Bundesministerium
für Verkehr,
Innovation und Technologie

Tagungsband - Proceedings

Nachhaltig thermisch kühlen
Sustainable cooling systems

31.03.2008
Solare Kühlung
Solar cooling
TECHbase Vienna

01.04.2008
Kühlen mit Fernwärme
Cooling with district heating
Media Tower

arsenal research
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e2050

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Für die nächsten Dekaden wird Vorhersagen zufolge der Klimatisierungsbedarf in Gebäuden sowohl weltweit als auch in Europa stark ansteigen. Es wird von entscheidender Bedeutung sein, effiziente und auf regenerativen Energieformen basierende Klimatisierungs- und Kühlsysteme zu entwickeln, um einer weiteren drastischen Steigerung des Energieverbrauchs und den dadurch verursachten Klimawirkungen entgegenzuwirken. Wärme aus Sonnenkollektoren aber auch Wärme aus Biomasse-Nahwärmenetzen lässt sich zum Antrieb von thermisch arbeitenden Klimatisierungs- und Kälteverfahren einsetzen.

Die Gebäudeklimatisierung mit Solarenergie steht kurz vor Ihrer weltweiten Markteinführung. Eine wesentliche Kostenverminderung dieser viel versprechenden Technologie soll sowohl durch international abgestimmte Forschungs- und Entwicklungsarbeiten als auch durch die Unterstützung der Markteinführung erreicht werden. Am ersten Konferenztag – **Solare Kühlung** – referieren internationale ExpertInnen und Marktakteuren über die neuesten Forschungs- und Entwicklungsarbeiten, marktverfügbare Produkte, die Potenziale zur Kostenreduktion und Aktionspläne zur verstärkten Implementierung der solaren Klimatisierung und Kälteerzeugung.

In den letzten Jahren hat sich das Interesse von Fernwärmenetzbetreibern verstärkt, die im Sommer überschüssige Wärme zur Gebäudekühlung einzusetzen. Am zweiten Konferenztag – **Kühlen mit Fernwärme** – wird über Erfahrungen zur Auslegung und den Betrieb solcher Anlagen sowie das technische Potenzial zur nachhaltigen thermischen Kühlung in Fernwärme versorgten Gebieten berichtet. Weiters werden Lösungen zur Überwindung von technischen und ökonomischen Barrieren diskutiert.

Solare Kühlung

31. März 2008
TECHbase Vienna
Giefingasse 2, 1210 Wien

Kühlen mit Fernwärme

1. April 2008
Media Tower
Taborstraße 1-3, 1020 Wien

www.e2050.at

Tagungsprogramm

Montag, 31. März 2008

Internationale Tagung

Solare Kühlung

Konferenzsprache Englisch mit Simultanübersetzung in Deutsch

TECHbase Vienna
Giefinggasse 2
1210 Wien

09:00 REGISTRATUR

09:30 Begrüßung
Brigitte Bach, arsenal research
Staatssekretärin Christa Kranzl, Bundesministerium für Verkehr, Innovation und Technologie (angefragt)

Moderation: Brigitte Bach, arsenal research

Initiativen für solare Kühlung

10:00 ESTTP - European Solar Thermal Technology Platform "Strategic Research Agenda focusing Solar Cooling Technology"
Werner Weiss, AEE INTEC

10:15 Austrian Solar Thermal Technology Platform (ASTTP) and the Special Austrian Solar Cooling Programme
Erich Podesser, ASTTP

10:30 Introduction to Task 38 "Solar Air-Conditioning and Refrigeration" of the IEA Solar Heating & Cooling Programme and the topic of solar cooling
Hans-Martin Henning, Fraunhofer ISE

11:00 KAFFEEPAUSE

Solarthermische Kühl- und Klimatisierungstechnologien

11:30 Overview of solar cooling technologies
Marcello Aprile, Politecnico di Milano

12:00 Existing solar cooling installations in Europe
Wolfram Sparber, EURAC

12:30 Experience in planning, concepts and operation
Tim Selke, arsenal research

13:00 MITTAGSPAUSE

Moderation: Michael Hübner, BMVIT

Markt und Wirtschaftlichkeit solarer Kühlsysteme

14:00 Economic and technical potential across Europe
Laura Sisó, AIGUASOL

14:30 Targeting prices for next generation of solar cooling systems
Reinhard Ungerböck, CONNESS

15:00 Strategies for market penetration
Anita Preisler, arsenal research

15:30 KAFFEEPAUSE

Zukünftige Entwicklungen – Die nächste Generation solarer Kühlsysteme

16:00 New concepts and promising technologies
Uli Jakob, SolarNext AG

16:30 Barriers, technology gaps and solutions
Amandine Le Denn, TESCOL SA

17:00 R&D activities on components and examples
Dong-Seon Kim, arsenal research

17:30 Zusammenfassung und Ausblick
Brigitte Bach, arsenal research

Dienstag, 1. April 2008

Workshop der Programmlinie "Energiesysteme der Zukunft"

Kühlen mit Fernwärme

MediaTower Wien
Taborstraße 1-3
1020 Wien

Konferenzsprache Deutsch mit Simultanübersetzung in Englisch

09:00 REGISTRATUR

09:30 Begrüßung
Brigitte Bach, arsenal research
Michael Hübner, Bundesministerium für Verkehr, Innovation und Technologie

Moderation: Theodor Zillner, BMVIT

Kühlen mit Nahwärme: Treiber und Herausforderungen

10:00 Einsatz von thermisch angetriebenen Kältemaschinen in Nah- und Fernwärmenetzen – Auswirkungen auf die Netze am Beispiel Mureck
Olivier Pol, arsenal research

10:30 Wirtschaftlichkeit der Einbindung von Absorptionskältemaschinen in Nahwärmenetzen am Beispiel Mureck
Reinhard Ungerböck, CONNESS

11:00 KAFFEEPAUSE

11:30 **Betriebserfahrung: Anlage in Güssing**
Richard Zweiler, reNet GmbH

12:00 **Einbindung von Absorptionskälte in ein Biomasse Nahwärmenetz – technische und wirtschaftliche Rahmenbedingungen**
Ursula Eicker, zafh.net

12:30 **MITTAGSPAUSE**

13:30 **Nahwärmenetze in Österreich: Potenziale, Chancen und Risiken aus Sicht der Fernwärmebetreiber**
Josef Füreder, Energie AG

14:00 **Thermisch angetriebene Kältemaschinen im kleinen Leistungsbereich - Aktuelle Entwicklungen, Forschungsschwerpunkte und Einbindung in Fernwärmenetze**
Werner Pink, Pink GmbH
Martin Stocker, Danfoss-Nopro GmbH

14:30 **KAFFEEPAUSE**

Moderation: Brigitte Bach, arsenal research

Kühlen mit Fernwärme und Großanlagen: Treiber und Herausforderungen

15:00 **Kraft-Wärme-Kälte Kopplung in Fussach**
Alfred Hammerschmid, BIOS Bioenergiesysteme GmbH

15:30 **Potenzial für Fernkälte in Großfernwärmenetzen am Beispiel Wien**
Adolf Penthor, Fernwärme Wien

Podiumsdiskussion: Barrieren, Forschungsbedarf und Lösungen

Einleitung: Ivan Malenkovic, arsenal research
Moderation: Ute Woltron, DER STANDARD

Josef Füreder, Geschäftsführer Energie AG Oberösterreich Wärme GmbH
Alfred Hammerschmid, Bereichsleiter BIOS Energiesysteme GmbH
Ivan Malenkovic, arsenal research
Werner Pink, Forschung & Entwicklung Pink GmbH
Erich Podesser, Consultant
Eberhard Reil, Prokurist Fernwärme Wien GmbH
Richard Zweiler, Geschäftsführer reNet GmbH

17:30 **Zusammenfassung und Ausblick**
Olivier Pol, arsenal research

The market on air-conditioning and cooling is anticipated to grow exponentially in the next decades, as the world-wide demand for building air-conditioning will definitely increase, also in Europe. It will thus be of utmost importance to develop high performance air conditioning and cooling systems based on renewable energy sources to counteract the significant rise in the use of fossil fuel and the associated climate change. Heating energy from thermal solar collectors and biomass-district heating systems can be used for thermally driven air-conditioning and cooling systems and have the potential to cover a large share of the growing cooling demand.

