Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Département fédéral de l'environnement, des transports,
de l'énergie et de la communication DETEC

Ofiice fédéral de l'énergie OFEN

Rapport final

IEA ECBCS Annex 51

Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers

Lausanne, Novembre 2012.

Mandant:
Office Fédéral de l'Energie (OFEN)
Programme de recherche *Energie dans les Bâtiments*
CH-3003 Berne
www.bfe.admin.ch

Cofinancement:
Ecole Polytechnique Fédérale de Lausanne (EPFL)
CH-1015 Lausanne

Mandataire:
Laboratoire d'Energie Solaire et de Physique du Bâtiment (LESO-PB)
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Bâtiment LE, Station 18
CH-1015 Lausanne
http://leso.epfl.ch

Auteurs:
Prof. Dr Jean-Louis Scartezzini, LESO-PB/EPFL, Lausanne
Prof. Dr Darren Robinson, LESO-PB/EPFL, Lausanne
(Until Oct. 2011, at present at University of Nottingham/UK)
Urs Wilke, LESO-PB/EPFL, Lausanne

Responsable de domaine de l'OFEN: Andreas Eckmanns
Chef de programme de l'OFEN: Rolf Moser
Numéro du contrat et du projet de l'OFEN: 154382 / 103322

Abstract

The goal of IEA ECBCS Annex *51 Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers* is to promote the design of long-term energy conservation and greenhouse gases (GHG) mitigation strategies, as well as their continuous optimization at the communities and/or municipality districts level.

The audience addressed by IEA Annex 51 included urban planners and stakeholders taking care of financial investments in cities (construction and renovation of buildings, infrastructures and commercials estates), as well local administrations. Forty-three international experts, issued from twelve countries of Europe, North America and Asia collaborated for that purpose in a worldwide research network.

The Swiss contributions to IEA ECBCS Annex 51 were mainly built around the participation of the Solar Energy and Building Physics Laboratory (LESO-PB) of Ecole Polytechnique Fédérale de Lausanne (EPFL), essentially focused on SubTasks A and D. A restricted participation was planned for the other SubTasks due to the limitation of available funding. The major part of the knowledge transfer and dissemination to the target group was achieved through the publication of a *GuideBook to a Successful Urban Energy Planning*.

IEA ECBCS Annex 51

Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers

1. Objectives and Methodology

1.1 Objectives

The goal of IEA ECBCS Annex *51 Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers* is to promote the design of long-term energy conservation and greenhouse gases (GHG) mitigation strategies, as well as their continuous optimization at the community and/or municipality district level.

A holistic approach was considered, which includes short-term and long-term measures such as the generation, supply, transport and use of energy in city districts, in order to achieve an optimal efficiency for the community. The use of state-of-the-art management methods involving the delegation of responsibilities, marketing and conflicts resolution was also envisaged in the approach.

Accordingly, IEA Annex 51 had the following specific objectives, defined in the corresponding Work plan (cf. www.annex51.org):

- To promote an integrated multidisciplinary approach as a basis for providing computer tools, guidelines, recommendations and best-practice case studies for urban designers and stakeholders;

- To enable communities to set-up sustainable and urban energy infrastructure and specify the actions necessary to reach challenging GHG mitigation targets;

- To transfer useful experiences to other communities and enable them to establish their own proper sustainable strategies to reach the desired mitigation targets.

The audience addressed by IEA Annex 51 includes the urban planners and stakeholders taking care of financial investments in cities (construction and renovation of buildings, infrastructures and commercials estates), as well as local administrations. The focus was placed on the exploration and identification of measures facilitating the implementation of technical innovations within communities, as well as on their development.

1.2 Methodology

In order to achieve an efficient organization, the IEA Annex 51 was subdivided into four different SubTasks, described as follows:

- SubTask A: *Methods and Design Tools for Energy Efficient Conversion*
- SubTask B: *Case Studies I - Local Energy Planning for City Quarters or Neighbourhoods and Implementation*
- SubTask C: *Case Studies II - Integrated Energy Planning for Communities and Implementation Strategies*
- SubTask D: *Knowledge Transfer and Dissemination*

Figure 1 gives an overview of the structure of IEA Annex 51 as well as a schematic view of the expected data and information flows.

