Available online at www.sciencedirect.com
SciVerse ScienceDirect
Energy Procedia 30 (2012) 495 – 504
Energy Procedia

SHC 2012

A review of solar cooling technologies for residential applications in Canada

Christopher Baldwin[a]*, Cynthia A. Cruickshank[a]

[a]*Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, K1S 5B6, Canada*

Abstract

In the last two decades, the demand for residential cooling has increased exponentially, creating a significant demand on the electrical grid during the summer months. Between 1990 and 2008, the total Canadian residential floor area that requires cooling has almost tripled, while the total energy consumed for space cooling has more than doubled. The implementation of solar cooling systems could assist in reducing this energy consumption, and consequently, reduce greenhouse gas emissions released into the atmosphere as a result of the generation of the required electricity to power typical air conditioners. This paper presents a review of the solar cooling technologies that have been developed and implemented for use in residential and commercial applications. Related work conducted under the International Energy Agency is also described and a review of cooling installations both worldwide and Canada are discussed.

Selection and/or peer-review under responsibility of PSE AG

Keywords: Solar cooling; absorption chiller; thermal energy; literature review; thermal storage; solar energy

1. Introduction

In the last two decades, the demand for residential cooling has skyrocketed, creating an increasingly large demand on the electricity grid during the summer months. Between 1990 and 2008, the total cooled residential floor space in Canada has almost tripled from 267 million square meters to 749 million square meters, while the total energy consumed for space cooling has more than doubled in the same time period [1]. This has subsequently caused the amount of greenhouse gases released, as a result of the production of the required energy to meet the residential cooling demand, to double.

* Christopher Baldwin
E-mail address: christopherbaldwin@cmail.carleton.ca.

1876-6102 © 2012 The Authors. Published by Elsevier Ltd.
Selection and/or peer-review under responsibility of PSE AG
doi:10.1016/j.egypro.2012.11.059

Due to Canada's climate, space cooling only accounts for 1.5% of the total secondary energy consumption and 4% of the electricity consumed by residential buildings [1]. This demand, however, places a significant peak load on the electricity grid during hot summer afternoons and early evenings. To meet this peak demand, many provinces in Canada use power plants to generate electricity from fossil fuels (e.g., natural gas and coal), which produce large quantities of greenhouse gases [2]. In Ontario, up to 50% more carbon dioxide is released per unit of electricity produced in the summer months when compared to the winter months [3]. As a result, space cooling is responsible for a disproportionately large share of greenhouse gases released by the residential sector. A promising solution that can reduce the amount of energy consumed for space cooling and consequently reduce the amount of carbon dioxide released into the atmosphere is through the use of solar cooling systems.

This paper indicates various solar cooling methods currently in use for residential applications, including desiccant based systems and thermally driven chillers. In addition, a literature review is presented and describes previous solar cooling work, which includes studies conducted under Task 25 and Task 38 of the Solar Heating and Cooling Programme of the International Energy Agency. Finally, the paper will conclude by discussing some of the current research being conducted worldwide, with an emphasis on the implementation of small scale solar cooling systems that could be used for residential applications, as well as some current solar cooling installations, in Canada.

2. Background

Solar cooling consists of using thermal energy collected from the sun as the principal energy input for the cooling system to cool and dehumidify the space [4]. This replaces the existing electrical power input typically required in a vapour compression refrigeration cycle. The benefit of this system is that it has the potential to reduce the amount of electricity used (and carbon dioxide produced from the generation of electricity) during Canada's hot summer months when the demand on the power grid is at its highest. These systems can be effective as the availability of solar radiation coincides with the energy demands imposed on buildings by cooling loads, allowing for the greatest amount of cooling to be generated when it is needed most [5].

In Canada, our energy demand is dominated by our heating loads during the winter months. To meet these demands using solar thermal energy, large collector arrays are typically sized in order to provide sufficient heat. During the summer months however, these collectors continue to capture large quantities of solar thermal energy that, if not used, could damage the system. This allows for the optimal integration of solar heating and cooling systems with a single collector array being used to meet both heating and cooling demands of a space [5].

