatory Issues

Topic 6: Solar Energy Education and Human Resources
- 6.1. Solar energy education: courses, workshops and seminars
- 6.2. Technology transfer issues

REGISTRATION AND FURTHER DETAILS

Registration costs $375 ($75 students) until 15 June and $425 ($125 students) after that. For full details of the conference please visit **www.solarbuildings.ca**.

28-30 August 2006
Alexandria, Egypt
http://biomath.ugent.be/~eurosis/conf/mesm/mesm2006/index.html

MESM 2006 Middle Eastern Simulation Multiconference

De Montfort University and members of the European Simulation Society

CONFERENCE TOPICS

The MESM'2006 International Middle Eastern Multiconference on Simulation and Modelling is the eighth conference in the MESM series. One of the major aims of this conference is to bring people from various parts of the Middle East in contact with colleagues working in modeling & simulation from around the world, including Europe, USA, Canada and the Far East. The other aim is to establish a local technical society in the Middle East and to integrate these into a wider Network of Simulation Excellence, a first meeting of which will be held in March 2006 in Belgium.

Conference topics include:

- Modelling and Simulation Methodology
- Modelling And Analysis Methodology
- Complex Systems Modelling
- Simulation of Networks and Communication Systems Simulation
- Simulation of Signal and Image Processing
- Energy Systems Simulation
- Simulation in Chemical and Petrochemical Engineering
- Multimedia and Virtual Reality Systems
- Decision Processing in Management
- Modelling and Simulation for Biomedical Applications
- Modelling and Simulation for Industrial Applications (Manufacturing, Robotics etc)
- Simulation in Logistics, Traffic, Transport and Harbour Simulation
- Simulation for the Built Environment
- Web-based Simulation
- Software Engineering and Simulation in Information Processing
- Simulation in Fuzzy Systems Neural Networks and Genetic Algorithms
- Simulation and Graphics in Archaeology
- Simulation projects in the Arab World

CALL FOR PAPERS AND SUBMISSION DEADLINES

The full Call for Papers can be downloaded from **http://biomath.ugent.be/~eurosis/conf/mesm/mesm2006/index.html**. The submission deadlines are:

Early Bird Submission:	5 March
Abstract Submission deadline:	5 April
Abstract Notification	30 May
Full Paper Submission Deadline:	15 July

PRICES

Middle Eastern Participants 150 Euro, EUROSIS Members and authors 485 Euro, others 535 Euro. Prices include proceedings, lunches, conference dinner, party and coffee.

6-8 September 2006
Geneva, Switzerland
www.plea2006.org

PLEA 2006: 23rd International Conference on Passive and Low Energy Architecture
PLEA

Next year's annual PLEA conference takes as its title Clever design, affordable comfort: A challenge for low energy architecture and urban planning.

The topics covered will include:

- Lessons from traditional architecture
- Design strategies and tools
- Comfort and well-being in indoor and outdoor spaces
- Indoor comfort in glazed buildings
- Research and technology transfer
- Strategies and tools for renovation
- Architectural education for sustainable design
- Examples of low energy design at the urban scale
- Case studies

For more information, please visit the conference website at **www.plea2006.org** or email **contact@plea2006.org**.

11-13 September 2006
Gaborone, Botswana
www.iasted.com/conferences/2006/Botswana/pea-specsess3.htm

Low Energy Buildings session at PEA 2006

There will be a special session on Low Energy Buildings at the IASTED International Conference on Power, Energy and Applications (PEA 2006) on 11-13 September 2006 in Gaborone, Botswana.

Researchers, faculty, students, and members of industry and government agencies are invited to participate in this important session, preferably by submitting research papers and case studies. After the session there will be a round table on the topic of Energy Policies for Low Energy Buildings.

The papers are due April 15, 2006 and should be emailed to Prof. Milorad Bojic at **bojic@kg.ac.yu**.

For further information, please visit **www.iasted.com/conferences/2006/Botswana/pea-specsess3.htm**.

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14 September 2006
Eindhoven, Netherlands
www.ibpsa-nvl.org

IBPSA Netherlands + Flanders symposium

IBPSA Netherlands + Flanders will present a half-day symposium on 14 September in a brand new venue at Technische Universiteit Eindhoven. The main theme will be how modeling and simulation may help in preparing the Architectural, Engineering and Construction sector for the future. The theme is inspired by a recent publication from the UK Chartered Institution of Building Services Engineers "Climate change and indoor environment: impacts and adaptation" (CIBSE Technical Memorandum 36:2005).

As a final conclusion, the CIBSE report states "The investigation was based upon a set of performance criteria and because relative performance was the main interest it was not essential to set absolute targets. It is probable that future Building Regulations will require engineers and architects to demonstrate the need for mechanical cooling and air conditioning. In that case it will be essential that the industry has:

1. appropriate overheating risk criteria
2. a standardised calculation method so that all designers can obtain the same predictions
3. standardised climatic data
4. standardised methodology for performance prediction.

These issues are outside the scope of this study, but are likely to be addressed in the future by the CIBSE and others."

The planned IBPSA-NLV Symposium was conceived in the interest of IBPSA representing one of these "others."

Professor Michael Holmes (Arup Research + Loughborough University), one of the principal authors of CIBSE TM36 as well as the IBPSA Outstanding Practice Award recipient in 2003, will give a keynote speech. Each of the other speakers from industry and academia will address one of the four criteria indicated above. For more information, visit their web site at **www.ibpsa-nvl.org**.

9-11 October 2006
Munich, Germany
www.ibpsa-germany.org/bausim2006

BauSIM 2006
IBPSA-Germany

IBPSA-Germany's first local bi-annual conference will be held in Munich, Germany on 9-11 October 2006 at Munich Technical University (TUM). The main focus will be on energy efficiency in building design and thermal comfort in rooms. BauSIM2006 brings together practitioners, researchers and developers working in the field of building performance simulation and related applications.

The deadline for submitting abstracts is 30 April 2006. A number of selected contributions will be published in Bauphysik (published by Ernst&Sohn).

Further information is available from the conference website at **www.ibpsa-germany.org/bausim2006**.

20-21 November 2006
Adelaide, South Australia
www.adelaide.edu.au/ibpsa2006

IBPSA Australasia 2006 conference

IBPSA Australasia 2006 Conference invites researchers, academics, and practitioners to participate and present their work in addressing the conference theme, "Investigating the roles and challenges of building performance simulation in achieving a sustainable built environment". The Conference will specifically explore the roles and challenges of building performance simulation in achieving a sustainable built environment. The conference invites researchers, academics, and practitioners to participate and present their work in dealing with the issues related to the topics below, although not limited to:

- Simulation for environmental performance assessments
- Simulation for building rating schemes
- Simulation for site or city planning
- The issue of weather data
- Natural ventilation simulation
- Daylighting and lighting simulation
- Thermal comfort simulation
- Case studies (simulation in practice)

Provisional important dates (2006) are:

Extended Abstract submission	29 April
Abstract acceptance advice	19 May
Full paper submission	31 July
Referee reports to authors	4 September
Final paper for publication	9 October
Early registration	7 September

It is expected that the conference will provide useful outcomes to government bodies, industry and practitioners, such as building regulators and code officials in developing building codes and standards; city planners in assessing planning development using building performance simulation; engineers, building architects and designers in improving the design of the built environment; and researchers in understanding the complex issues surrounding people and the built environment.

For further information visit **www.adelaide.edu.au/ibpsa2006**, or contact Veronica Soebarto at **veronica.soebarto@adelaide.edu.au**.

3-6 September 2007
Beijing, China
www.bs2007.org.cn

And finally … Building Simulation 2007, 3-6 September 2007

All the key dates are on the next page. Paper abstracts are due on 15 September 2006.

Further information is available on the conference web site at **www.bs2007.org.cn**.

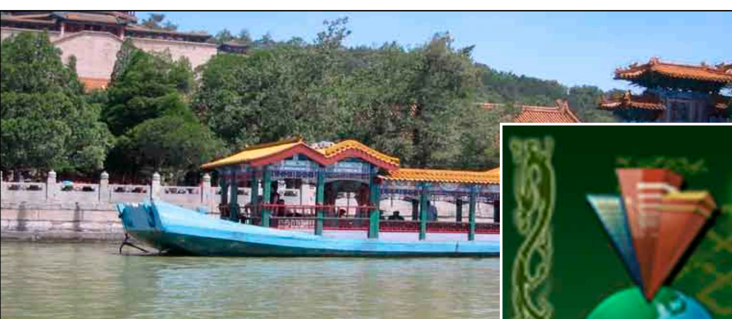
3-6 September 2007
Beijing, China
www.bs2007.org.cn

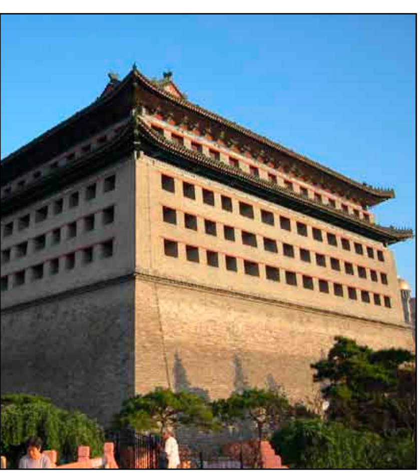
Building Simulation 2007, Tsinghua University, Beijing, China

The 10th IBPSA Conference and Exhibition will be held in Beijing, 3-6 September 2007, and will be hosted by Tsinghua University. Conference details are available at the web site **www.bs2007.org.cn.** Paper abstracts are due by 15 September 2006.

The key dates are:

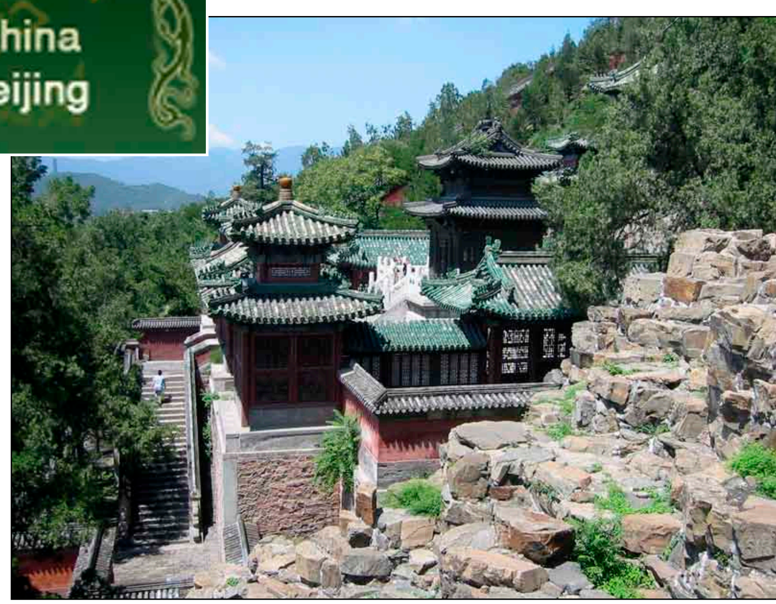
Second Announcement	15 Apr 2006
Deadline for submitting an abstract	15 Sep 2006
Notification of abstract acceptance/rejection	30 Nov 2006
Deadline for submitting a full paper manuscript based on accepted abstract	15 Feb 2007
Notification of result of review on first draft of paper	30 Apr 2007
Deadline for submitting revised papers which were conditionally accepted	15 May 2007
Deadline for final formatted papers	25 May 2007
Final acceptance notification	31 May 2007
Deadline for pre-registration for the conference	20 Jun 2007
Building Simulation 2007	3-6 Sep 2007





Erratum

We reported incorrectly in the last issue of ibpsaNEWS (page 17) that the agreement to hold BS2007 in China was signed by IBPSA President Spitler and Conference Chair Yi Jiang. In fact it was signed by President Spitler and Conference Vice Chair Yingxin Zhu. We are sorry for this mistake.