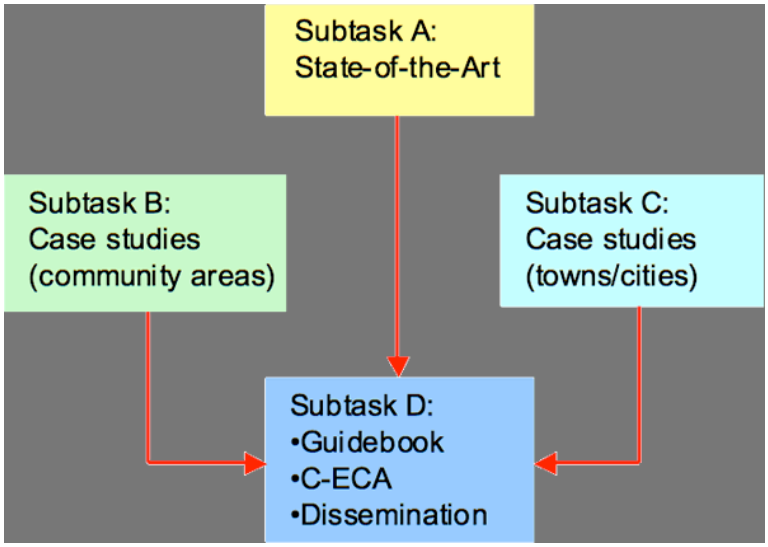

Figure 1: Schematic representation of the data and information flows in IEA Annex 51

IEA Annex 51 was expected to reach the following main achievements over a four years period extending from 2009 to 2012:

- State-of-the-art review of planning methods, tools and models for urban energy planning;
- Description of state-of-the-art energy efficient projects at neighbourhood scale;
- Presentation of case studies involving the use of holistic methods for long-term energy planning of cities;
- Presentation of case studies and strategic guidance for urban decision makers;
- Implementation of successful urban energy strategies among the targeted audience of IEA Annex 51 (stakeholders of local administrations, city developers and urban planners).

According to the usual practice at the International Energy Agency, IEA Annex 51 has been steered by an Operating Agent, Dr Reinhard Jank from Volkswohnung GmbH in Karlsruhe/Germany, as well as four SubTasks leaders. All contact addresses of the hereunderlisted persons as well as of other national contact persons can be found on the Annex Website (cf. www.annex51.org).

2. Research Activities

2.1 SubTask A: *Methods and Design Tools for Energy Efficient Conversion*

Objectives

The objective of SubTask A is to provide a state-of-the-art review of planning methods, tools and models for urban energy systems, as well as of instruments which are relevant for their implementation among local administrations, city developers and stakeholders within the participating countries.

***SubTask Leader*:** Andreas Koch, European Institute for Energy Research (EIFER), France.

Projects

SubTask A comprised the following main items and research projects:

- Success stories for community energy planning including principles, methods and implementation strategies;
- Review of data acquisition methods and monitoring tools for energy and GHG emissions of municipalities;
- State-of-the-art review of urban energy systems models and tools including conventional planning methods;
- Description of the legal framework for urban energy and climate change policies;
- Comparison and evaluation of approaches in participating countries;
- Evaluation of building related sustainability assessments methods issued from other IEA Annexes including their transferability at the community level.

Outcomes

The state-of-the-art review is essentially made of two parts. The first one is aiming at a better understanding of the existing community energy planning process (i.e. for conventional projects). The second part relates to a review of modelling tools to support the community energy planning. This involves two aspects:

- For the short term, existing tools were reviewed, so that recommendations can be made for the selection of the most appropriate tools for particular type of energy modelling problems;
- For a longer term, potential users' requirements of an "ideal" community energy modelling tool were defined and used to inform future research and development activities in order to insure that future tools meet users' requirements.