A complete solar cooling system consists of many individual components, each working together to provide cooling, but each serving their own purpose within the system. Typical solar cooling systems are comprised of solar collectors, a heat rejection loop, and a thermal energy storage. Solar collectors are used to capture solar energy, and the type of collector selected for a solar cooling system is based on the type of process and the temperature of the required heat input. Lower temperature applications often use flat plate collectors, while evacuated tube collectors and parabolic troughs are typically selected for applications requiring higher temperatures [6]. Most solar cooling applications also require a heat rejection loop or external heat dump, typically in the form of a cooling tower. This is critical for removing excess heat created from the thermodynamic processes used in solar heating. Lastly, to increase the effectiveness of the solar cooling system, a thermal storage is generally needed to store energy for use when the solar collectors are not providing adequate energy for the cooling process [6]. This typically occurs at night when solar energy is unavailable, or during cloudy days when the amount of solar radiation reaching the collectors is greatly reduced. Thermal storage systems can be achieved by: using a hot storage, generally by storing water at high temperatures; through the use of a cold storage tank, where water or other liquid is kept at a low temperature; and/or using ice to provide cooling as required at a later time [7].

3. Methods of solar cooling

When cooling a space or building using solar energy, there are two methods that have been commonly implemented. The first method involves the use of a desiccant material in a cycle that directly conditions the air, and the second involves the use of a thermally driven chiller, typically using an absorption or adsorption process to create chilled water that can be used directly in a conventional air handler unit [4]. Both methods are described below.

3.1. Desiccant based system

A desiccant based solar cooling system directly conditions incoming ventilation air. The process consists of three stages: the first stage includes dehumidifying the incoming air using either a solid or liquid desiccant (which absorbs moisture); the second stage involves recovering the sensible heat from the outgoing exhaust air; and the third stage involves using an evaporative cooling process to cool the air to the desired temperature [5]. The desiccant is subsequently regenerated using solar thermal energy (thereby removing water from the desiccant) [5]. Desiccant systems are most effective in temperate climates as the dehumidification of the air must be effective enough to allow for evaporative cooling to take place [4].

Desiccant based systems can also be effective when providing only dehumidification to the incoming ventilation air before the air enters the traditional air conditioning system, which would subsequently cool the air to the desired temperature [8]. These systems function by bringing the incoming ventilation air in contact with a concentrated liquid desiccant solution [8]. The concentrated desiccant absorbs moisture from the air. The diluted desiccant solution is then pumped to a regenerator where solar thermal energy is used to evaporate out the moisture and subsequently re-concentrate the desiccant [8]. This system is ideally suited for buildings in North America where high ventilation rates exist, as latent loads caused by the dehumidification of the air are typically 3 times higher than sensible loads in ventilation air and can be as high as 8 times greater [8, 9]. As residential buildings become more air tight, a larger portion of the cooling load is being attributed to ventilation air, and as this continues to increase, liquid desiccant based dehumidification could become much more attractive for use on a residential scale.

3.2. Thermally driven chiller

Thermally driven chillers use either an absorption or adsorption process to generate chilled water, with the primary energy input being solar thermal energy [4]. An absorption chiller contains two different chemical components, with one of them acting as the refrigerant and the second acting as the absorbent. The absorption refrigeration cycle can be described as a modified version of the vapour refrigeration cycle, where instead of compressing a vapour between the evaporator and condenser, the refrigerant is absorbed into an absorbent and pumped to the generator where heat is added to the processes, causing the refrigerant to desorb from the solution as a vapour [10]. The difference between the absorption and adsorption chillers is the chemical process that takes place in the process, and is dependent on the pair of working fluids that are chosen. Typically, adsorption chillers use water-silica, zeolite-water, activated carbon-methanol or activated carbon-ammonia, while absorption chillers use a wider range or working fluids, with lithium bromide-water, lithium chloride-water and water-ammonia being some of the most common [11]. Thermally driven chillers are applicable in almost all applications as they produce cold water that can then be used in most standard air handling units with only minor changes required.