Software news

Building Energy Tools Directory

Dru Crawley, DOE

The web-based Building Energy Tools Directory at www.energytoolsdirectory.gov contains information on more than 315 building-related software tools from more than 20 countries around the world. Haven't visited lately? Recent additions include a zoo of animals from Australia (BEAVER, CAMEL, DOLPHIN, DONKEY, PHOENICS, and PYTHON) as well as Flucs, LightPro, SPOT, SunPosition online, EBS, and VIPWEB.

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, visit www.energytoolsdirectory.gov/submit.cfm or contact Dru Crawley at **Drury.Crawley@ee.doe.gov**.

Report on Comparison of 20 Building Energy Simulation Programs

This report contrasts the features and capabilities of twenty 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. This comparison is based on information provided by program developers and users in the following categories: general modeling features; zone loads; building envelope, daylighting and solar; infiltration, ventilation and multizone airflow; renewable energy systems; electrical systems and equipment; HVAC systems; HVAC equipment; environmental emissions; economic evaluation; climate data availability; results reporting; validation; and user interfaces, links to other programs, and availability.

The almost 60-page report, jointly published in July 2005 by the U. S. Department of Energy, University of Strathclyde, and University of Wisconsin-Madison, is available for download (585 KB) from:

www.energytoolsdirectory.gov/pdfs/contrasting_the_capabilities_of_building_energy_performance_simulation_programs_v1.0.pdf

There's a link to it on the Building Energy Tools Directory home page at **www.energytoolsdirectory.gov** under Additional Resources on the lower right side.

EnergyPlus version 1.3 released April 2006

Dru Crawley, DOE

The latest release of the EnergyPlus building energy simulation program, Version 1.3.0, became available in early April 2006. In addition to many new features, there are updated and extended capabilities throughout the existing building envelope, daylighting, and HVAC equipment and systems portions of the program. A few of the new features include:

INPUT

- New weather data for more than 200 locations in China, 11 in Egypt, and 2 in Kuwait in the EnergyPlus/ESP-r weather format (1100 locations available worldwide)

ZONE MODEL

- UFAD (Underfloor Air Distribution) room air model for exterior and interior zones

NATURAL AND MECHANICAL AIR DISTRIBUTION

- Completely reworked AirflowNetwork model replaces both COMIS and ADS and moves infiltration, ventilation, mixing and cross mixing to system time step for future feature development of hybrid ventilation control
- Simple earth tube model for preconditioning (heating/cooling) outside air

HVAC

- Variable and constant speed headered pumps
- Detailed Ice Storage model
- New loop connection component allows control of secondary loop to a different setpoint than the primary loop, and removes restrictions on primary vs. secondary flow rates

OUTPUT

- Users can now define end-use subcategories
- Zone operative temperature can be reported
- Improved ABUPS report format and layout
- Users can define custom meters including capability to base on an existing meter and removing specific variables or meters from the results

UTILITIES

- Many IDFEditor improvements based on user suggestions

Input/Output Reference and Engineering Reference updated and extended for all new features and updates, bringing total documentation to more than 2500 pages.

There are 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**.

ENERGY-10™ version 1.8 helps designers to integrate photovoltaics and solar domestic hot water systems

Doug Schroeder, Sustainable Buildings Industry Council (SBIC)

The Sustainable Buildings Industry Council (SBIC) has just released Version 1.8 of ENERGY-10™ software. For the first time, building designers will have an easy to use tool to help them integrate Photovoltaics and Solar Domestic Hot Water in an energy efficient building. These solar features were added to ENERGY-10™ Version 1.8 at the urging of the solar industry. Version 1.8 offers many new features including:

- Photovoltaic module that provides the ability to model and simulate the performance of a PV system that is either stand-alone or integrated with the building.
- Solar Domestic Hot Water module provides a new solar domestic/service hot water modeling capability.
- A new library ("ASHRAELIB") is included defining constructions (wall, roof, window, etc.) as spelled out in ASHRAE 90.1-2004.

Building designers and students currently use ENERGY-10™ to make informed decisions about the energy performance of the smaller commercial buildings and homes they are designing. The software helps identify the best combination of nearly a dozen energy-efficient strategies, including daylighting controls, passive solar heating, and high-efficiency mechanical systems to name a few. It usually takes less than an hour at a project's outset to produce a simulation, but that small investment of time can result in energy savings of 40-70%.

Some of the unique features of ENERGY-10™ are that it:

- allows you to integrate and assess dozens of energy-efficient design decisions quickly and accurately.
- quantifies and clearly illustrates the impact of design decisions on first cost, operating costs, and pollution prevention.
- helps you obtain energy credits under the U.S. Green Building Council's LEED™ program. Output reports for "daylighting" and "total building energy use" facilitate the LEED™ submission process.
- has multiple levels of technical support, including free or hourly direct support for professionals seeking assistance with beginning through advanced simulations, and SBIC's free ENERGY-10™ NetForum, which allows users to discuss the program and share ideas. Visit **www.Energy-10.com** for details.

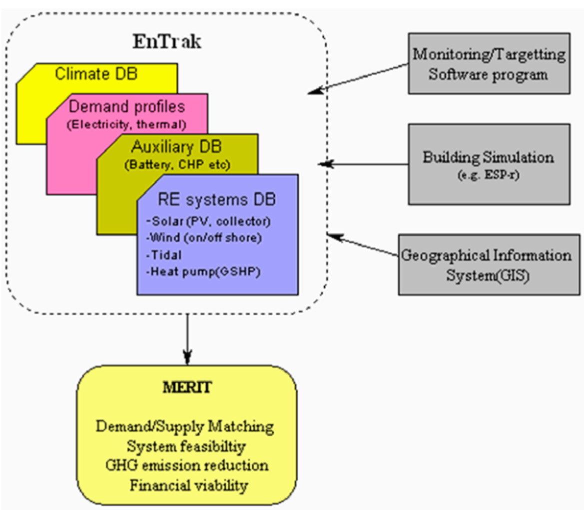
ENERGY-10™ Version 1.8 is now available for purchase online through SBIC at **www.Energy-10.com**. Upgrades, academic and professional site licenses are also available for purchase on-line.

Merit: a dynamic demand/supply matching-based design tool for renewable energy systems

Jae-Min Kim, Energy Systems Research Unit, University of Strathclyde

To successfully integrate Renewable Energy (RE) systems within a building, appropriate technology types and capacities must be identified and integrated. The basic methodology is to utilise demand-side management techniques (e.g. insulation improvement, high performance windows, natural/hybrid ventilation, air tight construction, passive solar design etc) to reduce energy demands to levels that present a favourable aggregate load for the RE system combination. The aim is to meet the residual temporal demand, minimise the capacity of the required energy storage system and maximise the capacity utilisation factor from the RE systems.

The Merit system, developed by ESRU, University of Strathclyde, is a quantitative evaluation tool that allows the user to determine the match between supply and demand in order to make informed decisions about the suitability of certain supply mixes for particular applications. In Merit, algorithms that model RE and low carbon energy systems (photovoltaic components, solar collectors, wind turbines, CHP, heat pump, fuel cells etc.) are established to simulate power production based on manufacturers' specifications, locational parameters and weather data. The program offers methods to generate half-hourly demand profiles (electricity, heat and hot water), which could be monitored data, statistical data or virtual demand profiles. EnTrak, an energy and environment information management tool, is used to store climate databases and the demand and supply profiles for use with Merit's profile matching feature. The system framework, depicted on the left, uses open database connectivity to communicate with a remote SQL database via the Internet. This also enables data exchange with other energy analysis tools, for example:

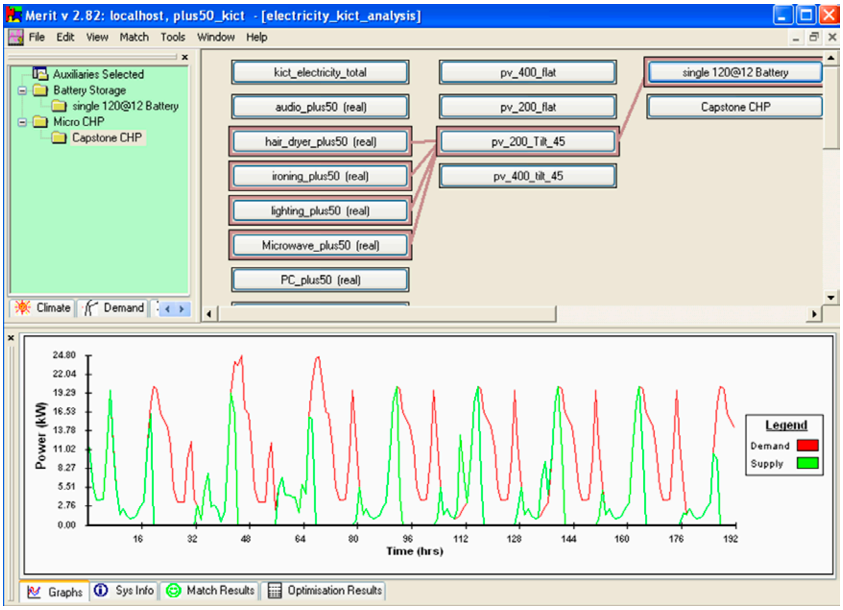


- building simulation tools can be used to provide virtual demand profiles relating to scenarios for which there are no real data

- energy monitoring and targeting software supports the analysis of time series data corresponding to the consumption of fuel and power at the individual meter level, and

- Geographical Information System (GIS) software can access the database and present energy supply/demand matching data enabling further RE systems analysis based, for example, on environmental sensitivity.

Demand/supply matching analysis is carried out against user specified criteria such as maximising RE utilisation or attaining best temporal match to determine the goodness



of fit for each possible demand/supply combination when deployed jointly and severally. When an auxiliary system is selected (e.g. battery storage), its performance and duty cycle are shown. The program then uses statistical methods to determine how closely the demand and supply profiles are matched. The reported statistics include an inequality metric (to indicate the quantitative fit) and a correlation coefficient (to indicate the dynamic fit). For low correlation coefficients, the energy surplus and deficit is given for the simulated period. Where a back-up system such as CHP is present, an indication of the cost of the additional energy is supplied as a function of the selected tariff. This process can then be repeated to examine the effects of changing seasons, building design parameters, demand reduction measures and supply technologies. In this way, different scenarios may be easily and quickly tested. The user interface of Merit is shown above. For more information on theoretical details, case studies and software training courses, visit the ESRU Web site, **www.esru.strath.ac.uk**.