2.2 SubTask B: *Case Studies I - Local Energy Planning for City Quarters or Neighbourhoods and Implementation*

Objectives

The objective of SubTask B is to document and evaluate district refurbishment projects, new settlements or a combination of both. Energy planning projects, which have been initiated within cities in 2009 and/or completed during the duration of IEA Annex 51, were considered; in both cases, technical innovations and novel methodological approaches are subject of planning and implementation.

***SubTask Leader*:** Prof. Dr Bahram Moshfegh, Linköping University, Sweden.

Projects

SubTask B comprised the following main items and research projects:

- Integration of long-term concepts for energy efficient neighbourhoods and city districts;
- Planning and development of new sustainable settlements.

Outcomes

The purpose of SubTask B is to document and evaluate the effectiveness of case studies, which demonstrate an innovative community energy planning process and/or innovative technologies; both should have ambitious targets regarding the net energy demand of neigh-

bourhoods and city districts. These small-to-medium scale projects were either in the planning stage or in the implementation stage in order to represent the real state-of-the-art at the time at which results were published.

2.3 SubTask C: *Case Studies II - Integrated Energy Planning for Communities and Implementation Strategies*

Objectives

The objective of SubTask C is to document methods and tools for long-term energy planning of cities and towns settlements. The goal it so initiate the necessary transition process in the different fields that are affected by the implementation strategy.

***SubTask Leader*:** Jacques Kimman, SenterNovem, The Netherlands.

Projects

SubTask C comprised the following main items and research projects:

- Implementation of energy demand and performance evaluation methods of decentralized energy systems over whole cities in the framework of case studies;
- Development of urban planning methods and tools for optimal combination of measures aiming at long-term energy consumption targets;
- Development of tools for monitoring of energy and GHG emissions at the city level;
- Development of decision methods and tools supporting stakeholders for implementation of long-term urban energy strategies.

Outcomes

SubTask C is aiming at the understanding of the effectiveness of citywide strategies for mitigation of net energy demand and GHG emissions. The available predictive tools, with which alternate strategies may be evaluated, as well as the tools and techniques available for measuring the effectiveness of adopted strategies, were considered.

2.4 SubTask D: *Knowledge Transfer and Dissemination*

Objectives

The main objective of SubTask D is to set-up the instruments and means that are necessary to enable the target group to establish and implement successful urban design strategies.

***SubTask Leader*:** Heike Erhorn-Kluttig, Fraunhofer Gesellschaft Stuttgart, Germany.

Projects

The objectives have been addressed through the following main items and projects:

- Elaboration of recommendations for a successful Urban Energy Planning;
- Design and set-up of a District Energy Concept Adviser;
- Dissemination of IEA Annex 51 results.

Outcomes

The expected outcomes of SubTask D are threefold, comprising: i) a *Guidebook to a Successful Urban Energy Planning*, which synthesizes in a practical way the results of SubTask A, B and C and targets local experts and urban planners, ii) a new strategic community energy planning tool for the scale of neighbourhoods and districts, as well as iii) the dissemination of these outcomes to the target group.

3. Swiss Contributions to IEA Annex 51

The Swiss contributions to IEA Annex 51 were mainly built around the participation of LESO-PB/EPFL, whose involvement was essentially focused on SubTasks A and D. Although a minimal participation was also planned for SubTasks B and C, funding limitations impeded further contributions to be brought to the Annex. This was partly compounded by the move of Darren Robinson to University of Nottingham (UK) in October 2011, following his promotion as Full Professor, which contributed also to disrupt the running of several urban projects in relation with Annex 51.

3.1 Contribution to SubTask A

A standardized methodology for documentation and evaluation of case studies, issued from a study tour of exemplary sustainable community projects in Northern Europe undertaken by Darren Robinson, was brought to IEA Annex 51. The methodology, which includes structured interviews and questionnaires, was made available to the Annex team in order to respond to its specific objectives.