Solar-assisted cooling for buildings is close to a world wide market introduction. In the next few years a substantial cost reduction of this promising technology can be achieved by internationally coordinated Research & Development activities as well as the specific support of a broad market introduction. On the first conference day – **Solar-Assisted Cooling** – international experts and relevant market actors will present ongoing Research & Development activities, products currently available on the market and the potential of cost reduction and action plans to support a wider implementation of solar-assisted cooling systems in buildings.

Recently, the interest of district heating companies to use the surplus heating energy of the district heating grid during the summer for cooling applications in buildings has increased. On the second conference day – **Cooling with District Heating** – practical experience in design, operation and technical potential of such sustainable thermally driven cooling systems in district heating supplied regions will be presented. Furthermore solutions to overcome technical and economical barriers will be discussed.

Solar cooling

March 31st 2008
TECHbase Vienna
Giefingasse 2, 1210 Vienna

Cooling with district heating

April 1st 2008
Media Tower
Taborstraße 1-3, 1020 Vienna

www.e2050.at

Conference Programme

Monday, March 31st 2008

International Conference

Solar Cooling

Conference language is English with simultaneous translation in German

TECHbase Vienna
Giefinggasse 2
1210 Vienna

09:00 REGISTRATION

09:30 Welcome and Opening
Brigitte Bach, arsenal research
State Secretary Christa Kranzl, Federal Ministry for Transport, Innovation and Technology (requested)

Chair: Brigitte Bach, arsenal research

Solar cooling initiatives

10:00 ESTTP - European Solar Thermal Technology Platform "Strategic Research Agenda focusing Solar Cooling Technology"
Werner Weiss, AEE INTEC

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Erich Podesser, ASTTP

10:30 Introduction to Task 38 "Solar Air-Conditioning and Refrigeration" of the IEA Solar Heating & Cooling Programme and the topic of solar cooling
Hans-Martin Henning, Fraunhofer ISE

11:00 COFFEE BREAK

Solar cooling technologies

11:30 Overview of solar cooling technologies
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Wolfram Sparber, EURAC

12:30 Experience in planning, concepts and operation
Tim Selke, arsenal research

13:00 LUNCH

Chair: Michael Hübner, Federal Ministry for Transport, Innovation and Technology

Market and economics of solar cooling systems

14:00 Economic and technical potential across Europe
Laura Sisó, AIGUASOL

14:30 Targeting prices for next generation of solar cooling systems
Reinhard Ungerböck, CONNESS

15:00 Strategies for market penetration
Anita Preisler, arsenal research

15:30 COFFEE BREAK

Future developments

16:00 New concepts and promising technologies
Uli Jakob, SolarNext AG

16:30 Barriers, technology gaps and solutions
Amandine Le Denn, TESCOL SA

17:00 R&D activities on components and examples
Dong-Seon Kim, arsenal research

17:30 Conclusions
Brigitte Bach, arsenal research

Tuesday, April 1st 2008

Workshop of the programme "Energy systems of tomorrow"

Cooling with district heating

MediaTower Wien
Taborstraße 1-3
1020 Vienna

conference language is German with simultaneous translation in English

09:00 REGISTRATION

09:30 Welcome
Brigitte Bach, arsenal research
Michael Hübner, Federal Ministry for Transport, Innovation and Technology

Chair: Theodor Zillner, Federal Ministry for Transport, Innovation and Technology

Cooling with small rural district heating networks: drivers and challenges

10:00 Integration of thermal driven chillers in district heating networks: impacts on the network, case study Mureck
Olivier Pol, arsenal research

10:30 Cost effectiveness of the integration of absorption chillers in district heating networks, case study Mureck
Reinhard Ungerböck, CONNESS

11:00 COFFEE BREAK

11:30 Practical experience: absorption chiller in Güssing
Richard Zweiler, reNet GmbH

12:00 Integration of an absorption chiller in a biomass supported district heating network – technical and economic framework
Ursula Eicker, zafh.net

12:30 LUNCH

13:30 District heating networks in Austria: Potential, chances and risks from the point of view of a district heating operator
Josef Füreder, Energie AG

14:00 Small capacity thermal driven chillers – current developments, research topics and integration in district heating networks
Werner Pink, Pink GmbH
Martin Stocker, Danfoss-Nopro GmbH

14:30 COFFEE BREAK

Chair: Brigitte Bach, arsenal research

Cooling with large urban district heating networks: drivers and challenges

15:00 Combined heat, power and cooling plant in Fussach
Alfred Hammerschmid, BIOS Bioenergiesysteme GmbH

15:30 Potential for district cooling in large district heating networks, case study Vienna
Adolf Penthor, Fernwärme Wien

Panel discussion: barriers, need of research and solutions

Introduction: Ivan Malenkovic, arsenal research
Chair: Ute Woltron, DER STANDARD

Josef Füreder, CEO Energie AG Oberösterreich Wärme GmbH
Alfred Hammerschmid, senior manager BIOS Energiesysteme GmbH
Ivan Malenkovic, arsenal research
Werner Pink, research & development Pink GmbH
Erich Podesser, consultant
Eberhard Reil, authorised representative Fernwärme Wien GmbH
Richard Zweiler, CEO reNet GmbH

17:30 Conclusion and outlook
Olivier Pol, arsenal research

Solare Kühlung

31. März 2008, TECHbase Vienna

Kühlen mit Fernwärme

1. April 2008, MediaTower Wien

Conference: Sustainable Cooling Systems
TECHbase Vienna
31st of March 2008

ESTTP - European Solar Thermal Technology Platform Strategic Research Agenda focusing Solar Cooling Technology

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Key words: 3 – 5 key words

European Solar Thermal Technology Platform, thermally driven cooling, Research and Development

1 Structure and organization of ESTTP

Technology Platforms are seen as a very important instrument to influence the future development of a technology. In order to strengthen the pan European understanding and development of solar thermal technology, especially within the EU's 7th Framework Programme for Research and Technological Development, an Initiator Group has been working towards a European Solar Thermal Technology Platform (ESTTP) since the beginning of 2005.
Several active members of the European Solar Thermal Industry Association (ESTIF) and the European Renewable Energy Centres Agency (EUREC Agency) founded the ESTTP Initiator Group. Both organisations strongly support the platform. Furthermore it involves "neighbouring" industries (e.g. from the construction sector, heating ventilation and air conditioning, metals) as well as policy makers.
The diagram below shows the structure of the Technology Platform.