Thermally driven chillers typically operate using a continuous thermodynamic cycle, with the working fluids continuously moving from one component to the next. An alternative to this set up involves the use of an intermittent absorption cooling cycle [5]. In this cycle only two components are used and are piped together. The first component acts as the generator and absorber, while the second component acts as the condenser and the evaporator [5]. These systems work with two independent and separate stages, which cannot occur at the same time. During the regeneration stage, heat is added from the solar collectors into the generator, and the refrigerant is desorbed from the absorbent which collects and condenses in the condenser. The condensation of the refrigerant releases heat, which must be dumped (e.g., through a cooling tower). Once the refrigerant has been desorbed and collected into the evaporator, the second stage begins where the condenser acts as the evaporator, drawing in heat from the surroundings to evaporate the refrigerant, and consequently cooling the surroundings. The refrigerant, now in a vapour state, travels back to the regenerator (which is now the absorber), and is subsequently absorbed back into the absorbent. This absorption process is exothermic, and the heat released must be dumped [10].

These intermittent absorption cycles have both benefits and drawbacks when compared to a continuous absorption cycle. The largest drawback to this type of system is that it can only provide cooling when in the cooling stage, and does not provide any cooling during the regeneration stage [5]. To ensure that cooling can be continuously provided, these systems are usually installed in pairs, allowing one system to charge while the second system provides cooling. Once the first system is completely charged, the roles of the systems reverse, with the first system providing cooling while the second system recharges [12]. One such system which makes use of this pairing of systems is the ClimateWell, manufactured in Sweden, where continuous cooling is provided by using two intermittent absorption cycles [13]. The main advantage to using an intermittent absorption cycle is that the system allows for the "storage" of energy. This energy is stored in the form of desorbed refrigerant in the condenser/evaporator, which is available for cooling as required, by allowing the refrigerant to flow from the evaporator to the absorber. This is an important feature when selecting a system for use in residential applications, as a large portion of the cooling is required when the occupants are present. This typically occurs in the evening and overnight periods when there is little or no solar radiation to drive the chiller.

4. International Energy Agency and the Solar Heating and Cooling Programme

Solar cooling has been investigated through the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programme. The IEA was established in 1974 as an autonomous agency within the framework of the Organisation for Economic Co-operation and Development (OECD) [14]. The IEA was created to carry out a comprehensive program of energy co-operation among the 25 member countries and the Commission of European Communities [14]. The Solar Heating and Cooling Programme was one of the first programmes established by the IEA in 1977 with a focus on advancing active solar, passive solar and photovoltaic technologies with a mission "to facilitate an environmentally sustainable future through the greater use of solar design and technology" [15].

4.1. Task 25

From June 1999 until May 2004, experts from over 10 different countries collaborated on a project under IEA-SHC Task 25 Solar Assisted Air Conditioning of Buildings. This task sought to address the three principle problems with standard air conditioning systems. These problems were defined as follows:

they consume a large quantity of energy; they cause large electricity peak loads; and in general, they employ refrigerants which have negative impacts on the environment [16]. The main objectives of Task 25 were to improve the conditions for market entry of solar assisted cooling systems and to promote the reduction of primary energy consumption and peak electrical loads. The results of the Task were directed towards the air conditioning industry, planners, architects, and facility owners and managers [16].

In order to address the objectives laid out by Task 25, the study was broken down into 4 subtasks [17]:

- Subtask A – Survey of Solar Assisted Cooling: this provided a review of the current technology available as well as the evaluation of past completed projects
- Subtask B – Design Tools and Simulation Programs: this developed a detailed simulation tool to layout, optimize and determine the control strategies for solar assisted cooling systems
- Subtask C – Technology, Market Aspect and Environmental Benefits: this provided an overview of the current equipment suitable for solar cooling applications, as well as supporting the development and market introduction of new systems
- Subtask D – Solar Assisted Cooling Demonstration Projects: this task carried out eleven demonstration projects to gain practical experience and at the same time provide real performance data of the systems

As a result of the work produced under these subtasks, several advancements were made in the area of solar cooling. Within Subtask C, a guideline was developed for the design and implementation of different solar assisted cooling systems [15]. This document presents a decision scheme to aid in the selection of the most applicable technical solution for a given situation. The design scheme takes into consideration the climatic conditions, building factors, and the occupation and use of the building in selecting a system design. The design scheme uses easy to navigate flow charts, in which based on the various factors as determined by the proposed building, a technical solution can be determined. Also, from Subtask C, a technical report was released that outlined recently completed and on-going research in the area of solar cooling [18]. One remaining obstacle as defined within this report was the need to overcome the lack of small scale chillers currently on the market.