This methodology was adapted by the SubTask coordinator as a basis for cataloguing exemplary case studies at the scale of the urban neighbourhood. Using this new methodology the LESO-PB/EPFL catalogued the EcoParc neighbourhood in the city of Neuchâtel. This involved documenting:

- The development and its energy concepts;
- The energy and environmental performance analyses that were undertaken;
- The political and financial landscape in which the project was developed.

Addressing this also involved completing a series of structured interviews.

3.2 Contribution to SubTask B

It was initially planned and agreed that the City of Lausanne's *Métamorphose* project would form the basis of the LESO-PB/EPFL contribution to this SubTask. But as the Annex progressed it became apparent that the timings of that project and of the Annex were incompatible, the project lagging too far behind the latter. It was eventually decided that Switzerland should be exempted from contributing a Case Study to SubTask B. Nevertheless, useful methodological contributions were made.

3.3 Contribution to SubTask C

As part of the SNSF research project *An investigation of strategies leading to a 2000W City based on a bottom-up model of urban energy flows*, the LESO-PB/EPFL has been working closely with the municipality of the City of Zurich to inform the development of its initial model as well as to define the scenarios to be tested by it (cf. Figures 2 and 3).

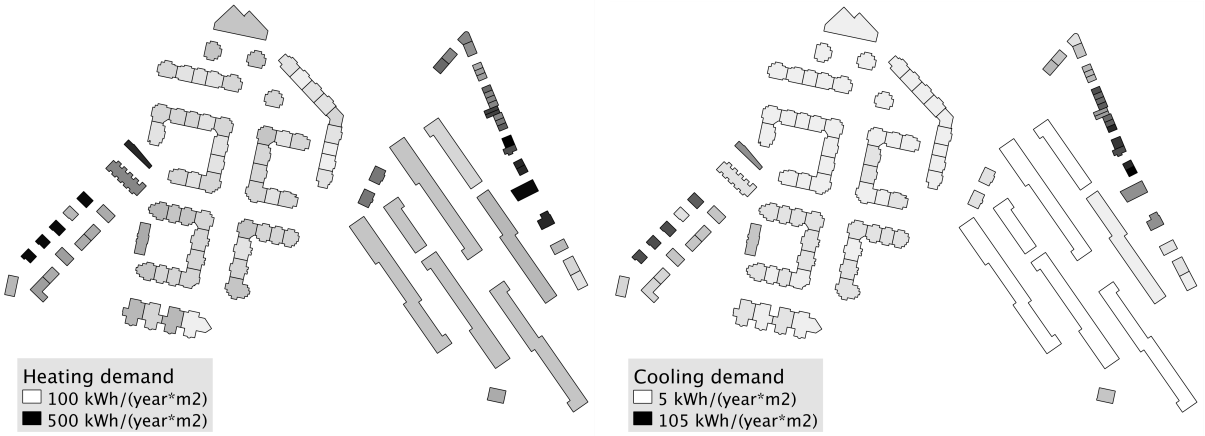

Figure 2: Simulated heating and cooling demand of the buildings in the Alt-Wiedikon neighbourhood, relative to the housing, office and commercial surfaces (continuous scale). Buildings without treated floor area are not included.