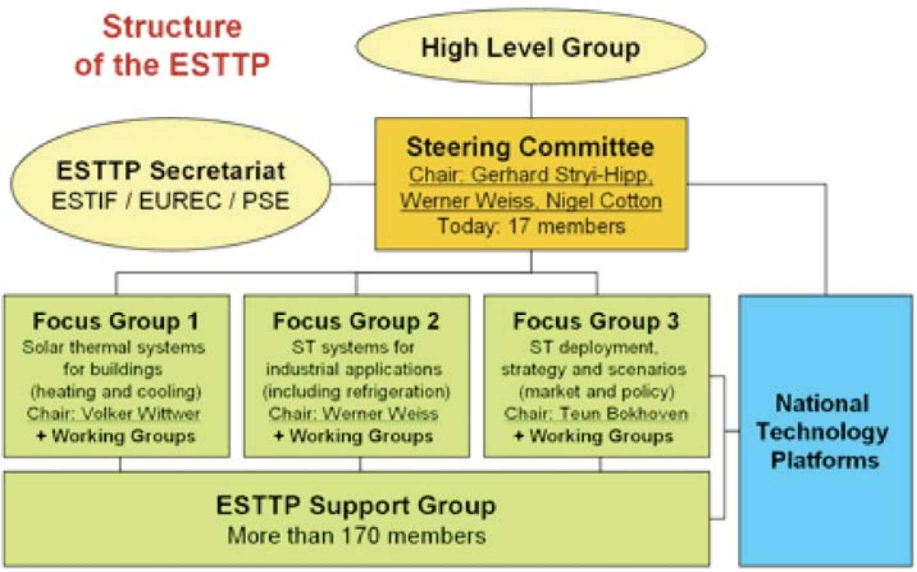


Fig. 1: Current structure of the European Solar Thermal Technology Platform

High level Group: Consist of CEOs, representatives of the European Commission and national ministries. It provides direction and is advising the work of the Technology Platform.

Steering Committee: Is responsible for managing the Technology Platform

Focus Groups: Coordinate the work activities of one field of research; provide information for a wide number of members interested in a particular field of solar thermal research such as the building sector, industrial applications or market and policy issues. The Focus Groups are subdivided in 12 working groups.

Working Groups: Work on different issues such as fundamental research, applied research, market deployment and political instruments etc. These groups take responsibility for progressing the work at detailed level. All interested European experts can apply for membership.

National Mirror Groups: Work on the national level to provide input for the ESTTP and harmonize the European and national research agendas. National mirror groups will be initiated by national experts.

Support Group: More than 180 companies, R&D institutes and associations have become Support Group member. The Support Group comprises all companies/organisations, which have signed the letter of support for the ESTTP. They are invited to participate in the working groups of the ESTTP and to attend General Assemblies.

1.1 The main objectives

The main objective of the ESTTP is **to create the conditions for the exploitation of the full Solar Thermal potential in Europe and worldwide, thereby ensuring a long term technological leadership of the European industry**.
To achieve this overall goal, the ESTTP focuses the attention on a long term technological vision and an ambitious **ESTTP Strategic Research Agenda**.

The **key elements of this vision** are:

- Establish the **Active Solar Building** as a standard for new buildings by 2030. The Active Solar building covers 100% of its heat and cooling demand with solar energy.
- Establish the **Active Solar Renovation** as a standard for the refurbishment of existing buildings by 2030. Active Solar renovated buildings will be heated and cooled by at least 50% with solar thermal energy.
- Satisfy a **substantial share of the heat demand up to 250 °C** with solar thermal energy, notably for applications like block and district heating, space and process cooling, desalination and industrial process heat.

In order to achieve the goals shown above the following developments are needed:

- **thermally driven cooling processes with improved COP** to be applied in a wide range of systems, from single family houses to large district cooling applications, allowing a large part of existing cooling loads to be covered by solar heat … 100% in new buildings and 50% in existing buildings …
- **storage technologies with improved storage capacity** (up to a factor 8) to be applied in a wide range of systems, from single family houses to large district heating applications, allowing a

larger part of existing heat loads to be covered by solar heat … 100% in new buildings and 50% in existing buildings …

- **solar collectors with improved output/cost ratios** (up to 250 °C) to be applied for industrial process heat and in thermally driven cooling systems …

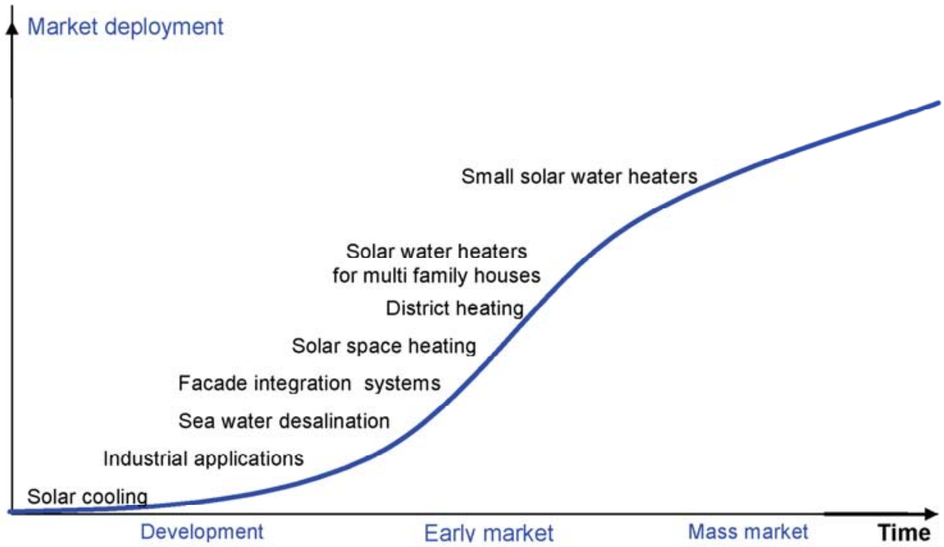


Fig. 2: Indication of the current state of deployment of solar thermal applications from development to application in the mass market

2 Development options and R&D areas

For the upcoming years the following main research topics have been identified by the working groups of ESTTP:

- Solar thermal collectors
    - Low temperature collectors
    - Process heat collectors

- Thermal storages
- Thermally driven cooling and refrigeration
- Multi functional components
- Control systems
- Water treatment

All research topics mentioned above are described in detail in the "Strategic Research Agenda" of ESTTP, which will be published in June on the ESTTP web site: www.esttp.org.

In the following the focus is just on R&D needs for solar cooling and refrigeration. It represents the R&D needs identified by the ESTTP working groups.

3 Thermally driven cooling and refrigeration

Solar thermal energy can be used to operate thermally driven cooling cycles. This enables solar thermal energy to be used for summer air-conditioning of buildings as well as for industrial refrigeration application. Although the basic technologies used can be the same for both applications there are three major differences.

(1) Comfort air-conditioning of buildings in the summer season includes both cooling, i.e. control of indoor temperature, and – depending on the climatic situation – dehumidification, i.e., control of indoor humidity. This causes that not only closed thermodynamic machines can be applied but also so called open cycles which treat fresh air to control its temperature and humidity in an air handling unit which uses heat as its main driving energy.

(2) A second major characteristic of systems used for comfort air-conditioning is the required temperature level on the 'cold' side. Depending on the indoor systems the temperature level will be in the range between approximately 6°C up to 16°C. No temperature level below 6°C is necessary unless ice storage has to be used as storage on the cold side.