The results of Task 25 form the basis of the book titled "Solar-Assisted Air-Conditioning in Buildings – A Handbook for Planners" [19]. This book details many of the findings of the different subtasks under Task 25. It outlines the different system configurations and components, as well as different methods for characterizing the performance of solar assisted cooling systems. It also highlights some of the demonstration projects completed within the Task.

4.2. Task 38

More recently, a second Task under the IEA-SHC further looked at solar assisted cooling. From September 2006 until December 2010, Task 38 – Solar Air-Conditioning and Refrigeration studied technologies for producing cold water or conditioned air by means of solar heat [20]. Task 38 set out to meet a list of objectives, with the main objective being the accelerated introduction of solar assisted cooling system into the market place through the development and testing of cooling equipment for the residential and small scale commercial sector [21]. Among other goals, Task 38 worked towards the development of pre-engineered systems for small and medium sized applications, as well as the development of simulation tools for the evaluation of these systems.

Similar to Task 25, Task 38 was further broken down into four subtasks, each focusing on specific areas within the solar cooling field [22]:

- Subtask A – Pre-Engineered Systems for Residential and Small Commercial Applications
- Subtask B – Custom Made Systems for Large Non-Residential Buildings and Industrial Applications
- Subtask C – Modelling and Fundamental Analysis
- Subtask D – Market Transfer Activities

Through these subtasks, a wide range of work was conducted on different solar cooling technologies and systems. The overall results of Task 38 are outlined in the final position paper, and will be included in the release of the second edition of the previously mentioned handbook for planners (released as part of Task 25) [23]. An overview on installed solar cooling systems over 20 kW was also published, outlining the type and location of all large systems in the world [24]. In 2008, there were 81 large scale cooling systems installed in the world, with the largest system located in Viota, Greece, with a total cooling capacity of 700 kW and 2,700 m^2 of flat plate collectors. Among all the solar cooling systems discussed, only one such system was located in North America (specifically, Mexico), with no large scale solar cooling systems installed in either the United States or Canada. Lastly, the publication outlined the distribution of cooling technologies, as well as the type of collectors used and the type of thermal storage implemented in the systems.

Another outcome of Task 38 was the creation of the "Checklist Method for the Selection and the Success in the Integration of a Solar Cooling System in Buildings" [25]. This checklist aims to determine if a solar cooling project is feasible or not at the design phase of the project. This checklist takes into consideration many factors that influence whether a project will be successful, including the location of the project and the climate at that location, as well as the building logistics and required cooling load. It also examines the economic feasibility of the project by looking at the energy costs for the given location as well as the motivation and ability for the owner to make the required investment for the solar cooling system. Finally, the checklist looks at the technical skills of the building operational staff, as well as the ability to monitor the long term performance of the system.

The checklist is comprised of several questions which address the previously mentioned factors, and awards a value to each question with a maximum score of 20 available. Based on the total score obtained by the project being considered, the feasibility of the project is determined (with a recommended minimum of 10 out of 20 to proceed with the project) [25]. This is an effective first step in determining whether a solar cooling system is a possibility for a given situation, however, after the completion of this checklist, a significant amount of design work would still be required before a project can be successfully implemented. Although this is a useful tool, one significant limitation is that this checklist method is only effective for projects being considered in Europe, as all climates and energy costs are for countries in Europe. As a result, this method cannot be applied directly to assess the feasibility of projects within Canada and the United States.

Of particular interest for residential applications was the work conducted by Subtask A of Task 38. Through this subtask, a report titled "Market Available Components for Systems for Solar Heating and Cooling with a Cooling Capacity of < 20kW" was completed outlining the current market availability of small scale solar cooling units (less than 20 kW) [7]. This report outlines that the components currently available for use within solar cooling systems include solar heating systems, thermally driven chillers, heat rejection methods and cold storage solutions. This report found that there are a limited number of thermally driven coolers currently available on the market, with a total of fourteen different systems either available, or that will be available in the near future on the market. Of these, five systems use an adsorption process with either water-silica gel or water-zeolite technology, while the remaining use an absorption process with either ammonia-water, lithium bromide-water or lithium chloride-water technology. These systems have nominal COP's of 0.5 to 0.78 with the absorption systems typically having a slightly higher COP when compared to the adsorption systems.