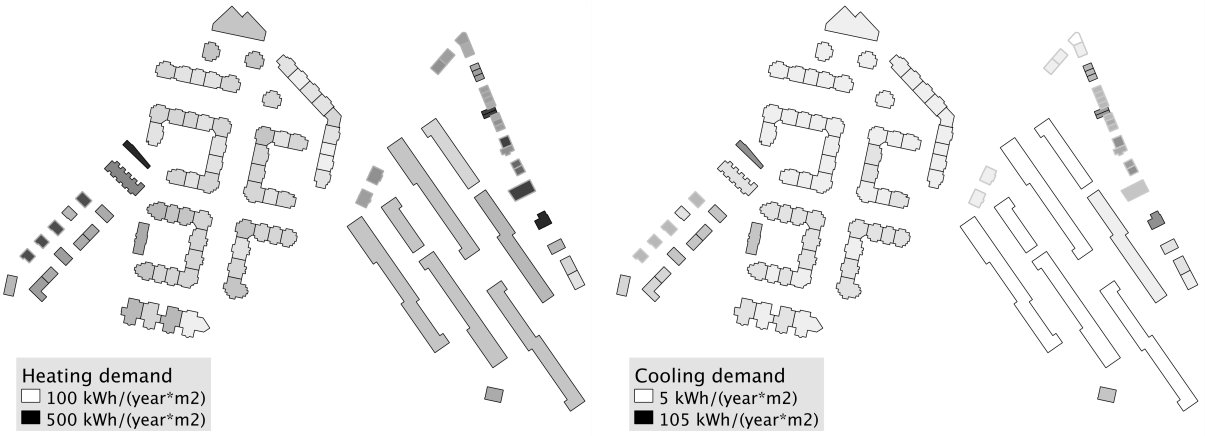

Figure 3: Simulated heating and cooling demand of the buildings for the scenario. Insulated buildings are represented with a grey border.

As part of this simulation exercise, the energy planning activities of the City of Zürich in pursuance of its "Energiestadt® Gold" Award, as well as its plans in pursuance of the achievement of 2kW City status, were documented. This work, which is also described in a paper presented at WREC 2011, was made available as a contribution to SubTask C Case Studies.

3.4 Contribution to SubTask D

As for each partner of Annex 51, the Swiss contribution to knowledge transfer and dissemination of results, originally planned in SubTask D, was indirectly made through the contributions to SubTasks A to C. Comments on drafts, as well as the writing of a chapter of the *Guidebook to Successful Urban Energy Planning* coordinated by Darren Robinson, made up the most significant part of the Swiss contribution to SubTask D.

Within this context, a review of existing community energy planning tools, elaborated for the book *Computer Modelling of Sustainable Urban Design* published in 2012 by Earthscan Press, was also made available for Annex 51. Their detailed description was used to assist with the formulation of a consistent methodology for the evaluation of existing tools, considering their functionality, usability and fitness for purpose.

These actions were completed by the design and development of two Web-based questionnaires, one destined to the developers and the other to the users of urban modelling software accessible at http://leso.epfl.ch/frmusers. A part of the latter is illustrated in Figure 4.