(3) Systems for comfort air-conditioning cover the whole range of capacities starting from small water chillers with a capacity of few kW for single-family houses up to centralized systems for air-conditioning of large buildings.

Thermally driven cooling systems applied for industrial refrigeration are always using closed thermodynamic cycles which produce cold that is transferred by a liquid (or solid/liquid, e.g. ice slurries) heat transfer medium. The temperature on the cold side in principle covers a broad range from < -30°C up to 20°C. Typically, required cooling capacities lie in the medium and large capacity range starting from approximately 100 kW up to MW's.

The following description covers both applications sectors as the main conversion technologies are similar in both cases. Specific explanations for either application sector are made as appropriate.

3.1 Description of the sector

Summer air-conditioning of buildings deals with cooling technologies driven by heat from solar collectors for ensuring indoor comfort in buildings during summer conditions. Summer air-conditioning includes control of indoor air temperature and humidity. Such technologies include at present systems employing low and medium temperature solar collectors, which are normally roof mounted. In case of large buildings also ground mounted collector systems are used. Two major types of cooling cycles are used: (1) The first type of systems are open cooling cycles which are in direct contact with environmental air. They use a sorptive component which is able to dehumidify air. Thereby the potential of using evaporative cooling is increased. Heat is required to remove the water vapour bond in the sorption matrix. (2) The second type of systems are closed machines employing a refrigerant which undergoes a closed thermodynamic process and thereby is able to take up heat at a low temperature level (the useful cooling effect) which is released at a medium temperature level (heat rejection, normally heat is rejected to the environmental air). The driving energy is a heat input to the system at the highest temperature level (driving heat) which originates from a solar thermal system in the case of solar cooling. In general the solar collector system is used not only for cooling but also heating and other heat appliances such as domestic hot water. About 200 installations from small size for residential single-family houses up to large sizes for air-conditioning of e.g. factory buildings are installed in Europe (2007).

Refrigeration of industrial processes deals with cooling technologies driven by solar thermal systems for the refrigeration (low and medium temperature refrigeration) of industrial processes in all the range of capacities. Such technologies include at present systems employing low and medium temperature solar collectors, both roof or ground mounted. The systems can be coupled with hot or cold storages depending on the application. Just a small number of these applications have been studied and few new systems will be in operation by 2008, mainly in countries south of the Mediterranean Sea. Given the high investment costs of these alternative systems, it is difficult to compete with established commercially available electrically driven compression refrigeration equipment. Solar refrigeration is therefore a big challenge since the cold production for industrial processes directly influences the cost of the product. However, one drawback of electrically driven refrigeration in many regions of the world is the instability of electricity supply.

3.2 Technology status

Comfort air-conditioning of buildings represents a strongly growing market world-wide in both residential and tertiary sectors. Energy consumption for cooling is significantly increasing in south European countries where the installation rate of room air conditioners is growing exponentially. In these areas the related increase of power demand, electrical energy consumption, and the raising energy costs mandate the use of alternative refrigeration technologies to electrically driven systems. Conventional air-conditioning is based on vapour compression cycles that consume significant amounts of electrical energy to drive the compressor. In the building sector small single-split systems (for a single room) or multi-split systems for a flat or a storey are dominating the market. The performance of a refrigeration cycle is usually described by the coefficient of performance (COP), which is defined as the benefit of the cycle (amount of heat removed or cooling capacity) divided by the required total energy input to operate the cycle. For a mechanical vapour compression system, the net energy supplied is usually in the form of work, mechanical or electrical, and includes work to the compressor and fans or pumps. The COP for small split systems is about 2.5 to 3. In larger commercial buildings (e.g. department store, office building) often cooling networks are installed which are operated by centralized large water chillers. These systems can achieve much higher COP-values up to 5-6, in particular when they use a wet cooling tower to reject the medium temperature waste heat.
Industrial refrigeration is needed in various ways for cooling of processes or process products as well as conservation of goods such as medicine or food. There is a large and slowly growing market for this type of applications. Depending on the specific application temperatures can range from down to -30°C and below up to 20°C. Conventional systems in general are operated by large vapour compression refrigeration machines which supply cold to a cold network. The COP depends strongly on the temperature at which cold is produced and ranges from 3 up to 6. Normally large cooling towers are employed to reject the condenser heat. Already today there are various industrial installations which use waste heat from heat consuming processes to operate thermally driven cooling equipment for refrigeration application.

Alternative technologies that can use solar thermal energy

Open cooling cycles which are also referred to as desiccant cooling systems can implement solid or liquid sorption. The central component of open solar assisted cooling systems is the dehumidification unit which is available from several suppliers in form of a desiccant wheel for different air volume flows. Silica gel or lithium chloride is used as sorption material. All the other components of the system are commonly used in standard air-conditioning applications, where an air handling unit is employed, e.g., heat recovery units, heat exchangers, humidifiers etc.. The majority of the solar assisted cooling systems based on thermodynamic open cycles use this type of technology. The heat required for the regeneration of the sorption wheel can be provided at low temperature level (in the range of 45-90°C); therefore solar air collectors are in principle also applicable. For what liquid sorption concerns first prototypes have recently been put in operation. The input air is dehumidified by contact with a salt solution, e.g., water/lithium chloride. The diluted solution is re-concentrated using low temperature heat e.g., from solar thermal collectors. The advantage of the method is the loss-free storage ability of the concentrated and diluted salt solution which facilitates energy storage at high energy density. The required regeneration temperature is similarly low as in the case of the solid sorption. Open cooling cycles are mainly of interest for building air-conditioning.

Closed heat driven cycles for large capacities (100 kW and above) are available since many years. The physical principle used in most systems is based on sorption phenomena. There are two markets

established heat driven technologies which can be employed for low and medium temperature process refrigeration: adsorption and absorption. Adsorption refrigeration cycles using, for instance, silica gel and water as the adsorption pair can be driven by low temperature heat sources down to 55°C producing cold on a temperature level down to 5°C. Coefficient of performance (COP) values of 0,6 – 0,7 can be achieved. Moreover the financial viability of systems based on this technology is limited due to the far higher production costs, in comparison to other sorption technologies (i.e., absorption).
Absorption technologies cover the 97% of the world market of thermally driven systems. Advantageous for the complex absorption cycles is their high COP value which ranges between 0,6 – 0,75 for single stage machines and between 0.9 – 1.3 for double stage technology. Typical heat supply temperatures are respectively 80 – 95°C and 100 – 130°C. The absorption pair in use is either lithium bromide – water or ammonia – water. For lithium bromide – water cycles the evaporator temperature is limited to 4 °C and the condenser temperature to the range below 35°C. The latter is the reason why a costly and high water consuming (i.e., wet) cooling tower is required. Ammonia – water cycles allow designs which can instead reach evaporator temperature below 0°C and heat rejection temperatures of up to 50°C. Therefore they can be used for deep freezing applications as well and use dry air-cooling for heat rejection.