References

Born F (2001) 'Aiding Renewable Energy Integration through Complementary Demand-Supply Matching', PhD Thesis, Glasgow: University of Strathclyde

Born F, Clarke J and Johnstone C, 2004, Development of a Simulation-Based Decision Support Tool for Renewable Energy Integration and Demand-Supply Matching, Proc. eSim 2004, pp205-12, Vancouver

Kim J, 2004, Integrated Information System Supporting Energy Action Planning via the Internet, PhD Thesis, University of Strathclyde

Kim J, Clarke J, Hong J, Strachan P, Hwang I and H. Lee (2005), Simulation-based Design Procedure to Evaluate Hybrid-Renewable Energy Systems for Residential Buildings in Korea', Proc. Building Simulation '05, Montreal, 15-18 August

Smith N (2002) 'Decision support for new and renewable energy systems deployment', PhD Thesis, Glasgow: University of Strathclyde

Workshops on Integrated Design announced by Integrated Environmental Solutions

IES (Integrated Environmental Solutions) has announced the availability of one-day and two-day detailed training courses in the <Virtual Environment> software. Aside from providing a healthy environment for people to work and live in, owners and tenants today demand more from their building. Buildings need to be durable, flexible, adaptable and sustainable. In order to demonstrate value over the course of their lifetime, an integrated team approach to design, construction and facilities management is essential if a comprehensive set of performance measures are to be implemented and achieved. The workshop in integrated design explores how a design team can use IES <Virtual Environment> software to work from a single building model to analyze whole building performance issues such as daylighting, solar access, energy modeling and airflow modeling. Visit **www.iesve.com** to learn more about this and other features.

Workshop registrants receive a workshop pack including literature and a free 30-day trial of the <Virtual Environment> software. Check with Laura at **laura.melvin@iesve.com**.

IES (Integrated Environmental Solutions) is not affiliated with the other well-knows IES (Illuminating Engineering Society.)

Software training courses and fair

Other software-related events in the next few months include a Software Fair and training courses on ESP-r, VisualDOE and EnergyPlus:

ESP-r training courses: Strathclyde University, 5 May, 8-9 June, 10-11 July and 11-12 September 2006

Software Fair: SESG Software Fair at Strathclyde University, Glasgow, 9 May 2006

VisualDOE training seminars: San Francisco 18-19 May, New York July or August (dates to be announced) and Boulder, Colorado, 13-14 November

EnergyPlus training workshops: West Coast USA, May/June 2006, Atlanta Georgia, 15-16 June 2006 and at the IBPSA-USA SimBuild conference at MIT, 1 August 2006

Details of all of these are given in the Forthcoming Events section beginning on page 8.

Feature articles

The application of shading masks in building simulation

Andrew Marsh, Welsh School of Architecture, Cardiff University UK & Square One research, Australia [1]

[1] *www.squ1.com; andrew@squ1.com*

ABSTRACT

Calculating the dynamic effects of surface overshadowing is a major part of most thermal analysis engines. It also represents a significant overhead in the analysis process yet, once a run is complete, this information is usually lost and must be entirely recalculated before the next run. However, detailed overshadowing for specific surfaces is valuable information to the designer. It is also useful for many other forms of building performance analysis such as detailed shading design, material selection, daylighting, right-to-light and even solar-access calculations.

This paper proposes the widespread use of pre-calculated shading masks in thermal analysis engines. It discusses why this is important, the different techniques for calculating and storing these masks as well as the benefits and disadvantages of different methods. A comparison of both the accuracy and computational overhead of different sky-subdivision techniques is also presented. More importantly, it shows that complex effects such as solar reflection and incidence effects can be accommodated within the masks themselves and how they can also be used in the calculation of average daylight factors, glare potential, radiant exchange and even internal surface solar tracking.

INTRODUCTION

Incident solar radiation (insolation) on external surfaces is a major influence on a building's overall performance, impacting on internal comfort, energy use, lighting and even general amenity. The accurate calculation of insolation is fundamental to thermal simulation tools and a whole range of different techniques have been developed for this purpose. However, within these differences often lie problems of access and inflexibility.

In many tools, the calculation of detailed shading effects is computationally expensive, requiring that each shading device be explicitly defined and a whole range of cached data generated for each surface within the model. This cached data is then discarded at the end of the analysis run.

From a designer's perspective, detailed shading data for each surface in a model represents a wealth of potential design information. If visualised in an appropriate way - mapped over a sun-path diagram for example - it can immediately show exactly when a surface is in shade, by what and for how long. This in itself can form the basis of many important design decisions.

However, none of the major freely available thermal analysis tools such as EnergyPlus (Crawley et.al. 2004) allow access to this detailed information, other than through some simplified summary data or single time-specific values. Also, because the calculations are usually done internally in each tool, the effect of complex shading devices must be approximated or modelled abstractly using the often quite limited techniques and geometric primitives the tool provides. This lack of modelling control, coupled with the inability to view in detail what the final effect is, often means that shading is treated quite cursorily in many instances.

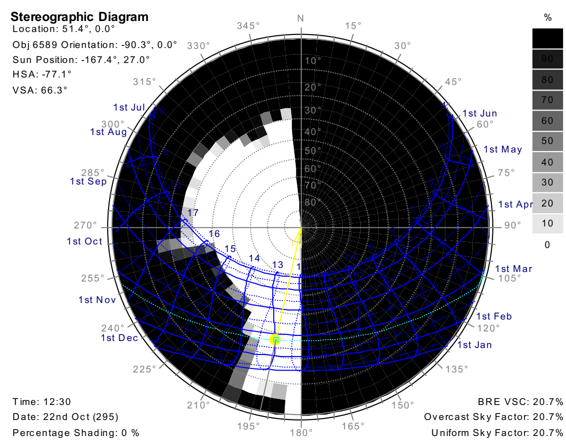


Fig 1 **An example shading mask generated for an overshadowed window in London mapped over a sun-path diagram**

This paper proposes the use of shading masks as a solution to these problems. As described later, shading masks allow for detailed shading information to be stored between runs and should ideally be done in a format that other tools can view, edit or even generate. Using shading information this way has the following potential benefits:

- Shading masks need recalculation only when the actual building or site geometry changes. The same masks can be used for any orientation, calculation period, location and, if reflection data is not stored directly, are even tolerant of changes in material and surface properties.

- Complex shading situations that may not be easily modelled within one particular analysis tool could easily be generated within another and applied to relatively simple surfaces with the same effect.

- Where complex CAD models of the site are available, there would be no need to modify and import this into the analysis tool itself, thereby significantly reducing the overheads and complexity of the analysis model. With the right shading masks, the same (if not greater) accuracy could be achieved, resulting in much simpler and faster thermal models.

- Being able to visualise and even create the shading input means the designer knows exactly what the calculation is based on, making it easier to track down anomalous results and control the level of detail to their own specific requirements.

- Future tools could support multiple shading masks representing different environmental conditions. These could then be applied to objects at different times during a calculation to accurately simulate dynamic events such as deciduous vegetation or complex moveable shading devices.

With computational analysis fast becoming an important part of the entire design process, not just as a final validation tool, the flexibility to control, store and view this kind of information is increasingly important. Also, in performance-driven design processes and parametric analysis, the same model may be run many thousands of times so any reduction in calculation time through the caching of shading data is vitally important.

SHADING MASKS

A shading mask is simply a mechanism for recording which parts of the sky are visible from a particular point in the model and which are not. For any given set of obstructions, this information can be overlaid on a sun-path diagram to show when in the year the point is in shade or not.

Whilst this diagram can be generated by projecting obstructing surfaces back towards the point from which the mask is generated, and drawing a series of transformed polygons (as shown in Figure 2 - left side), it is more useful for numerical analysis to divide the sky into discrete segments and simply store shading values for each one (as shown in Figure 2 - right side). Once segmented in this way, information can be obtained quickly by simply referencing all or parts of the mask directly.

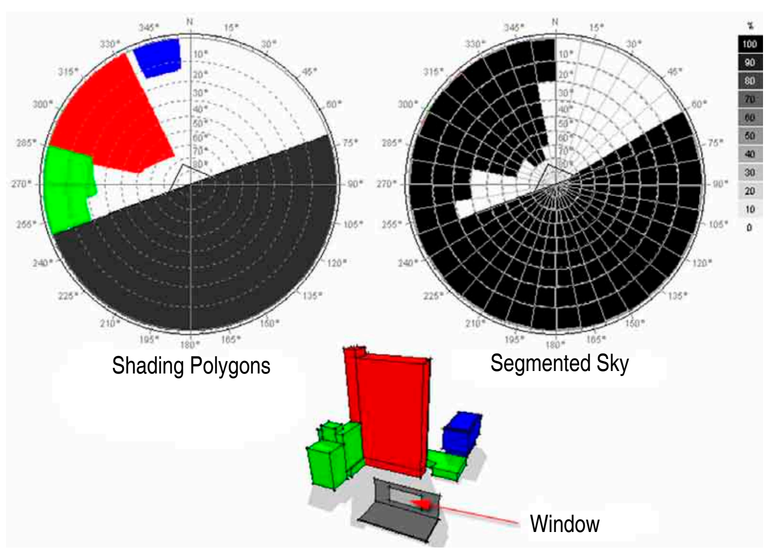


Fig 2 Example shading masks for window centre, showing shading polygons (left) and the sky dome divided into discrete segments (right)

A major benefit of using the sky segment approach is that each segment can store quite complex data. As shown above, the shading mask for a single point is hard edged - it is either in shade or not. However, a shading mask for a planar surface is usually soft-edged as the surface may only be partially in shade at a particular time.

One of the simplest ways of determining the partial shading of a surface is to sample it as a series of distributed points and average the results into a single mask. This way each segment can be used to store fractional obstruction values or a shading percentage.

Figure 3 shows how the shading percentage for any sky segment can be calculated by spraying rays out from a number of sample points on a surface and then determining the percentage that were obstructed by surrounding objects. If this is done for all sky segments, an image of the occlusion of the sky from that surface can be generated, shown here as the soft-edged shading mask to the right of Figure 3.

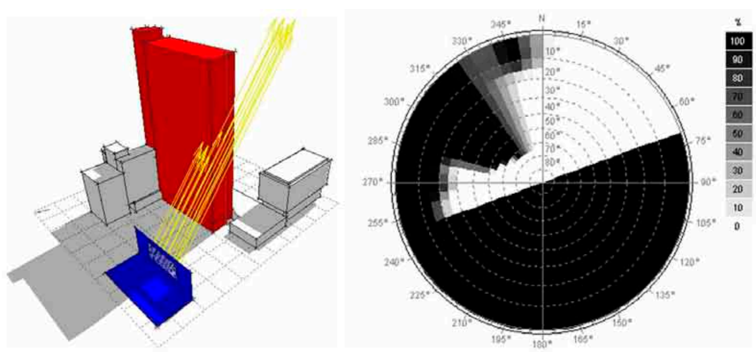


Fig 3 **Shading masks for planar surfaces must store fractional shading information**

Instantaneous insolation

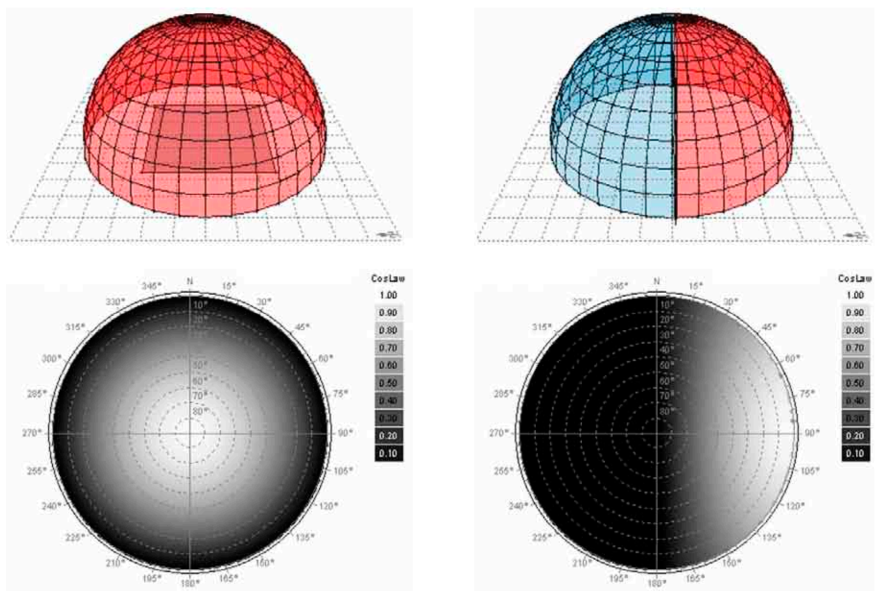
The calculation of insolation on a surface involves several steps, including both geometric occlusion and the solution of many trigonometric equations which are quite processor intensive. Whilst the shading mask is a useful means of caching occlusion data so that it does not need to be recalculated many times, it has the additional benefit of eliminating a significant number of trigonometric functions in each analysis, resulting in a further reduction in calculation times.