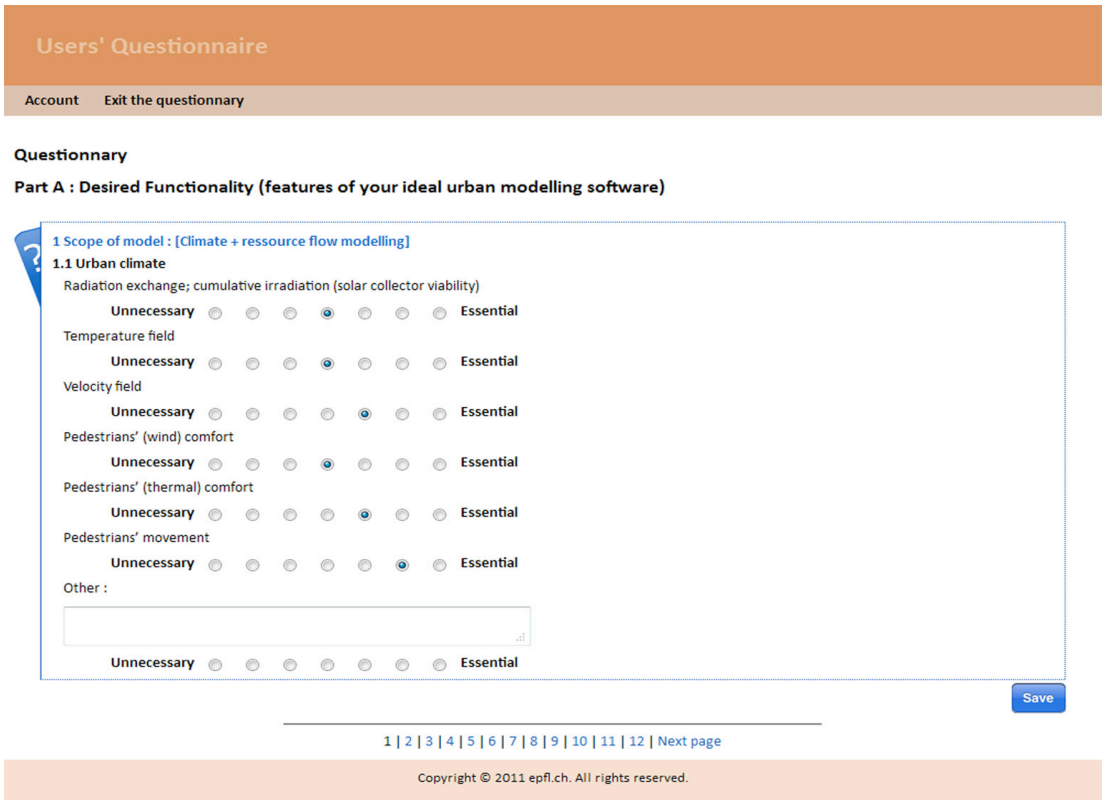

Figure 4: Web-based questionnaire disseminated to the target group of IEA Annex 51

The main aims of the analysis of returns from these questionnaires were to provide a basis for users to select the software best adapted to their needs and also to define the requirements of an “ideal” urban modelling tool; this is essentially a requirements specification for future urban modelling tool development efforts.

This was complemented by the completion of a questionnaire describing the legal, financial and planning instruments employed in Switzerland, prepared by Planair SA Ingénieurs-conseil under sub-contract to the LESO-PB/EPFL for another Chapter of the Guide Book.

4. Conclusion and Outlook

The IEA ECBCS Annex 51 is seeking to promote the design of long-term urban energy conservation and greenhouse gases mitigation strategies, as well as their continuous optimization at the communities and/or municipality districts level.

Forty-three international experts, issued from twelve countries of Europe, North America and Asia collaborated for that purpose in a worldwide research network (cf. List of participants, www.annex51.org). The major part of the knowledge transfer and dissemination to the target group was achieved through the publication of a Guide Book.

IEA Annex 51, extending over the period of the years 2009 – 2012, was subdivided into four different SubTasks:

- SubTask A**:** *Methods and Design Tools for Energy Efficient Conversion*
- SubTask B**:** *Case Studies I - Local Energy Planning for City Quarters or Neighbourhoods and Implementation*
- SubTask C**:** *Case Studies II - Integrated Energy Planning for Communities and Implementation Strategies*
- SubTask D**:** *Knowledge Transfer and Dissemination*

The Swiss contributions to IEA Annex 51 were mainly built around the participation of the Solar Energy and Building Physics Laboratory (LESO-PB) of Ecole Polytechnique Fédérale de Lausanne (EPFL), essentially focused on SubTasks A and D.

The contribution to SubTask A related mainly to the development of a standardized methodology for documentation and evaluation of case studies, based on results from recent research conducted at the LESO-PB/EPFL, as well as the application of this methodology to document the EcoParc project in Neuchâtel.

SubTask B benefited from a minor methodological contribution with respect to the documentation of larger scale case studies.

The case study of the City of Zurich was presented as exemplary practice for SubTask C in medium and far range city-scale energy planning. This also benefited from work conducted as part of the SNSF Project *An investigation of strategies leading to a 2000W City based on a bottom-up model of urban energy flows*.

The contribution to SubTask D required the largest efforts and dedicated manpower in comparison to the other SubTasks. This is mainly linked to the publication of a GuideBook, which represents the main knowledge transfer and results dissemination instrument of Annex 51.