As a final noteworthy aspect of Subtask A, thirteen small scale systems in Europe were monitored on an on-going basis with eleven providing enough data for analysis [26]. Through the monitoring of these systems, the thermal COP of nine of the chillers were found to have COP's ranging from 0.5-0.7, being in-line with the manufactures specifications. When the entire system is evaluated, the electrical COP of the system peaked at 8, with many systems having electrical COP's between 5 and 6. It was also found that some systems had an overall electrical COP of less than 3, meaning that a traditional vapour compression refrigerator may be more energy efficient. The conclusion from this study was that many of these systems could achieve a higher COP if the systems were further optimized, and a COP of 3 should be obtainable in most, if not all of the systems. To be able to monitor these systems, a method had to first be developed and is detailed in a separate report entitled "Monitoring Procedure for Solar Cooling Systems" jointly released by Subtask A and B [27].

5. Current projects

There are currently many on-going or completed research projects taking place worldwide that are examining solar cooling technologies. To date, most research projects have focused on large scale installations for use in industrial and commercial complexes. Consequently, less research has been conducted on the implementation of small scale solar cooling systems. The following section will outline some of the work that has been completed or is currently being conducted on the implementation of small scale solar cooling systems worldwide. Some discussion on current solar cooling installations in Canada will then follow.

5.1. Research projects

A study conducted by Florides et al. looked at the performance of a domestic absorption chiller installed in Cyprus that consisted of a solar collector, a storage tank, a back-up boiler and a lithium bromide-water absorption chiller [28]. The heat transfer coefficients of the absorption chiller were obtained experimentally, and the entire system was modelled using the TRNSYS simulation program varying the collector array size, orientation and type, as well as the thermal storage capacity of the system. The optimal system configuration for the 11 kW absorption chiller was found to have a 15 m^2 compound parabolic trough collector and a 600 L hot water storage tank.

A paper produced by Wang et al. looked at the various methods for solar cooling including absorption, adsorption and desiccant cooling and their applicability to small scale residential applications [29]. This paper outlines the advantages and disadvantages of each of the different systems as they could be applied on a residential scale. The main challenges inhibiting the wide spread implementation of these systems are the initial cost of the system and the required on-going maintenance required. Finally, the authors list five recommended system configurations that they believe have the most potential for integration into a residential dwelling. The authors also conclude that for optimal cooling performance, it is important to incorporate thermal storage system to allow for continuous (around the clock) cooling.

Mateus and Oliveira conducted a study to evaluate the performance of a solar absorption cooler for use in different building types and climatic locations in Europe [30]. Through the use of TRNSYS simulation software, the performance of an absorption heating and cooling system was evaluated for three building types: a residential building, an office building, and a hotel. In addition, each of these simulations were conducted for Berlin, Lisbon and Rome climate regions. It was found that for all three locations, the annual costs were lower when compared to standard cooling system, but a 60% solar fraction only accounted for an annual saving of 35%-45% due to the increase in maintenance costs and an increase in water consumption. It was also found that at the current cost of energy and the current start-up costs of a solar cooling system, the lifetime cost of the system (including capital investment, annual costs and maintenance) would be higher compared to conventional cooling system even when used over many years and for prolonged periods of time.

To date, most research conducted in the area of small scale solar assisted cooling has been in Europe. Limited work has been conducted in this area in North America. A recent Canadian study conducted by Edwards looked at the performance of an absorption chiller in Ontario, Canada [31]. The study used an ESP-r model to determine the optimal system configuration comprised of solar collectors, a cooling tower, hot and cold thermal storages and a 35 kW absorption chiller. Experimental data was used to first create a custom component in TRNSYS to perform preliminary system sizing, and then the data was subsequently used to create a custom plant network in ESP-r to model the absorption chiller as part of a house [32]. From this study, it was determined that a collector array of 50 m^2, a hot storage tank of 0.5 m^3 and a cold storage tank of 1.5 m^3 would be required to meet the cooling loads of a typical residential home in an Ontario climate. Although both of these storage volumes are quite large, they can be accommodated by larger houses in Canada. It was also determined within this study that the implementation of a solar cooling system in a house in Ontario would reduce the amount of greenhouse gases released in the generation of the electricity consumed by the house by approximately 12% and would reduce the amount of peak loading on the electricity grid during the summer months.