A number of installations have been built using solar thermal energy as the major part of the driving heat. In this large capacity range both single-effect cycles which have COP-values in the range of 0.6-0.8 are available as well as high-efficient double-effect cycles which achieve COP-values of 1-1.3. While single-effect cycles require driving temperatures in the range of 80°C-100°C double-effect cycles need driving temperatures of 130°C-160°C. In the last 5-8 years a number of systems has been developed in the small capacity range below 100 kW and in particular below 20 kW down to 4 kW. All these systems are single-effect machines which are mainly used for building applications; the small machines are mainly designed for application in residential buildings. Closed heat driven cooling cycles can be used for both building air-conditioning and industrial refrigeration.
Beside sorption based cycles also other options for conversion of solar energy in useful cooling are possible. In an ejector cycle heat is transformed in kinetic energy of a vapour jet which enables evaporation of the refrigerant. In a solar mechanical refrigeration cycle a conventional vapour compression system is driven by mechanical power that is produced with a solar-driven heat power (e.g. Rankine) cycle in which a fluid is vaporized at an elevated pressure by heat exchange with a fluid heated by solar collectors. Last but not least electricity generated in a photovoltaic array can be used to operate well-known vapour compression machines.
Thermally driven cooling technologies play a key role for an efficient conversion of energy in the field of building air-conditioning and refrigeration. Today they are mainly used in combination with waste heat, district heat or co-generation units. In contrast the market for solar thermally driven cooling has not yet been developed. Most installations are based on funds in the framework of demonstration programs. Recently a start of market development can be observed in the residential sector in Mediterranean countries, in particular in Spain.

3.3 R&D needs

In the following only research activities are described which specifically refer to the topic of thermally driven cooling. Research activities related to major components of solar thermal systems in general such as solar collectors and thermal storage are only mentioned here if they need specific attention under the viewpoint of thermally driven cooling.

3.3.1 Basic research

Basic research is mainly needed with the long term focus of optimized thermally driven cooling cycles, which achieve higher efficiency values (COP-values), are more compact and can operate at lower driving temperatures compared to today's technology. This includes material research on new sorption materials, new coatings of sorption materials on heat exchanger surfaces, new heat and mass transfer concepts and design of new thermodynamic cycles. Other components where basic research is needed are mainly compact cold storage using phase change materials or thermo-chemical reactions. Basic research topics include:

- Development of new highly porous sorption materials, in particular using adsorption phenomena. A large family of materials is not yet fully investigated for heat transformation applications. Also ionic liquids may be candidates for new liquid sorption working pairs.
- Sorptive materials coatings on different metal substrates for optimized heat and mass transfer
- Micro-fluid systems for compact high efficient heat exchangers in the sorption and desorption regime
- New sorption heat exchanger matrices such as e.g. metal foams
- Nano-coated surfaces in heat exchangers for reduced friction losses at fluid flow
- Development of new materials for cold storage at different temperature levels for high storage density
- Development of new cycles (high temperature lift; double, triple stage, novel open sorption, etc.) with optimized internal heat recovery for high COP-values
- Development of performance analysis tools, such as e.g., exergy analysis, life cycle analysis and comparison methodologies to assess new concepts
- Development of advanced simulation tools for system modelling at different scales starting from molecular scale (sorption phenomena) up to the system scale

3.3.2 Applied research

Main focus of applied research is to develop machines or apparatuses based on the fundamental new approaches. Applied research also includes testing and development of test methods for standardization of thermally driven cooling cycles. Applied research topics include:

- Integration of the new heat exchanger concepts developed in fundamental research into a machine concept
- Development of advanced machines based on the new thermodynamic cycles including hybrid sorption-compression systems for operation with heat and electricity alternatively
- Development of highly compact machines in the small capacity range for decentralized application in a single room; these machines may be also promising for automotive application
- Adjustment of machines for solar operation, i.e., under variable temperature and power conditions (highly flexible cycles)
- Development of advanced ejector cycles using different working pairs adjusted to different applications
- Development of advanced open cycles using liquid sorption materials with high storage density
- Development of cooled open solid sorptive cycles with high dehumidification potential for warm and humid climates
- Development of advanced control concepts for components and overall systems including self-learning control, fuzzy logic, adaptive control etc.
- Development of process integration methodologies for the solar driven refrigeration systems with the considered processes
- Development and assessment of new heat rejection options using air or ground as heat sink; heat rejection devices have to be adjusted to different sizes and temperature levels of thermally driven

cooling cycles and have to focus on low water consumption, low health risk, low power consumption, low first cost and low operation and maintenance cost.

- Develop advanced modelling and simulation tools for systems thermodynamic analysis and support to system planning and design.
- Design and optimisation of large solar refrigeration plants.
- Development of advanced control systems for the solar refrigeration systems (solar collection, cold production and cold storage charge and discharge according to the load).

3.3.3 Demonstration and technology transfer

Activities in this field are needed in order to guarantee a successful transfer of existing and new concepts into practical application and to ensure high quality during operation in the real world.

- Development of suitable commissioning procedures and guidelines.
- Development of hydraulic concepts, design guidelines and proven operation and maintenance concepts for overall systems
- Identification of the most promising industrial applications for solar refrigeration systems in energy and financial terms
- Hybrid systems: combining compression technology, with customized solar heat driven machines and suitable cold (heat) storage
- Installation and long time monitoring of various systems in different configurations, sizes, climates and operating conditions
- Development of standardized performance criteria for components and overall systems
- Documentation of lessons learned in practical operation of installations to ensure transfer to professionals
- Development of appropriate training materials including curricula for different levels of engineering education

Source:

Final draft of the Strategic Research Agenda: Solar Heating and Cooling for Europe's Sustainable Energy Future., Brussels 2008.

International Conference **„SOLAR COOLING“**
Date: 31.3.2008
Location: TECHbase Vienna, 1210 Wien, Giefinggasse 2

Austrian Solar Thermal Technology Platform (ASSTP) and the special Austrian Solar Cooling Programme

Erich Podesser

1. Austrian solar thermal market

Austria has a leading role in the usage of solar thermal technologies in theory and practice since 1974. The Austrian solar market expands every year for about 20%. A share of 76 % of the produced solar thermal equipment is exported and the rest of the solar thermal products are used in Austria. About 6500 people earn their money in the solar thermal market and the annual turnover lies in the range of 400 Mio. Euro.

Since Austria has been joining the EU more than 50 large projects could be worked out and finished together with the international partners. Lots of information could be gathered and also exchanged.

The aims of the ASSTP are focussed on

- Enlargement of the Austrian R,D&D capacities
- Intensification of networking between
  - R&D capacities,
  - commercial companies and industries
- Enlargement of the Austrian solar thermal market on the international level.

2. Austrian solar cooling programme in the past

The topic “Solar Cooling” has a special tradition in Austria. between 1976 - immediately after the first energy price crises – up to 1986. Development work on small, solar operated absorption refrigeration machines has been executed by Forschungszentrum Graz, the former Joanneum Research. About 2 Mio € have been invested in R, D&D in solar cooling. The financing of the projects was done by the former Austrian Ministry of Science and Research and the local government of Styria. The necessary solar cooling equipment has been developed and produced at the Forschungszentrum Graz. Several demonstration plants with different solar cooling equipment were set up and were operated during some years. Lots of experiences and data could be gained.

The following demonstration plants were erected:

- 1979: Split, Dalmatinian coast, 12 kW solar driven absorption air-conditioning plant with open heat rejection
- 1981 – 1986: Austrian Maltese Research Centre at the island Malta in the Mediterranean Sea. Two 12 kW absorption air-conditioning plants, one 10 kW absorption refrigeration plant for food cooling in a container (evaporation temperature at – 10°C). Both with open heat rejection.

- 1985: Waste heat driven 60 kW absorption refrigeration plant with evaporation temperature at – 27 °C for the storage of deep frozen food.