Insolation depends on the angle of incidence at which radiation strikes each surface, calculated using the cosine law in which radiation arriving normal to the surface has a greater effect than that arriving at grazing incidence. Thus, for the direct solar component, the angle between the position of the Sun and each surface's normal must be known at each time-step. For hourly calculations over the whole year this will require as many as 4380 solutions for each object in the model (sunrise to sunset) - many more for sub-hourly time-steps.

The contribution of the diffuse solar component also depends on incidence angle. In this case, different parts of the sky will contribute more or less depending on where they are in relation to each object's surface normal. This is particularly important when using anisotropic sky distributions.

The solution is simply to embed this information in the shading mask of each object, as either a separate layer of data or as an additional shading modifier. This does not even need to be calculated trigonometrically for each surface. It need only be calculated once and then transformed based on the azimuth and altitude angle of each flat surface or surface segment. Figure 4 shows resulting mask data for both a horizontal and vertical surface.

The resulting incidence angle factors for each sky segment can then be applied to both the instantaneous diffuse and direct components.



Horizontal (Alt = 90°) Vertical (Alt = 0°)

Fig 4 The effect of incidence angle on the relative contribution of different parts of the sky

Diffuse Solar Component

If a single sky distribution model is used, the overall contribution of the diffuse solar component need only to be calculated as a factor once at the beginning of each analysis. This can be done by first assuming a total diffuse radiation value of 1.0W/m^2 and applying the sky distribution model to generate the diffuse contribution of each segment.

The result for each segment is then multiplied by both the incidence angle factor and the shading percentage for that segment and summed together. The result is a single value representing the overall fraction of diffuse radiation from the sky arriving at that surface, which can be stored alongside the shading mask. Figure 5 (next page) shows the three stages in this calculation process.

Multiple distribution models to represent dynamic conditions under clear and overcast skies can also be accommodated using multiple diffuse radiation factors and either interpolating between them or re-calculating from the three masks whenever required.

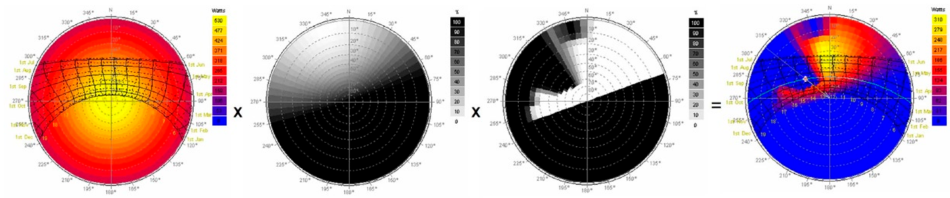


Fig 5 A diffuse radiation factor can be determined by multiplying the diffuse sky distribution by both incidence angle and shading factors for each sky segment

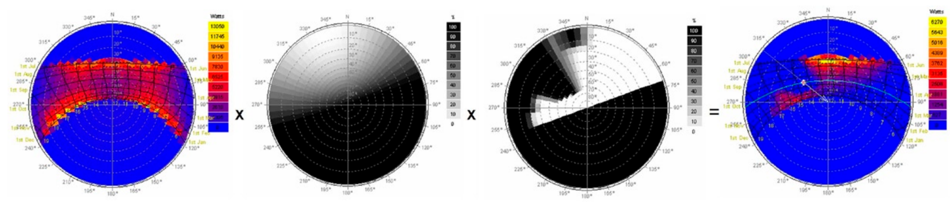


Fig 6 Total solar collection can be calculated using a cumulative sky, in which solar radiation through each segment is aggregated over time and then multiplied by incidence angle and shading factors

Direct Solar Component

For instantaneous direct solar radiation, the azimuth and altitude of the Sun is calculated once for each time step and the sky segment through which it passes is determined. As the masks for all objects are aligned to the same north point, the instantaneous beam solar radiation value can be multiplied by the incidence angle factor and the shading percentage for that segment in any object's shading mask to give the direct solar component.

Cumulative Insolation

Whilst not usually required in a thermal analysis calculation, it can often be useful to know the total solar collection on a surface over an extended time period. This can be achieved very simply using the same technique, but this time with a cumulative sky generated by aggregating the total solar radiation passing through each sky segment over the chosen calculation period.

To generate a cumulative sky, each hourly or sub-hourly diffuse sky distribution is summed for each segment over the calculation period. At the same time, the Sun position at each time-step is used to determine the sky segment to which the beam radiation is added. Because all the geometric analysis is already embedded in the masks themselves, a single cumulative sky array can be used to very quickly calculate and display the relative solar exposure over all objects in even the most complex model. As this involves simple multiplication of data arrays, this can even be done in close to real time.

An example of such a cumulative sky distribution is shown in the left-most image in Figure 6. In this case, taken over the entire year, the direct component clearly dominates the resulting cumulative sky distribution.

PRACTICAL CONSIDERATIONS

Sky Subdivision

There are many ways to subdivide the sky dome into discrete segments. Some seek to achieve a roughly equal-area (solid angle) for each segments whilst others apply a simpler latitude/longitude or equal-angle approach. Figure 7 shows some examples of different techniques as well as how the resolution can vary.

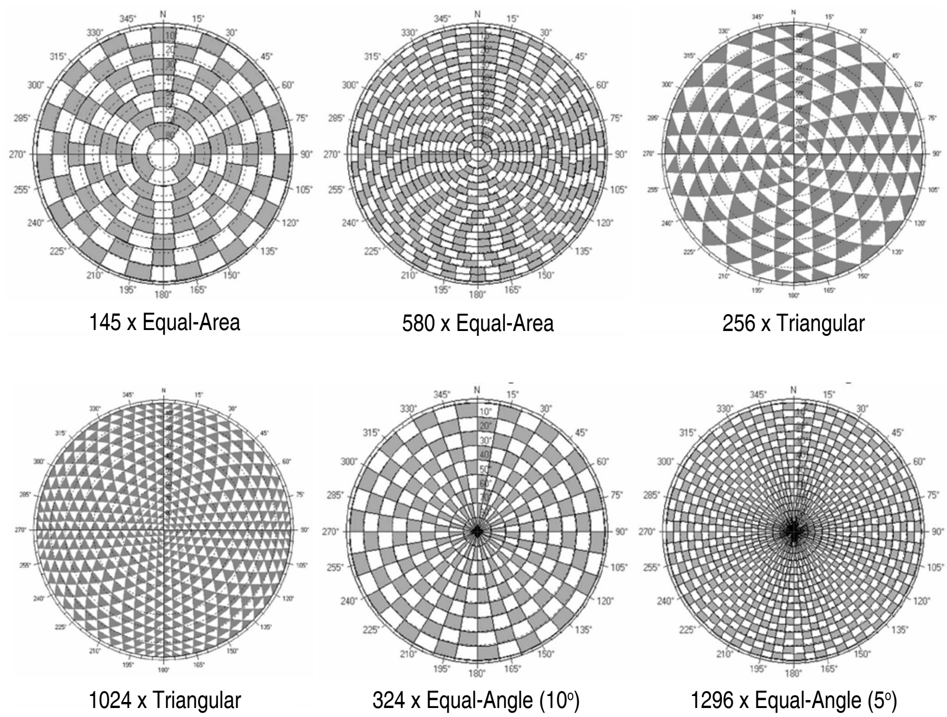


Fig 7 Some examples of different sky subdivision techniques

The methods used to generate these different subdivisions have been widely published (White, et. al. 1998, Tregenza, 1995 and Wenninger, 1999) so will not be covered here. However, given that it is possible to weight each sky segment by its relative area compared to all others, it is not actually necessary that each segment be of even close to equivalent size. It is therefore more practical considerations that will influence the choice of technique.

Access Times

Once the shading mask for a surface has been pre-calculated, it's data must be accessed many times during the analysis process, typically once per time-step. As previously discussed, this can be 4380 or more times for each object in an annual calculation. Thus, the processor time spent accessing the shading mask is an important consideration as different techniques vary significantly.

For equal-area techniques, the procedure for finding the right segment index given an altitude and azimuth for the Sun involves an iterative solution in which the number of step depends on the segment resolution (Tregenza, 1995). A similarly complex process is required for the triangular technique, which also depends on segment resolution.

The equal-angle approach, on the other hand, uses altitude and azimuth values to directly index the shading mask so access time is much quicker - requiring only two integer divisions - and completely independent of resolution.

The extra access time issues in the more complex models can be overcome to a large extent using look-up tables in which altitude and azimuth values are mapped to specific sky segments. The look-up table is then accessed in the same way as the equal-angle shading mask, making access times for each technique almost indistinguishable.

Segment Resolution

Obviously the smaller the size of each segment, the greater the accuracy of the calculation - but also the longer it will take to resolve and the more memory it will require to store the results. In terms of accuracy, sampling the sky in discrete segments reduces the level of non-uniformity in the radiant sky distribution and simplifies the surrounding geometry from the perspective of each surface.

Kendrick (1989) suggests that, for daylighting, segments with a solid angle of approximately 0.2 radians (11.5 deg.) are small enough to be considered as point sources without significant error. This corresponds to the 145xEqual-Area example shown in Figure 8. As very detailed sky distribution data is not generally available anyway, the need for a higher segment resolution will more likely be driven by the geometric complexity of the model than by any definition of the sky.

In addition to segment size, shading calculation accuracy is also affected by the number of points sampled over the surfaces of large objects. The more points, the smoother and more accurate the partial shading mask. Both aspects of resolution suffer from the law of diminishing returns. To test this, shading calculations using different sky subdivisions at a range of resolutions were performed on an example geometric model, shown in Figure 8.