5.2. Current Canadian installations

In recent years, a number of solar cooling installations have been implemented in Canada. The first of these installations was completed in 2010 in Woodstock, Ontario at Oxford Gardens Retirement Home [33]. The installed system was designed to provide space heating and space cooling for a 9,900 m^2 floor area, as well as domestic hot water production and pool heating. The system consists of 3,240 evacuated tubes in 162 solar collectors, arranged in 9 rows producing up to 364 kW of thermal power, a 105 kW Yakazi absorption chiller and a 13,600L thermal storage tank [34]. This system has a backup heater and chiller ensuring the space is conditioned, even on cloudy days. To date, the system has provided over 740GJ of heating and over 420GJ of cooling, greatly reducing the amount of carbon dioxide released by this institution and the operating costs to the owners.

A second installation was announced in 2010 and completed in 2011 to install an absorption cooling system at the Shouldice Hospital in Thornhill, Ontario. The system includes ten 10 kW ClimateWell chillers, 131 Thermomax Collectors, a 4,364 L thermal storage tank and a cooling tower to act as a heat sink [35]. Energy modelling predicts the system will be able to offset 36% of the cooling load, 44% of the heating load and 91% of the domestic hot water load, allowing for a total of 56% of the required energy to be collected from the sun. If the system meets the modelled energy savings, the system will reduce the amount of CO_2 released annually by the hospital by 100 metric tonnes and will provide an 80% reduction in the peak electricity use due to cooling [35].

6. Conclusion

This paper presented a review on solar cooling methods, with a focus on small scale systems and their applicability in the residential sector. To date, significant advancements have been made as a result of the work completed by the International Energy Agency's Solar Heating and Cooling Programme under Task

25 and 38. Extensive research has been conducted in Europe on large scale cooling systems, however limited work has been conducted in the area of small scale systems worldwide, and the use of solar cooling in Canada. These systems have a large potential to reduce the energy consumption of residential buildings in Canada, and consequently reduce the amount of carbon dioxide released into the atmosphere. This review will form the basis of experimental and simulation work to be conducted on a full scale residential solar absorption chiller system in Canada.

Acknowledgements

The authors acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC) and the NSERC Smart Net-zero Energy Buildings Strategic Research Network (SNEBRN).

References

[1] NRCan, "Energy Use Data Handbook, 1990-2008," Ottawa, On, 2009.

[2] Ontario Ministry of Energy, "Ontario's Long Term Energy Plan," Toronto, On, 2007.

[3] I. Urgursal and A. Farhat, "Greenhouse Gas Emmision Intensity Factors for Marginal Electricity Generation in Canada," *Dalhousie University,* 2009.

[4] H. Henning, "Solar assisted air conditioning of buildings - an overview," *Aplied Thermal Enegineering,* 2006.

[5] J. Duffie and W. Beckman, Solar Engineering of Thermal Processes, Third Edition, Hoboken, New Jersey: John Wiley & Sons, Inc., 2006.

[6] U. Eicker, Low Energy Cooling for Sustainable Buildings, Great Britain: John Wiley & Sons, Ltd. , 2009.

[7] D. Jaehnig, "Market Available Components for Systems for Solar Heating and Cooling with a Cooling Capacity <20kW," *A technical report of subtask A,* 2009.

[8] M. Andrusiak, S. Harrison and L. Mesquita, "Modelling of a solar thermally-driven liquid-desiccant air-conditioning system," in *SOLAR 2010 Conference Proceedings*, 2010.

[9] L. G. Harriman III, D. Plager and D. Kosar, "Dehumidification and Cooling Loads from Ventilation Air," *ASHRAE Journal,* pp. 37-45, 1997.

[10] K. Herold, R. Radermacher and S. Klein, Absorption Chillers and Heat Pumps, Boca Raton: CRC Press, 1996.