After the year 2000 the Company S.O.L.I.D, Graz, installed relatively large solar assisted air-conditioning plants in China, USA and at several locations in Europe. In these plants market available LiBr/H2O – absorption cooling machines and open heat rejection systems have been used.

a solar/biomass driven desiccant air-conditioning plant was built in the Styrian town Hartberg by Joanneum Research and financed by the Styrian government and the utility Hartberg.

After 2006 the Company Pink, Langenwang, Styria, started with the production of small NH3/H2O absorption machines, which need generally open heat rejection systems.

3. Austrian solar cooling programme proposed for the future

Based on these experiences the following actions are proposed:

- Governmental aid based on valuation of CO2 reduction for solar cooling
- Intensify the demonstration of solar assisted cooling in Austria
- Optimization of pre-engeneered small solar assisted packages
- Optimization of the wet open heat rejection systems (R, D&D: hygienic problems, water consumption, noise).
- Significant reduction of the electricity demand of solar cooling plants:
  - Highly efficient AC-motor pumps
  - Highly efficient DC-motor pumps including rectification & PV
  - Zero electricity consumption by integrated Kalina-Process (R, D&D)
- Demonstration plants of solar assisted Desiccant Air-conditioning (optimization of control strategy for year around operation).

Finally it is worth to mention that in most cases the costs of the solar assisted cooling will be higher than that of conventional vapour compression cooling if the energy price remains at the present level. But it has to be a public interest that energy conversion plants with low CO2-emission have to be sufficient supported that customer can buy they without disadvantages. It is the task of people in research, development, plant design, production and distribution to make the solar cooling equipment technical mature and the conveniences of use comparable to the conventional vapour compression technique.

Conference: Sustainable Cooling Systems
TECHbase Vienna
31st of March 2008

Introduction to Task 38 "Solar Air-Conditioning and Refrigeration" of the IEA Solar Heating & Cooling Programme and the topic of solar cooling

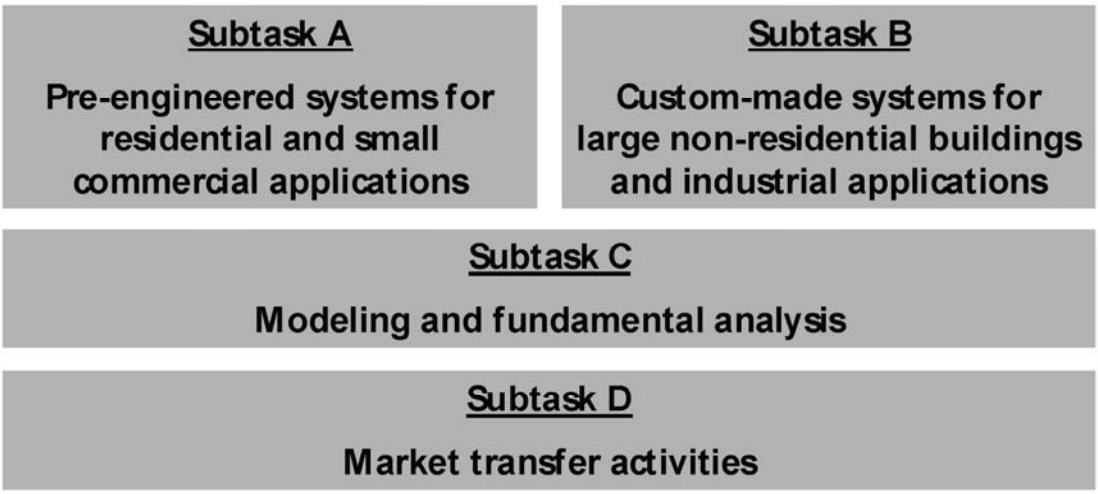
Dr. Hans-Martin Henning, Fraunhofer-Institut für Solare Energiesysteme ISE, Heidenhofstr. 2, D-79110 Freiburg

Key words: International Energy Agency (IEA); Solar Heating & Cooling Programme (SHC); Solar Cooling Overview

1. Abstract

In the presentation an overview will be given about the IEA framework for collaboration in R&D and the implementing agreement "Solar Heating & Cooling Programme" will be described in more detail. A brief introduction about the Task 38 "Solar Air-Conditioning and Refrigeration" will be shown. This includes the structure of the Task 38 work (see figure below) and information about the major deliverables.

In addition a general overview about the physical ways to transform solar radiation in useful cooling will be given and the key technologies will be briefly introduced. Major focus will be given on thermally driven technologies and a brief introduction into the energy balance of these systems will help to understand the potential for saving of primary energy by application of these technologies.



Basic structure of Task 38 „Solar Air-Conditioning and Refrigeration" of the IEA Solar Heating & Cooling Programme

Introduction to Task 38 "Solar Air-Conditioning and Refrigeration" of the IEA Solar Heating & Cooling Programme and the topic of solar cooling

Hans-Martin Henning
Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg/Germany

"Sustainable cooling systems – solar cooling"
International Conference
March 31, 2008
TECHbase Vienna

The International Energy Agency

- The International Energy Agency (IEA) is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD)
- It was established in 1974
- It has 26 member countries

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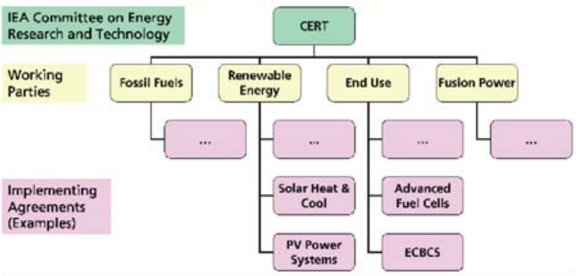
Task 38 Solar Air-Conditioning and Refrigeration

International energy technology co-operation



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Task 38 Solar Air-Conditioning and Refrigeration

Solar Heating & Cooling Implementing Agreement

- Established in 1976
- Works on technologies that use the energy of the sun to heat, cool, light and power buildings
- 19 countries + European Commission
- Mission: "To facilitate an environmentally sustainable future through the greater use of solar design and technologies."
- International co-operation on a Task sharing basis

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Task 38 Solar Air-Conditioning and Refrigeration

IEA SHC TASK 25
Solar Assisted Air Conditioning of Buildings

- June 1999 – November 2004
- 11 countries
- 4 Subtasks
  - A: Survey of solar assisted cooling
  - B: Design tools and simulation programs
  - C: Technology, market aspects and environmental benefits
  - D: Solar assisted cooling demonstration projects
- 11 expert meetings; 3 trade fair participations
- Several national workshops in different countries

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Task 38 Solar Air-Conditioning and Refrigeration

Main outputs of Task 25

- Handbook for planners
- Computer design tool for planners, architects & engineers
- Technical report about newly developed systems and components
- Guideline for system selection (decision tree)
- Technical report about the demonstration systems (11 systems)

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Task 38 Solar Air-Conditioning and Refrigeration

Solar cooling and air-conditioning - main needs

- standardized systems
- small capacity systems
- advanced operation & control
- transfer to professionals

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Main objective & Scope of Task 38

- Implement measures to accelerate the market introduction of Solar Cooling systems in different sectors (residential, commercial, industrial)
- Technical scope
  - Standardised, pre-engineered systems for applications in the low capacity range (residential, small commercial)
  - Develop concepts and create tools for a proper implementation in large scale applications (e.g., large office and residential buildings, hotels, industry, etc)
  - Contribute to the realisation of new research activities for the development of advanced systems and concepts