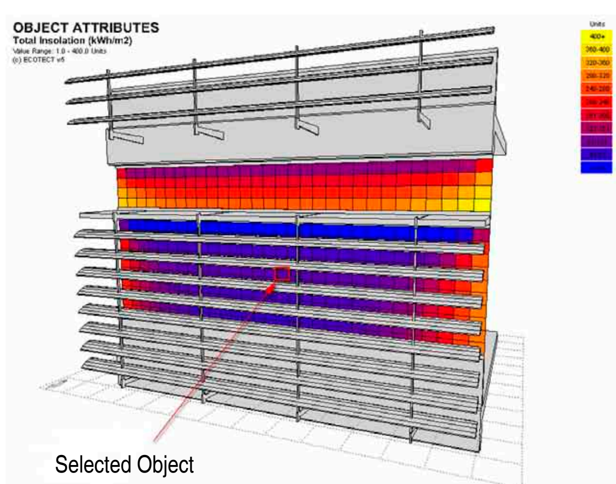


Fig 8 **Model for comparative shading analysis**

To compare each calculation, four different values were used: the diffuse radiation factor for a sample surface; the shading factor at a pre-determined time, selected to ensure partial shading of the example surface; the cumulative insolation over the entire year on the selected surface; and the total time taken to generate shading masks for all tagged surfaces in each model. All calculations were run on the same computer using the exact same base model.

Table 1 shows the results for each method at different resolutions, showing variations of less than 4% between both different resolutions in the same method, and between different methods. There is some computational economy when calculating high-resolution masks, but the seconds per segment only slightly favours the equal-angle method.

Equal Area Resolution	Diff. Fract. (%)	Shading (%)	Insolation (kWh/m2)	Time (secs)	Seconds / Segment
145	11.33	38.83	61.65	43	0.29773
580	11.31	38.85	61.65	156	0.26873
2320	11.45	38.70	61.65	586	0.25263
9280	11.11	38.77	61.65	2324	0.25047
Triangular Resolution	**Diff. Fract. (%)**	**Shading (%)**	**Insolation (kWh/m2)**	**Time (secs)**	**Seconds / Segment**
64	10.91	38.71	61.65	20	0.31456
256	11.33	38.94	61.65	72	0.28165
1024	11.34	38.48	61.65	271	0.26501
4096	11.05	38.69	61.65	1077	0.26287
Equal-Angle Resolution	**Diff. Fract. (%)**	**Shading (%)**	**Insolation (kWh/m2)**	**Time (secs)**	**Seconds / Segment**
144 (15x15)	11.30	38.89	61.65	41	0.28472
324 (10x10)	11.28	38.75	61.65	83	0.25617
1296 (5x5)	11.41	38.65	61.65	312	0.24074
2700 (4x3)	11.06	38.54	61.65	645	0.23889
8100 (2x2)	11.09	38.57	61.65	1887	0.23296

Table 1 A comparison of values and calculation times using different techniques and resolutions

Storage and Transfer

A shading mask is simply an array of data, irrespective of the sky subdivision technique used. If each sky segment contains multiple layers of information, the array simply becomes multi-dimensional.

At its most basic, each member of the array simply stores a percentage shading value. Depending on the accuracy required, this value could be a single byte with a range from 0-100 (accurate to within 1%), a 2 byte word with a range 0-10000 (accurate to within 0.01%) or a 4 byte floating point value with almost unlimited accuracy. This is important because large CAD models can contain many thousands of individual polygons, all potentially requiring a mask in an insolation analysis.

Table 2 (next page) shows the rapid increase in memory size required to store shading masks with different segment resolutions and accuracies. At its highest level, this can be as much as 37 kilobytes per mask layer per object. For a 1,000 object model, this equates to 37 megabytes, compared to just 145 kilobytes for the lowest resolution and accuracy.

		Sky Segments			
		145	580	2320	9280
Bytes	1	145	580	2320	9280
	2	290	1160	4640	18560
	4	580	2320	9280	37120

Table 2 The number of bytes required to store shading masks of different resolutions & accuracy

When used internally within an analysis tool, the exact storage method is not particularly important as machine memory is usually more than sufficient. However, if used by external tools, the format in which they are stored does become important. Here too there is a trade-off. The aim is obviously for a flexible and universally accessible format - preferably human readable - which can accomm-odate the many different sky subdivision, resolution and accuracy options. The use of an XML schema for example would simplify the development of viewers or editors and offer just such a universal and readable format.

However, the requirement to include a validating XML parser would add a significant overhead to those analysis tools that must read and write many thousands of masks during a single calculation run. Moreover, a flexible and readable XML format would add a significant number of extra characters to the file which, when storing many thousands of masks, would greatly increase the amount of storage space required. Much of this could be overcome using file compression, however this defeats the very purpose of using a text-based format.

When considering shading as design information, the designer is usually only interested in a relatively small number of surfaces (assuming that most of the objects in the model form the surrounding urban environment that actually does the shading). This suggests that the requirement is really two-fold - in that there is a need for:

- a flexible transfer format for single or small numbers of individual masks, selectively accessed by the user for editing or email, and

- a long-term, optimised and high-volume format for storing large numbers of masks for access during calculations.

Typically long-term, high-volume formats are determined by each tool's individual requirements, are stored locally (usually alongside the actual model) and are not flexible in terms of the types of shading masks they can store. However, once a suitably flexible XML schema is developed, it would be possible to develop a compatible database table format with the same field structure.

Masks could then be stored in a central database for access by many different tools. This would eliminate much of the storage overhead of the XML format whilst providing a fast searchable method that is shareable amongst groups of analysts and designers. With the right set of SQL search criteria, it would also be possible for any member of the team to identify surfaces above or below particular exposure limits, etc, from the database alone.

As a result, work is currently underway on both the development of a flexible XML schema for exchanging shading mask data and a compatible but optimised SQL table format for more efficient storage and access to this data.

OTHER DESIGN APPLICATIONS

In addition to accelerating thermal calculations, shading masks have many other uses. Figure 1 not only shows how shading masks can be visualised, but also shows how values such as sky components (overcast sky) and sky factors (uniform sky) can be determined directly from the shading information (shown as text in the bottom-right corner). If the appropriate room properties are known, each window's shading mask can be used to accurately calculate average daylight factor values (Tregenza, 1995, Algorithm 2.12) and even mean vertical obstruction angles.

By layering additional data in each sky segment, the application of shading masks can be extended further to include the following.

Reflected Solar Radiation

Within a shading mask it is also possible to accommodate the effects of specular reflection off surfaces in the surrounding environment. This can be done by spawning reflected rays at each intersection with an obstructing surface, and then tracing each ray until finally unobstructed. At this point the sky segment through which the final spawned ray passes is calculated from the altitude and azimuth of the ray, as shown in Figure 9.

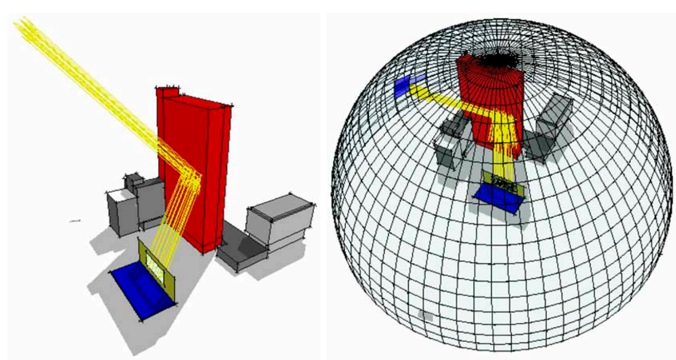


Fig 9 It is also possible to calculate and store reflected solar radiation in a shading mask

The value contributed by each reflected ray to that sky segment is determined by multiplying the reflectance and specularity values of each surface struck, and then dividing the result by the total number of sampled rays generated over the surface of the original object being shaded. The final values of each ray are summed within each sky segment intersected. This means that it is theoretically possible for the fractional value in a particular sky segment to be greater than one. This can occur when many obstructions focus specular reflections at the same point, effectively magnifying the solar intensity there.

Diffuse reflections are slightly more complex to accommodate. In addition to shading data, a direct reference to the obstructing surface(s) for each sky segment can also be stored. This works best when dealing with single point masks as there is only ever one obstructing object in each direction. In the case of large surfaces it is certainly possible to store multiple objects and the fraction of rays hit, however this has not been attempted or investigated at this stage.

This means that the shading mask can effectively store dynamic information related to each surrounding object. Thus, using their own shading masks, it is possible to calculate the instantaneous incident radiation on every surface in the model, and then perform a second iteration in which object references in each mask are used to determine the radiant exchange between surfaces. This is a well known process used in radiosity-based lighting analysis tools - the shading mask simply serving again as storage for calculated data.

Internal Solar Tracking

Shading masks can also be used to easily track solar radiation through windows and appertures and onto the internal surfaces within a space. To do this, masks are generated from both sides of all building surfaces, even those that are completely internal. Most of the rays sprayed on the internal side will be obstructed by the surfaces that form the envelope of each space, however some will escape out through windows and appertures. Thus, it is possible to determine the percentage in shade for each internal surface for any particular time and, based on its surface area, the effective area exposed to the Sun. Figure 10 shows an example shading mask for a floor object with windows on the north and east facades.

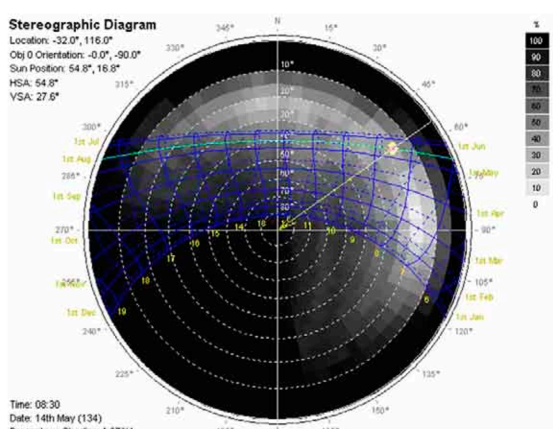


Fig 10 An example shading mask for an internal floor surface with windows along the northern and eastern facades

The instantaneous insolation on internal surfaces is found by summing the direct and diffuse solar gains through all of the windows and appertures in the space, and dividing the result by the total effective exposed area. Given that the shading mask already accounts for incidence angle and external obstruction, as well as the transparencies and shading coefficients of each apperture, the result is a W/m2 value that can be multiplied by the effective exposed area of each surface to give the instantaneous insolation.

This information can then be used, along with the material properties of each surface, to determine how much of the insolation is absorbed into the fabric and how much becomes an instantaneous space load. By dividing internal surfaces up into smaller sub-surfaces, it is also possible to determine the exact location of Sun-patches and to more accurately calculate the spatial distribution of surface temperatures for detailed radiant temperature analysis.

Mean Radiant Temperatures

If object references are included in the shading masks for a grid of analysis points distributed within a space, it is then possible to dynamically calculate mean radiant conditions at each point based on the changing surface temperature of surrounding objects. Used in conjunction with the internal solar tracking capability and subdivided surfaces, this can yield a highly accurate and dynamic simulation of spatial comfort.

Such a system has been implemented as part of this work to calculate the distribution of mean radiant temperatures based on the proximity of objects to each point on an analysis grid. In this case, each shading mask segment stores the object index of each obstruction in each direction and its distance from the point. In the example shown in Figure 11, hourly surface temperatures for a whole day can be stored for each object, allowing time-based recalculations to be performed fast enough for the distribution to be animated dynamically.