[11] J. Deng, R. Wang and G. Han, "A review of thermally activated cooling technologies for combined cooling, heating and power systems," *Progress in Energy and Combustion Science,* 2009.

[12] C. Bales and S. Nordlander, "TCA Evaluation; Lab Measurements, Modelling and System Simulations," Solar Energy Research Center, 2005.

[13] "Technology," ClimateWell, [Online]. Available: http://www.climatewell.com/index.html#/technology.

[14] "About the IEA Solar Heating & Cooling Programme," [Online]. Available: http://www.iea-shc.org/about/. [Accessed 2012].

[15] H.-M. Henning and J. Albers, "Decision Scheme for the Selection of the Appropriate Technology using Solar Thermal Air-Conditioning," *IEA Solar Heating and Cooling; Task 25: Solar-Assisted Air-Conditiong of Buildings,* 2004.

[16] "Task 25 Background," IEA-SHC, [Online]. Available: http://www.iea-shc.org/task25/background.htm.

[17] "SHC Task 25 - Subtasks," [Online]. Available: http://www.iea-shc.org/task25/subtask/index.html.

[18] "Ongoing Research Relevant for Solar Assisted Air Conditioning Systems," *IEA Solar Heating and Cooling; Task 25: Solar-Assisted Air-Conditioning of Buildings,* 2002.

[19] H.-M. Henning, Solar-Assisted Air Conditioning in Buildings - A Handbook for Planners, New York: Springer Wien, 2004.

[20] "IEA-SHC Task 38: Scope," [Online]. Available: http://www.iea-shc.org/task38/scope.htm.

[21] "IEA-SHC Task 38: Objectives," [Online]. Available: http://www.iea-shc.org/task38/objectives.htm.

[22] "IEA-SHC Task 38: Subtasks," [Online]. Available: http://www.iea-shc.org/task38/subtask/index.html.

[23] H.-M. Henning, "Solar Cooling Position Paper," *IEA SHC Task 38 Solar Air-Conditioning and Refrigeration,* 2011.

[24] W. Sparber, A. Napolitano and P. Melograno, "Overview on world wide installed solar cooling systems," in *2nd International Conference Solar Air Conditioning*, Tarragona, Spain, 2007.

[25] "Check-List Method for the Selection and the Success of the Integration of a Solar Cooling System in Buildings" [Online]. Available: http://www.tecsol.fr/checklist/.

[26] D. Jaehnig and A. Thuer, "Monitoring Results," *A technical report of subtask A,* 2011.

[27] A. Napolitano, W. Sparber, A. Thur, P. Finocciaro and B. Nocke, "Monitoring Procedure for Solar Cooling Systems," *A joint technical report of subtask A and B,* 2011.

[28] G. Florides, S. Kalogirou, S. Tassou and L. Wrobel, "Modelling simulation and warming impact assessment of a domestic-size absorption solar cooling system," *Applied Thermal Engineering,* pp. 1313-1325, 2002.

[29] R. Wang, T. Ge, C. Chen, Q. Ma and Z. Xiong, "Solar sorption cooling systems for residential applications: Options and guidelines," *International Journal of Refrigeration,* pp. 638-659, 2009.

[30] T. Mateus and A. C. Oliveira, "Energy and economic analysis of an integrated solar absorption cooling and heating system in different building types and climates," *Applied Energy,* pp. 949-957, 2008.

[31] C. Edwards, "Performance Assessment of Solar Absorption Cooling for Ontario Housing," Master's Thesis, Carleton University, Ottawa, 2011.

[32] G. Johnson, "Design and Commissioning of an Experiment to Characterize the Performance of a Lithium-Bromide Absorption Chiller," Master's Thesis, Carleton University, Ottawa, 2011.

[33] "Canada's Largers Solar Thermal Cooling and Heating Installation," [Online]. Available: http://www.oxfordgardenssolarproject.com/.

[34] "Description of the Installation," [Online]. Available: http://www.oxfordgardenssolarproject.com/installation/.

[35] "Shouldice Hospital," GEMCO Solar Inc., [Online]. Available: http://www.gemcosolar.co/PDF/CaseStudies/Shouldice%20Case%20Study.pdf.