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Task structure

Subtask A	Subtask B
Pre-engineered systems for residential and small commercial applications	Custom-made systems for large non-residential buildings and industrial applications
Subtask C: Modeling and fundamental analysis	
Subtask D: Market transfer activities	

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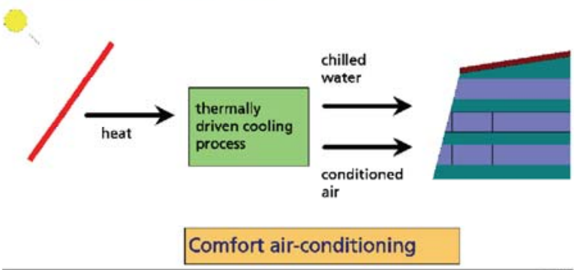
Technical scope - application



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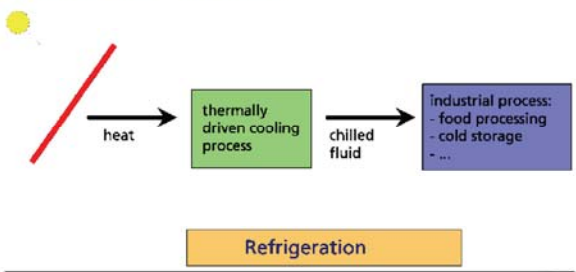
Technical scope - application



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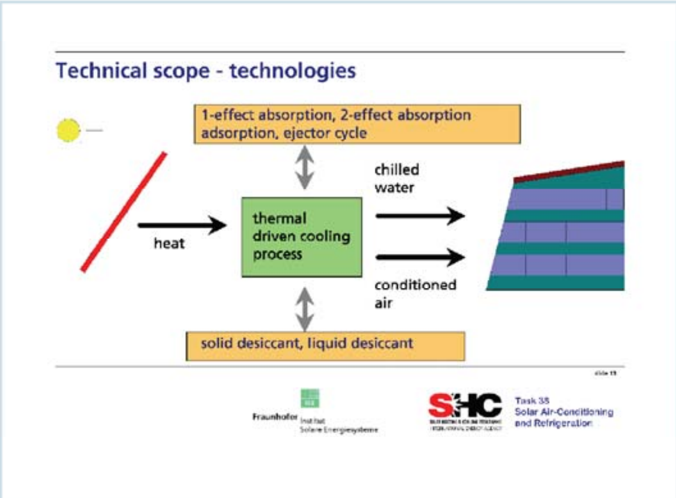
Technical scope - technologies
1-effect absorption, 2-effect absorption adsorption, ejector cycle
heat
thermal driven cooling process
chilled water
conditioned air
solid desiccant, liquid desiccant
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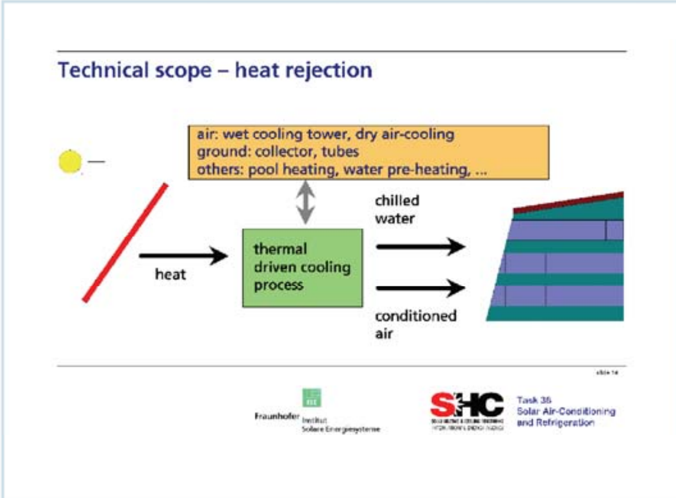
Task 38 Solar Air-Conditioning and Refrigeration


Technical scope – heat rejection
air: wet cooling tower, dry air-cooling
ground: collector, tubes
others: pool heating, water pre-heating, ...
heat
thermal driven cooling process
chilled water
conditioned air
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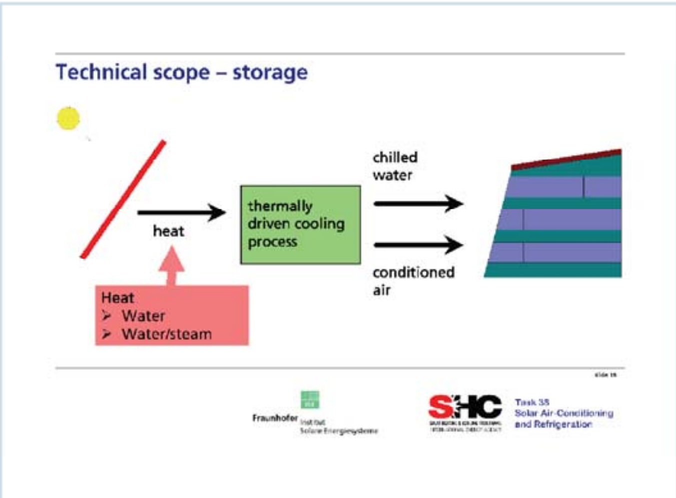
Task 38 Solar Air-Conditioning and Refrigeration


Technical scope – storage
heat
thermally driven cooling process
chilled water
conditioned air
Heat
➢ Water
➢ Water/steam
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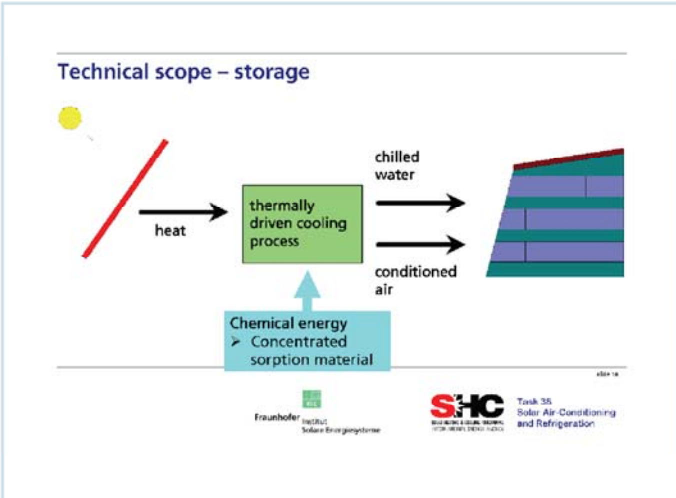
Technical scope – storage
heat
thermally driven cooling process
chilled water
conditioned air
Chemical energy
➢ Concentrated sorption material
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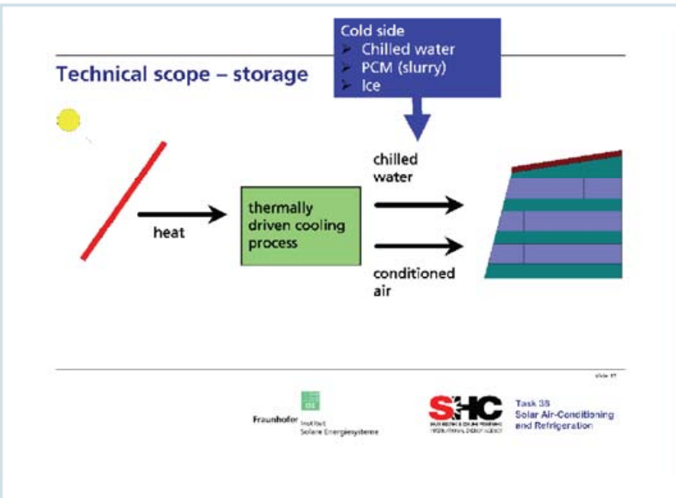
Task 38 Solar Air-Conditioning and Refrigeration