As part of this effort a Web-based questionnaire was designed and developed to support the evaluation of modelling tools' fitness for purpose and the requirements for the next tools generation. In addition, existing literature on urban energy and environmental modelling tools was also reviewed; this benefitting from the editing of the book *Computer Modelling for Sustainable Urban Design* by Darren Robinson.

Three key issues, requiring further research to accomplish substantial energy savings in urban sites, were identified for that purpose within IEA Annex 51:

- To promote an integrated multidisciplinary approach as a basis for providing computer tools, guidelines, recommendations and best-practice case studies for urban designers and stakeholders;

- To enable communities to set-up sustainable reliable urban energy infrastructures and specify the proper actions necessary to reach challenging GHG mitigation targets;

- To transfer useful experiences to other communities and enable them establishing their own proper sustainable strategies to reach the desired targets.

These issues will be hopefully addressed by upcoming national and international dissemination and technology transfer platforms imbedded within novel sustainable urban policies.

5. References

Scientific Publications issued from IEA Annex 51

U. Wilke, M. Papadopoulou, D. Robinson, Towards a 2kW city, the case of Zürich.
In *Proc. of World Renewable Energy Congress 2011*, Linköping, Sweden, May 8-13 (2011)

IEA ECBCS Annex 51 Case Studies and Strategic Guidance for Urban Decision Makers, SubTask A Final Report *Description of the State-of-the-art of EnergyEefficient Projects on the Scale of Neighbourhoods*, 89 p., International Energy Agency, Paris (2011)

All reports available on the IEA Annex 51 Website: www.annex51.org

Scientific Publications related to IEA Annex 51

Refereed Journals

Haldi F., Robinson D., On the behaviour and adaptation of office occupants,
In *Building and Environment*, Vol. 43, p. 2163-2177 (2009)

Haldi F., Robinson D., Interactions with window openings by office occupants,
In *Building and Environment*, Vol. 44, num. 12, p. 2378-2395 (2009)

Kämpf J., Wetter M., Robinson D., A hybrid CMA-ES and DE optimisation algorithm with application to solar energy potential, In *Applied Soft Computing*, 2(9), p.738-745 (2009)

Haldi F. Robinson D., On the unification of thermal perception and adaptive actions, In *Building and Environment*, 45(11), p. 2440-2457 (2010)

Haldi F., Robinson D., Adaptive actions on shading devices in response to local visual stimuli
In *Journal of Building Performance Simulation*, 3(2) p. 135-153 (2010)

Kämpf J., Wetter M., Robinson D., A comparison of global optimization algorithms with standard benchmark functions and real-world applications using EnergyPlus, In *Journal of Building Performance Simulation*, 3(2) p. 103-120 (2010)

Kämpf J., Montavon M., Bunyesc J., Bolliger R., Robinson D., Optimisation of buildings' daylight availability, In *Solar Energy* 84(4) p. 596-603 (2010)

Kämpf J., Robinson D., Optimisation of building form for solar energy utilisation using constrained evolutionary algorithms, In *Energy and Buildings*, 42(6) p. 807-814 (2010)

J. H. Kämpf and D. Robinson. Optimisation of Urban Sustainability, In *Computer Modelling for Sustainable Urban Design*, p. 203-258 (2011)

Robinson D., Haldi F., Kämpf J. and Perez D., Computer Modelling for Sustainable Urban Design, In *Computer Modelling for Sustainable Urban Design*, p. 113-147 (2011)

Rasheed A., Robinson D., Clappier A., Narayanan C., Lakehal D., Representing complex urban geometries in mesoscale modeling, In *International Journal of Climatology* 31: 289-301 (2011)

Haldi F., Robinson D., Modelling occupants' personal characteristics for thermal comfort prediction, In *International Journal of Biometeorology*, 55(5), pp. 681-694 (2011)

Wilke U., Haldi F., Scartezzini J.-L. and Robinson D., A bottom-up stochastic model to predict building occupants' time-dependent activities, In *Building and Environment* 2012 (accepted).