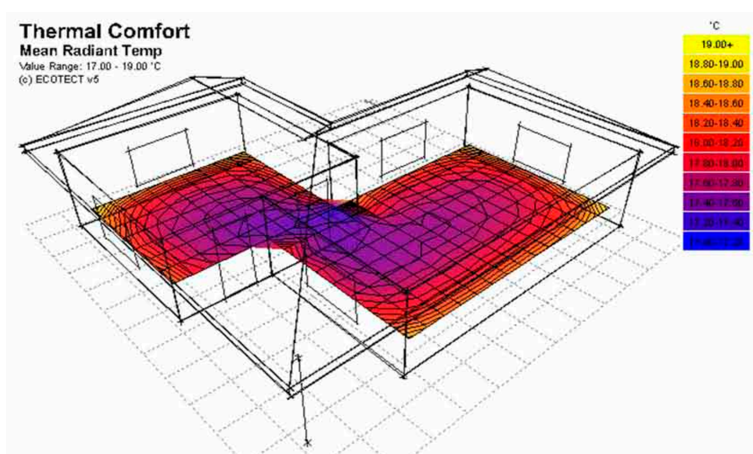


Fig 11 Shading masks can be modified to include object proximity data for dynamic radiant temperature and comfort calculations

Dynamic Shading Conditions

With the increasing use of operable shading devices and solar controls linked to building management systems, many analysts require the ability to model dynamic shading conditions. The use of shading masks makes this a relatively simple process whereby a schedule can be used to transition between shading masks at different times of the year or even different hours of the day.

Most thermal analysis tools already use schedules to change single parameter values, either in discrete steps or as fractional interpolations between two extremes. This same approach can be applied to shading masks. If a separate indexed list of shading masks is kept, then the schedule could either switch the index assigned to any object at any time, or interpolate between shading values stored in two different masks, as shown in Figure 12.

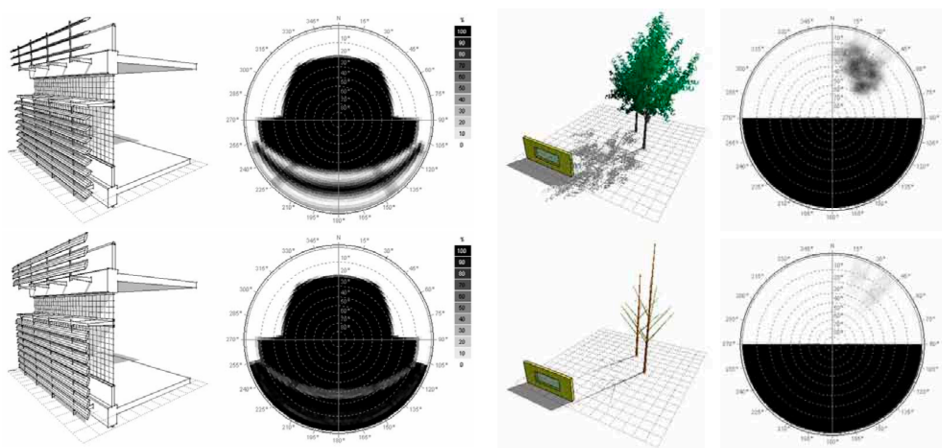


Fig 12 The effect of dynamic shading devices and deciduous vegetation on object shading masks

CONCLUSION

The concept of the shading mask is certainly not new. In fact most thermal analysis tools already include many aspects of their implementation. However, the bulk of the shading data these tools generate is inaccessible and too readily discarded. This paper has shown that the use of shading masks and the ability to share them between tools can have significant potential benefits.

These benefits are not solely in terms of calculation speed, though this is an important concern. The extra information and insight offered to designers and the modelling flexibility shading masks provide are equally if not more important.

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Review and recommendations for improving the modelling of building-integrated photovoltaic systems

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ABSTRACT

The models for photovoltaic (PV) systems currently in ESP-r prove very useful in estimating the electrical and thermal impact of building-integrated photovoltaics. However, while they represent well the impact of photovoltaics on the building's thermal energy balance, they may lack in accuracy in the prediction of the system's energy production. To achieve both goals at once it is suggested to improve the PV models in ESP-r, taking into account all phenomena affecting the power output of PV modules: solar radiation intensity, cell temperature, angle of incidence, spectral distribution, uncertainty in manufacturer's ratings, ageing, mismatch, soil and dirt, snow, partial shading, diodes and wiring. This would provide a more realistic estimate of the probable output of the PV system over its lifetime. It is suggested to implement three models: a simple model based on constant efficiency, a one-diode equivalent model with explicit temperature dependency of the parameters, and the Sandia model for cases when detailed modeling is required.

INTRODUCTION

Modeling building-integrated photovoltaics (PV) in building energy simulation tools presents many challenges. For example, photovoltaics respond to many environmental influences, such as irradiance, temperature, wind speed, angle of incidence of solar rays, and spectral distribution of irradiance. Furthermore, PV modules are susceptible to hard-to-quantify effects such as the presence of snow or dirt, and shading from one part of the building onto the module.

In addition, parameters characterizing PV modules are often hard to come by. Manufacturer's data often provide relatively easy access to parameters such as open circuit voltage, short circuit current, and nominal efficiency under standard test conditions (1000 W/m2, 25 °C, air mass 1.5). But representing accurately the electrical characteristics of the modules from such a small set of parameters, and under a wide range of environmental conditions, is challenging.

Finally, most PV simulations programs are chiefly interested in the power output of the module. By contrast, tools for energy simulation in buildings require additional outputs such as light reflected by the modules and transmitted through it, and radiative, convective and conductive heat transfer at the front and the back of the PV array.

This paper examines the various environmental effects affecting the behaviour of PV modules, and quantifies their importance upon the calculation of energy delivered by the PV array on an hourly, monthly and yearly basis. It reviews the PV models currently used in ESP-r, and describes its strengths and weaknesses. Finally the paper proposes a more complete PV model for building integrated photovoltaics in ESP-r.

PHOTOVOLTAICS: BACKGROUND

Photovoltaic modules convert sunlight into electrical power. Several kinds of modules are commercially available: crystalline silicon (c-Si), which can be either monocrystalline silicon (mono-Si) or polycrystalline silicon (poly-Si), and amorphous silicon (a-Si). Other more exotic technologies such as spheral silicon or Cadmium Indium Selenide (CIS) are also available, although their commercial impact is so far limited.

The modules differ chiefly by their efficiency, their packaging, and their cost. Different technologies respond also differently to environmental stimuli such as temperature, spectral conditions, etc.

From an electrical point of view, PV modules are characterized by their current vs. voltage curve, commonly called I-V curve, some examples of which are shown in Figure 1. The power delivered by the module is the product of its voltage and current, so one has to know the operating point (i.e. voltage and current) of the module to determine the energy produced. In some systems the operating point is determined externally, for example in the case of a direct connection to a battery. In that case, the voltage is basically set to the battery voltage (e.g. 12 V) and the PV module current is determined by the intersection of the I-V curve with the 12 V vertical line. In most building-integrated PV systems, though, an electronic device called a maximum power point tracker adjusts the voltage so as to maximize the power delivered by the module. In that case the module operates near the 'bend' in the I-V curve.

As shown in Figure 1 the shape of the I-V curve depends on irradiance and temperature; very roughly, irradiance is a first-order effect and temperature is a second order effect. There are other influences as well, such as angle-of-incidence, spectral distribution of irradiance, etc., which also change the shape of the I-V curve; these will be described later in the paper.

Modules are usually not used alone. Photovoltaic systems usually include power conditioning equipment, inverters, and in some cases batteries (for stand-alone systems). All these additional components constitute what is called the balance of system (BOS) and will be briefly touched upon at the end of this paper.

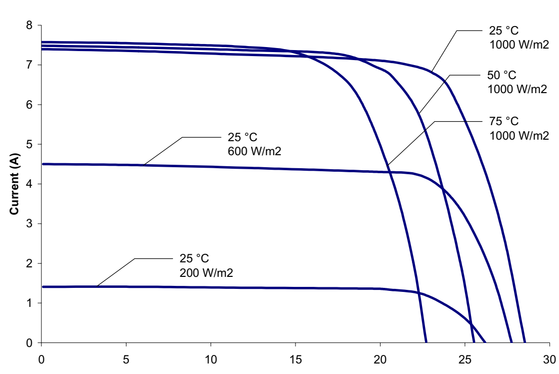

Fig 1 PV module I-V curves

ENVIRONMENTAL EFFECTS ON PV MODULES

PV modules are most often characterized by their power rating at Standard Test Conditions (STC), that is, under a normal irradiance of 1000 W/m2, with a cell temperature equal to 25 °C, and with a spectral distribution corresponding to air mass 1.5. In practice, the power delivered by the module is lower because of effects due to irradiance level, operating temperature, angle of incidence, spectral distribution of irradiance, and so on. Quantifying the relative importance of these various effects is a key interest of a simulation program, and is the object of this section.

Solar radiation

Solar radiation is the main influence on PV module output. Roughly speaking, module output is proportional to the irradiance level. (This is not true, however, in the presence of partial shading, as will be seen later). This 'proportionality' should not be interpreted in a true proportionality law. In practical terms only the short-circuit current is almost exactly proportional to irradiance. For the maximum power the relationship is more an affine one (i.e. linear with offset), as shown in Figure 2 which is derived from data measured by Kenny et al. (2003). Representing correctly the offset (i.e. predicting module performance at low light levels) is a major challenge.

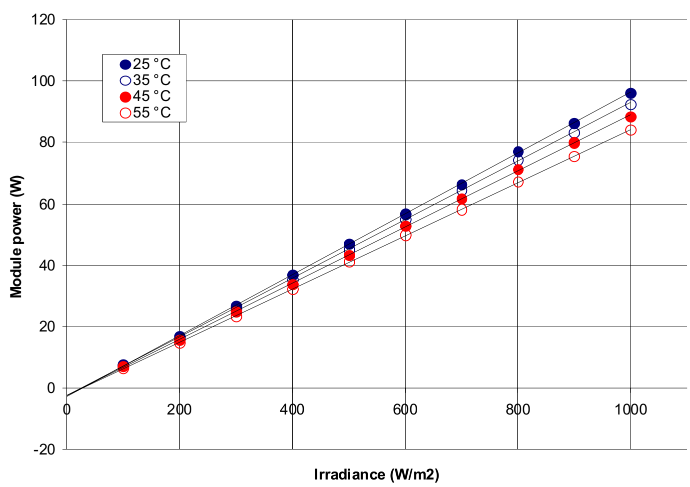

Fig 2 Power as a function of irradiance. Data from Kenny et al, 2003

Temperature

Temperature is the second most important effect. Typically voltage decreases with increasing temperature, and current increases (although slightly), the combined effect being that power decreases. Temperature coefficients for the maximum power are reported as 0.5 %/°C for poly Si and 0.25 %/°C for a Si (King et al., 1992; see also King et al., 2000); values of -0.4 %/°C are also reported (Sick and Erge, 1996) for c-Si, as well as values of 0.45 %/°C for c-Si and -0.22 %/°C for a-Si (Ransome and Wohlgemuth, 2002). A poly-crystalline module operating typically at 45 °C will therefore produce roughly 10% less power than predicted by its nominal STC rating.

The effect on annual energy production was found in King et al. (1992) to be between 1% and 6% for mc-Si and between 0% and 2% for a-Si. However this depends on many factors such as mounting structure and local wind conditions. The values may be higher for poorly ventilated building-integrated PV modules. Values up to 11% are reported in Xantrex (2001).

Angle of incidence

Optical losses vary with the angle of incidence of light striking the module. In particularly there are increased reflection losses at the module's air/glass interface when angles of incidence are above 60°. At very high angles of incidence the losses are very significant (approaching 100% at 90° incidence). However modules are often properly oriented (for example facing the equator with a tilt equal to the latitude) and for most hours receive light under an appropriate incidence angle, so over a whole year the decrease in energy production imputable to angle of incidence effects is estimated in the range 1% to 5%; and on a monthly basis, in the range 0% to 9% (King et al., 1992).