Wilke U., Haldi F., Scartezzini J.-L. and Robinson D., Approaches to predict households' ownership of electrical appliances, In *Applied Energy 2012* (submitted).

Refereed International Conferences

Filchakova N., Robinson D., Thalmann P., A model of whole-city housing stock and its temporal evolution, In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Haldi F., Robinson D., A comprehensive stochastic model of window usage: theory and validation, In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Haldi F., Robinson D., A comprehensive stochastic model of blind usage: theory and validation, In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Kämpf J., Robinson D., Optimisation of urban energy demand using an evolutionary algorithm, In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Rasheed A, Robinson D., Multiscale modelling of the urban climate
In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Rasheed A, Robinson D., On the effects of Complex Urban Geometries on Mesoscale Modeling, In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Robinson D., Haldi F., Kämpf J., Leroux P., Perez D., Rasheed A., Wilke U., From the neighbourhood to the city: resource flow modelling for urban sustainability,
In *Proc. CISBAT 2009 Conference*, p. 445-450, Lausanne, September 2-3 (2009)

Robinson D., Quiroga C., Sustainable masterplanning in practice: evaluation and synthesis
In *Proc. CISBAT 2009 Conference*, p.397-402, Lausanne, September 2-3 (2009)

Robinson D., Haldi F., Kämpf J., Leroux P., Perez D., Rasheed A., Wilke U., City-Sim: Comprehensive micro-simulation of resource flows for sustainable urban planning,
In *Proc. 11th IBPSA Conference Building Simulation*, Glasgow, July 27-30 (2009)

Haldi F. Robinson D., Results from the monitoring of indoor environment and occupant perceived productivity in office buildings, In *Proc. Adapting to change: new thinking on comfort,* Windsor UK, April (2010)

Haldi F. Robinson D., On the unification of thermal perception and adaptive actions In *Proc. Adapting to change: new thinking on comfort*, Windsor UK, April (2010)

Haldi F., Pröglhöf C., Mahdavi A., Robinson D., The double blind verification of a comprehensive window opening model, In Proc. *BauSim 2010*, Vienna (2010)

Haldi F., Robinson D., The impact of occupants' behaviour on urban energy demand, In *Proc. BauSim 2010*, Vienna (2010)

Kämpf J., Robinson D., Optimisation of solar energy utilisation potential in the urban context In *Proc. SEUS - Solar Energy at Urban Scale*, Compiègne, France, 25-26 May (2010)

Robinson, D., Solar radiation modelling for urban environments, In *Proc. SEUS - Solar Energy at Urban Scale*, Compiègne, France, 25-26 May (2010)

Pol O., Robinson, D., Impact of Urban morphology on building energy needs: A review on knowledge gained from modeling and monitoring activities, In *Proc. CISBAT 2011 Conference*, Lausanne, September 14-16 (2011)

Robinson D., Wilke U., Haldi F., Multi agent simulation of occupants' presence and behaviour, In *Proc 12th Conference of International Building Performance Simulation Association*, Sydney, 14-16 November (2011)

Wilke U., Haldi F., and Robinson D., Stochastic Activity Modelling in Residential Buildings, *In Proc. CISBAT 2011 Conference*, Lausanne (2011)

U. Wilke, F. Haldi, and Robinson D., A model of occupants' activities based on time use survey data, *In Proc. Building Simulation 2011*, Lausanne (2011)

Robinson D., Wilke U. and Haldi F., Multi Agent Simulation Of Occupants' Presence And Behaviour, *In Proc. Building Simulation 2011*, Lausanne (2011)

Books

D. Robinson (Ed.). D. Robinson, A. Rasheed, M. Bruse, F. Haldi, J. Kämpf, D. Perez, K. Axhausen, F. Flourentzou, M. Batty, *Computer Modelling for Sustainable Urban Design*. Earthscan, London, Washington, DC (2011)