Spectral distribution

The response of solar cells varies depending on the spectral composition of incident light. For example amorphous Si cells respond better in the 'blue' part of the spectrum than in the 'red', and therefore will proportionally deliver more power in the middle of the day, when the sun is high in the sky and 'bluer', than in the early morning or late afternoon, when it is low on the horizon and therefore 'redder'. Similarly some modules will exhibit enhanced or reduced performance depending on the presence of clouds.

For individual hours these effects can range from +5 to -50% depending on module technology (King et al., 1992). However, as was the case for angle of incidence, these effects tend to be much lower when the sun is high in the sky, which is also when the module produces more energy; so over longer periods of time the effect is much smaller, and is reported in the range +1% to -4% on a monthly basis, and 0% to -3% on a yearly basis. Similar values can also be found in Nann and Emery (1992).

Spectral effects may be somewhat higher for amorphous silicon modules, as reported in Kenny et al. (2002); they are reported to be in the range ±7% on a monthly basis in Gottschalg et al. (2002).

Uncertainty in the output of crystalline PV modules

PV modules are normally rated by the manufacturer at a given wattage. However, there is no standard way of reporting module power in manufacturers' literature. Several possible effects should be taken into consideration:

- Brand new modules placed in the field usually see their maximum power decrease by a few percents within a few hours of exposure (see Cereghetti et al., 2001; some specifications sheets from manufacturers also mention this, but for commercial reasons give a period of months rather than hours).

- Modules are normally sorted in 'bins' according to their rated power - for example the best modules will be 100 W and the second-best will be 95 W (on binning see also Ransome and Wohlgemuth, 2002). A same batch can therefore contain modules rated within a certain fork, sometimes specified by the manufacturer in the form of a power tolerance (for example ± 5%, or +0/-5%).

- Cereghetti et al. (2001) show that power measurement of new modules was lower than nominal values stated by manufacturers in 12 out of 13 modules tested, with values lower by as much as 23%. The power rating declared by the manufacturer is sometimes 'fictitious'.

Uncertainty in the output of amorphous PV modules

Amorphous modules suffer the same uncertainties as their crystalline counterparts, however there is an added uncertainty that is inherent to the technology, namely that the module suffers from a light-induced degradation; this degradation results in an initial loss of efficiency reaching typically 20% within the first six months (King et al., 2000). Complicating the picture is that some of this initial loss may be reversible, for example the efficiency increases during hot periods due to self-annealing (which may induce variations of typically ±4% around the stabilized power, as shown in King et al., 2000).

Normally, manufacturers provide a 'stabilized' power rating for their modules, which takes into account the light-induced degradation. For that reason and because not all modules degrade at the same rate, it may happen that modules in the field will perform better than what they are rated at, as shown in Ransome and Wohlgemuth (2002). However the uncertainty as to what the module will deliver once installed is larger than for crystalline modules.

Ageing

The power rating of PV modules tends to degrade slowly over time. Depending on module technology, encapsulant technology, and so on, the ageing is more or less pronounced - for some newer technologies it may not be fully known. For crystalline silicon the power loss has been reported between 0.2% and 0.7% per year, with a typical value of 5.5% over the lifetime of the module (Dunlop, 2003). This is in addition to the initial light degradation mentioned earlier. Module manufacturers usually guarantee the power of their modules over their lifetime; for example, that the module power will not fall below 90% of its original value after 12 years and not below 80% after 25 years.

Mismatch

Because of slight variations in the electrical characteristics of the modules within an array, the maximum power output of the total PV array is always less than the sum of the maximum outputs of the individual modules. The associated losses are called mismatch losses. They are usually minimized by connecting modules with very similar characteristics, however mismatch losses of a few percent should be taken into account (CEC, 2001 recommends at least 2%) .

Soil and dirt

Soil and dirt accumulate on the front surface of the PV module and therefore limit the amount of solar radiation that reaches the solar cell. The amount of dirt will depend on factors such as presence of dust and pollution, amount and frequency of rain, and array orientation. The magnitude of this effect is hard to estimate; values range from 0 to 15% with a recommended value of 7% (CEC, 2001). Values up to 10% are reported in Sick and Erge (1996).

Snow

The accumulation of snow on the PV module may be a problem in some regions, particularly in Canada where some areas of the country are susceptible to heavy snow fall. Through natural heating, PV modules can often shed accumulated snow by themselves after a few days. However this is true only if (1) the accumulation of snow is not too important, so the PV module still receives enough sunlight to warm up, and (2) the slope of the PV array is steep enough, for example greater than 45 or 60°. If these conditions are not met the PV array may not produce any significant amount of power during those months with large amounts of snow.

Partial shading

Shading part of a PV module has a very dramatic effect on its power output. Shading even a small fraction (for example, 5%) of the module may result in a very large reduction (50% or more) of the module power. This is due to the fact that, in a string of cells connected in series, the cell with the lowest illumination determines the operating current of the whole string (this is compared in Sick and Erge (1996) to pressing a water hose tight at one point, preventing the flow of water in the whole hose). Furthermore, shaded cells may become reverse-biased and dissipate energy forced into them by other cells in the string, creating 'hot spots' which have the potential of thermally destroying the module. For those two reasons, the occurrence of shadows on PV modules should be avoided at all costs. This includes shading by utility poles, chimneys, trees, by other buildings or and by other parts of the same building.

Diodes and wiring

Losses due to blocking diodes and wiring are estimated around 3% (Xantrex, 2001; CEC, 2001), even for a very well-designed system.

Summary

The following table provides a summary of secondary effects in PV arrays, with an estimate of their effect on monthly energy production estimates. Similar tables can be found in Xantrex (2001) and King et al. (1992).

EFFECT	RANGE
Temperature	1% to 10%
Angle of incidence	1% to 5%
Spectral distribution	0% to -3%
Uncertainty in manufacturer's rating	0 to 5% or more
Ageing	5% over lifetime
Mismatch	2%
Soil and dirt	0 to 15%
Snow	Location dependent
Partial shading	Location dependent
Diodes and wiring	3%

THE ESP-R PV MODELS

Description

The ESP-r PV model is described in Kelly (1998) and in Clarke et al. (1997). The model actually comprises two models: a simple one based on a constant efficiency, and a more elaborate one based on an equivalent one-diode model.

Photovoltaics in ESP-r are modeled as an active material, which can be located at any node inside a construction. An example is shown in Figure 3; this example is taken from the choices of silicon PV modules proposed in ESP-r and corresponds to a BP Solar BP 585 module. The construction is simplified into a pane of 3 mm toughened low-iron glass, and a layer of ethylene vinyl acetate (EVA) and tedlar, which also represents the cells. For the purpose of the simulation, the active material (the silicon solar cell) is located at the middle node of the EVA/tedlar layer. The temperature of that node is assumed to be representative of that of the PV module, and solar radiation reaching the cell is set equal to solar radiation incident on the glazing system. Knowing temperature and solar radiation it is possible to calculate the power output of the PV cell. Since it is evacuated in the form of electric power, this power output is then subtracted from the nodal absorption of the incident radiation. The energy balance and heat flow calculation is handled by ESP-r, in the same way it would normally calculate heat transfer through a construction. This simulates quite effectively the absorption of solar radiation at the cell level and its diffusion as heat through the module assembly and, possibly, the envelope of the building.

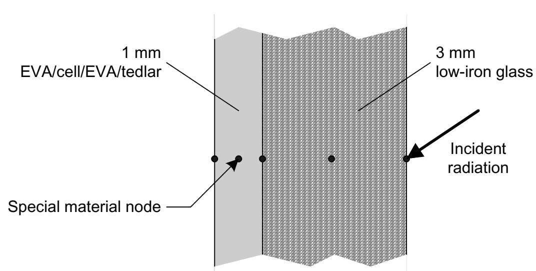

Fig 3 ESP-r model of a PV module

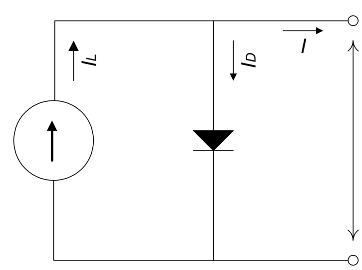

Fig 4 Equivalent one-diode circuit in ESP-r

If the module is modeled as an opaque construction, the part of incident radiation that is converted to electricity is deducted from the short-wave radiation absorbed at the front of the module. If the module is modeled as a transparent assembly, half of the converted radiation is deducted from short-wave radiation absorbed at the front and half from the short-wave radiation absorbed at the back.

When the simple PV model is used, the power output of the module is calculated based on a constant efficiency. In the more complicated crystalline silicon model, based on a model by Buresch (1983), the electrical behaviour of the module is modelled through the use of an equivalent circuit, shown in Figure 4. The equations describing the circuit include an explicit irradiance dependency; the diode is modelled as a thermally activated device (through an Arrhenius relation in the form exp(eV/kT) term, with

T the absolute temperature of the module, k the Boltzman constant, e the charge of the electron and V the voltage) to account for variations of module performance with temperature.

Discussion

The ESP-r photovoltaic model was developed for ease of use and has proved fit for that purpose on a number of occasions. The basic premises of the ESP r PV model are valid: the module can be modeled as a special material which takes away some of the heat transferred through it. However some of its aspects are somewhat too simplistic:

- Module power is calculated using solar radiation incident on the outside surface of the module assembly, rather than radiation at the active material node itself. It is true that electrical characteristics of the PV module entered by the user take into account light reflection on the front surface; but these characteristics are measured only under normal incidence. In practice solar radiation reaching the cell depends strongly on the angle of incidence of sunlight on the module. Since ESP r handles this kind of calculation quite well, solar radiation reaching the active material node itself should be used, rather than solar radiation on the outside surface. This would also help represent custom-made or architectural PV modules, for which the characteristics of the cell can be known but the assembly itself has not been tested.

- The Buresch model upon which the ESP-r model is based is too simplistic, particularly because it does not include a series resistance. The shape of the I-V curve in the absence of a series resistance may differ significantly from the real I-V curve, particularly in the right part of the curve (near the maximum power and open-circuit conditions). Figure 5 illustrates the influence of the series resistance on the shape of the I-V curve. A complete equivalent circuit, including series resistance, will be seen in Figure 6.

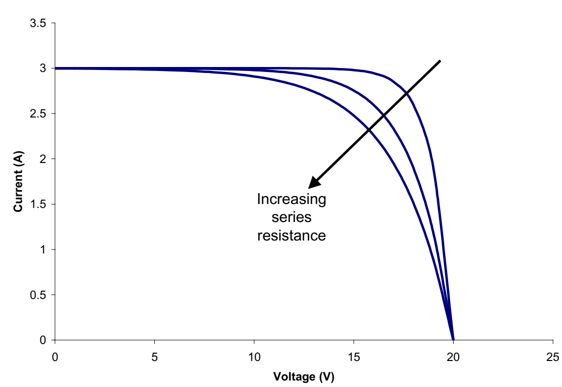

Fig 5 Effect of series resistance on the I-V characteristics of a solar cell

- The ESP-r model assumes a pre-determined temperature dependence of some of its parameters, particularly the diode current and the light generated current. However experience shows that such functional forms are somewhat simplistic and do not represent properly the module's behaviour (in part because there are many temperature-dependent effects in a module, not all of which follow simple physical laws; and in part because the equivalent circuit used is too simplistic and does not include the series resistance).

To alleviate these limitations, it is suggested to improve the ESP r PV model, as will be explained now.

PROPOSED PV MODEL

To improve on the PV model currently in ESP-r, a combination of three models is proposed:

- a simple model based on constant efficiency;
- an equivalent one-diode model;
- a more complicated model based on the Sandia model.

All three models would share the same method for temperature calculation, which is reviewed first; the models are then described in detail.

Temperature calculation

Most PV models described in the literature include a calculation of cell temperature, sometimes utilizing the concept of nominal operating cell temperature (NOCT). However it is probably best to leave temperature calculation to ESP-r itself, as is done now, since ESP-r is able to take into account not only the thermal characteristics of the module assembly itself, but also those of the module surroundings. For example a module will operate at a different temperature depending on whether it is mounted on a rack or integrated in a façade.

A problem arises from the temperature calculation, namely that the amount of heat released by the module to its surroundings depends on its efficiency, which itself depends on the module temperature, which cannot be known without calculating a heat balance with the surroundings. To avoid solving simultaneously for module temperature and efficiency, one can safely assume that temperature calculations can be uncoupled from power calculations, and calculate the module's temperature assuming that it operates a the maximum power point, as explained by Thevenard et al. (1992). An alternative is to use for the current time step the module temperature calculated at the previous time step. However this last approach should be discouraged, especially with hourly time steps, as PV modules have very little thermal inertia and, under changing conditions, the module temperature at the previous hour will likely be inconsistent with the radiation level for the current hour.

Simple model

The simple model based on a constant efficiency currently used in ESP-r is adequate. It would benefit, however, from using solar radiation actually reaching the active material, rather than incident on the outside surface, in order to properly take into account angle of incidence effects.

Equivalent one-diode model

A more complete model would be based on an equivalent one-diode circuit. This circuit should include the representation of the series resistance, which cannot be ignored without a significant loss of accuracy. Such a circuit is shown in Figure 6.
Several such models exist in the literature; two good examples, which derive the I-V curves in somewhat different ways, are the TRNSYS model (Duffie and Beckman, 1991) and the WATSUN-PV model (Thevenard et al., 1992). These models characterize the equivalent circuit using only parameters that are widely available to the users, such as the open-circuit voltage, short circuit current, and maximum power point voltage and current. They also explicitly take into account variation of these parameters with temperature. Temperature coefficients are routinely published in module specifications by manufacturers and can be used for that purpose. This explicit and empirical temperature dependency of the I-V curve varies according to module technology and better represents the behaviour of individual modules than the assumed functional form used by the present ESP r model.

Which of the two models should be implemented is mostly a matter of taste. The author has a slight preference for the WATSUN-PV model, which is based on simpler equations than the TRNSYS model. This latter model requires parameters such as the energy bandgap of the material or the number of cells in series, whereas the WATSUN-PV model limits itself to readily available quantities (short circuit current, open circuit voltage, maximum power point, and their variations with temperature). Both models have been found to model the behavior of PV modules to a reasonable degree of accuracy.

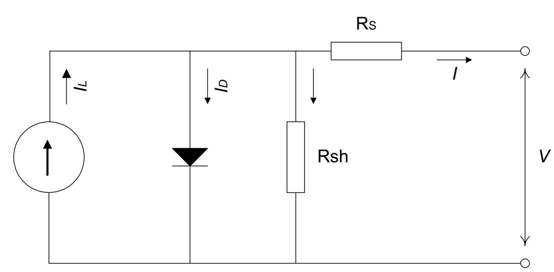

Fig 6 Proposed equivalent one-diode circuit

Sandia model

Finally the model developed by Sandia National Laboratories (King et al., 1998; King et al., 2004) could also be implemented. The Sandia model is a totally empirical model describing how the module's I V curve varies with parameters such as irradiance level, module temperature, angle of incidence, and spectral distribution (through a term dependent on air mass). The strength of this model is that it is fairly complete. It tries to take into account most of the phenomena that influence the power output of a PV module. According to its authors, it also compares favorably with field tests.

The model's main drawback is that it requires the experimental determination of a very large number of parameters (30 or so). No manufacturer provides that much information about their module. Sandia does make available a database of parameters for over 120 modules, however each new module coming to market needs to be tested according to their method to obtain the parameters required by the model. To be of any use, the incorporation of Sandia's model into ESP-r would also require the inclusion of the Sandia database.

Other common features of the models

All three models should be complemented by algorithms to take explicitly into account the various effects listed in the previous version of the paper: mismatch losses, losses due to soil, dirt or snow; and diodes and wiring. The algorithms could be as simple as derating short-circuit and maximum power point currents according to losses specified by the user. The models should also include (as is done now) a provision to reduce the output of modules in case of shading; such an algorithm would also benefit from an improvement of the shading algorithm in ESP-r.

BALANCE OF SYSTEM

Photovoltaic modules constitute an essential part of residential PV systems, but the balance of system requires also attention. Inverter efficiency, for example, should not be assumed constant, but be represented by an efficiency curve such as the one shown in Figure 7.

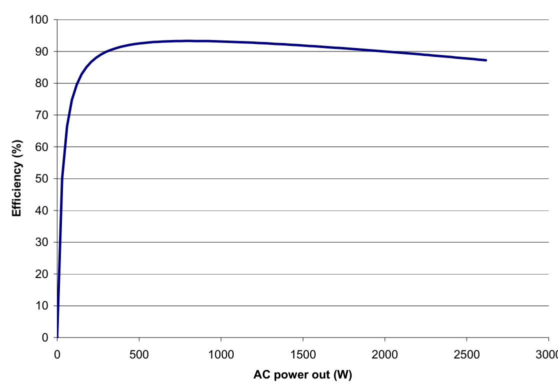

Fig 7 Typical inverter efficiency curve

CONCLUSIONS

The current ESP-r PV model is adequate to predict the impact of photovoltaics on the building's thermal energy balance, but may lack in accuracy to predict the energy production of the PV system. To achieve both goals at once it is suggested to improve or rewrite the PV models in ESP-r.

All phenomena affecting the power output of PV modules should be explicitly taken into account: solar radiation intensity, cell temperature, angle of incidence, spectral distribution, uncertainty in manufacturer's ratings, ageing, mismatch, soil and dirt, snow, partial shading, diodes and wiring. This would provide a more realistic estimate of the probable output of the PV system over its lifetime.

Three models should be implemented:

- A simple model based on constant efficiency (as is done now).

- A more complicated model based on a one-diode equivalent circuit such as the TRNSYS or WATSUN-PV models. The one-diode model should include the representation of the series resistance, which cannot be ignored without a significant loss of accuracy. The model should use parameters that are widely available to the user, and expend on the crystalline silicon model currently in ESP-r by providing explicit temperature of short circuit current, open-circuit voltage and maximum power point.

- The Sandia model could also be considered for inclusion. This would also require using Sandia's database of PV modules since most of the parameters required by the model are not available from manufacturer's data sheets.

The models should calculate the power output based on the absorbed solar radiation in the PV material layer, rather than at the outside surface. Module temperature calculations should be handled by ESP-r, as is done now. To simplify the calculation, module temperature can be safely uncoupled from power calculations; it is not recommended to use temperature from the previous time step (i.e. cell temperature for the current hour has to be consistent with the radiation level for the current hour, not for the previous hour).

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News from IBPSA affiliates

IBPSA-Japan

Yasuo Utsumi, Institutes of National Colleges of Technology, Japan

Japan branch has continued regular collaborative activities with related organisations. Topics have included building energy simulation, heat load, and building equipment behavior. There have been several meetings with AIJ, the Architectural Institute of Japan, and SHASE, the Society of Heating, Air-conditioning and Sanitary Engineers and others since last year.

We are also collaborating with a new project, BEST (Building Energy Simulation Tool). This was established in November 2005 under the auspices of IBEC, the Institute of Building Environment and Energy Conservation. It aims to provide a comprehensive building energy simulation tool that can be applied both to new construction and to the enormous amount of existing building stock. In order to achieve the targets agreed under the Kyoto protocol, Japan has to reduce energy consumption drastically, especially in the public welfare section.

The project comprises two major sections, one devoted to program development and the other to encouraging widespread uptake of BEST. At the moment the specification for BEST is still being prepared; substantive work is planned to continue until March 2008. An international symposium featuring BEST is planned in January 2007 as a joint enterprise with IBPSA-Japan.

Other IBPSA Affiliates

Five other Affiliates also have forthcoming events:

IBPSA-Canada: eSim2006, 3-5 May 2006

IBPSA-USA: SimBuild 2006, 2-4 August 2006

IBPSA-Netherlands+Flanders: symposium on how modelling can help prepare the architectural, engineering and construction sector for the future, 14 September 2006

IBPSA-Germany: BauSIM 2006 conference, 9-11 October 2006

IBPSA-Australasia: IBPSA Australasia 2006 conference, 20-21 November 2006

There is further information about all of these in Forthcoming Events beginning on page 8.

Late News

23-25 October 2006
Toulouse, France
www.eurosis.org

ESM 2006 European Simulation and Modelling Conference 2006 EUROSIS

CALL FOR PAPERS

The European Simulation and Modelling Conference is the original European international conference concerned with state of the art technology in modelling and simulation. ESM 2006 aims to provide an overview of academic research in the field of computer simulation. It is sponsored by the European Technology Institute and hosted by LAAS-CNRS (**www.laas.fr**).

A number of major tracks of simulation research are presented next to specific workshops, which capture the art and science of present-day simulation research.

All submissions will be peer-reviewed by at least three members of the International Program Committee. Accepted papers will be published in the conference Proceedings (both print and electronic format on the web), which will be copyrighted and widely disseminated. All talks and tutorials must be accompanied by a paper of between three to eight Proceedings pages. Contributions are solicited in the following general areas:

- Methodology and Tools
- Simulation and AI
- High Performance and Large Scale Computing
- Simulation in Education and Graphics Visualization Simulation
- Simulation in the Environment, Ecology, Biology and Medicine
- Analytical and Numerical Modelling Techniques
- Web Based Simulation
- Agent Based Simulation

- Workshop Simulation with Petri Nets
- Modelling and Simulation with Bondgraphs
- DEVS Workshop
- Fluid Flow Simulation Modelling Workshop
- SIMULA Workshop
- Complex Systems and Self-Organization Modelling

- Tutorials
- Student Papers
- Poster Sessions
- Partners for Projects Sessions
- Exhibition

REQUIREMENTS AND DEADLINES

The official conference language for all papers and presentations is English.

Only original papers which have not been published elsewhere will be accepted for publication.

Send all submissions in an **electronic form only** in uuencoded, zipped Microsoft Word format, PDF or Postscript format indicating the designated track and type of submission (full paper or an extended abstract) to **philippe.geril@biomath.ugent.be**. Please include your name, affiliation, full mailing address, telephone/fax number and email address. Email submissions with 'ESM2006' and the designated track in the subject of your email, or use the abstract submission page on the web site. The deadlines are:

Early bird submission:	15 June 2006
Submission deadline:	1 July 2006
Late submission deadline:	15 August 2006

For the latest information, visit **http://biomath.ugent.be/~eurosis/conf/esm/esm2006/** or **www.eurosis.org.**