Technical scope – storage
Cold side
➢ Chilled water
➢ PCM (slurry)
➢ Ice
heat
thermally driven cooling process
chilled water
conditioned air
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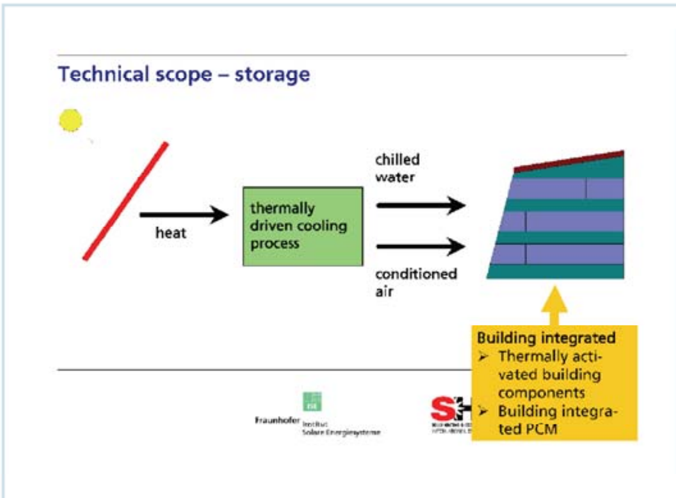
Task 38 Solar Air-Conditioning and Refrigeration


Technical scope – storage
heat
thermally driven cooling process
chilled water
conditioned air
Building integrated
➢ Thermally activated building components
➢ Building integrated PCM
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Participating countries

- Participating
  - Austria
  - Australia
  - Canada
  - Denmark
  - France
  - Germany
  - Italy
  - Mexico
  - Portugal
  - Spain
  - Switzerland
- Countries with interest being no member of the Implementing Agreement
  - Greece
  - Malta
  - UK

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Operating Agent and Subtask Leadership

- Operating Agent
  - → Germany: Fraunhofer ISE (Hans-Martin Henning)
- Subtask A Pre-engineered systems
  - → Austria: AEE INTEC, Gleisdorf (Dagmar Jähnig)
- Subtask B Custom-made systems
  - → Italy: EURAC Research, Institute for Renewable Energies, Bolzano (Wolfram Sparber)
- Subtask C Modeling and fundamental analysis
  - → France: Institut National d'Energie solaire INES, Chambery (Etienne Wurtz)
- Subtask D Market transfer activities
  - → Italy: Polytecnic di Milano (Mario Motta)

Fraunhofer Institut Solare Energiesysteme — SHC Task 35 Solar Air-Conditioning and Refrigeration

Expected results + Information plan

- State-of-the-art report describing market available cooling equipment and suitable new solar components (A+B),
- Technical report on the experimental activities on the systems that have been developed and monitored during the Task work (A+B),
- Soft tool package for the fast pre-design assessment of successful projects (B),
- Report on the review on new Solar Cooling developments suitable for the application in the air-conditioning and refrigeration sector (C),
- Report on the results of the comparative analysis of novel concepts using exergy analysis and the analysis tools for the theoretical and technical assessment of the new concepts (C),

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Expected results + Information plan (cont'd)

- Technical report with developed standardisation schemes (D),
- Technical report about the results of the Life Cycle Assessment of Solar Cooling systems (D),
- Second edition of the Handbook for Planners (A, B, C, D),
- Training material for installers and planners (D),
- Semi-annual e-newsletter for the industry (D),
- Industry workshops in national languages in participating countries addressing target groups (D),
- Market analysis report (D)

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Bolzano/Italy, October 2006

Aix-les-Bains/France, April 2007

Barcelona/Spain, October 2008

Solar cooling

PV Modul → elektrisch-mechanische Umwandlung → Kompressionskälteanlage

Solarkollektor → thermo-chemische Umwandlung → Geschlossene Sorptionsanlage

Solarkollektor → thermo-chemische Umwandlung → Offene Sorptionsanlage

Solarkollektor → thermo-mechanische Umwandlung → Dampfstrahlkälte

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System schematic

	open cycle	closed cycle
non-tracking solar collector system (flat plate, evacuated tube, optical concentration without tracking)	desiccant cooling systems ■ solid desicccant (e.g. rotor) ■ liquid desiccant	closed cycle water chillers ■ single-effect absorption ■ adsorption ■ others
tracking solar collector system with optical concentration (parabolic trough, fresnel type)	-	closed cycle water chillers ■ double-effect absorption ■ single-effect absorption with high T-lift

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System schematic

	open cycle	closed cycle
non-tracking solar collector system (flat plate, evacuated tube, optical concentration without tracking)		
tracking solar collector system with optical concentration (parabolic trough, fresnel type)		

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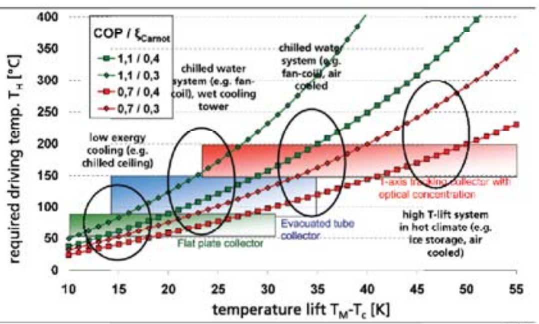

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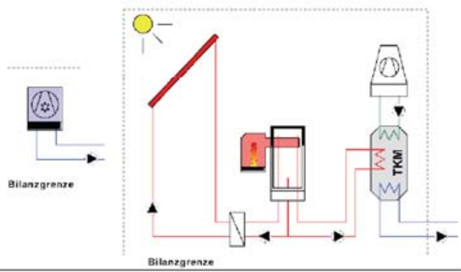
Energy balance – energy benefits



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Governing equations

$$PE_{K,Ref} = \frac{Q_{Kälte}}{COP_{KKM} \cdot \eta_{PE,Strom}}$$

$$PE_{K,sol} = \frac{Q_{Kälte}}{COP_{TKM}} \cdot \left[\frac{(1 - SF_K)}{\eta_{Kessel} \cdot \eta_{PE,fossil}} + \cdot \frac{SF_K \cdot f_{el,Solar}}{\eta_{PE,Strom}} + \frac{f_{el,RK} \cdot (COP_{TKM} + 1)}{\eta_{PE,Strom}} \right]$$

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Task 38 Solar Air-Conditioning and Refrigeration

Reference values

Parameter	Bedeutung	Wert
$\eta_{PE,Brennstoff}$	Primärenergetischer Wirkungsgrad Brennstof	0.95
η_{Kessel}	Effizienz Backup-Kessel	0.90
$\eta_{PE,Strom}$	Primärenergetischer Wirkungsgrad Strom	0.36
COP_{KKM}	COP Kompressionskältemaschine	3.50
COP_{TKM}	thermischer COP der thermisch angetriebenen Kältemaschine	0.70
$f_{el,Solar}$	spezifischer Strombedarf Solaranlage, kWh_{el}/kWh_{th}	0.02
$f_{el,RK}$	spezifischer Strombedarf Rückkühlung, kWh_{el}/kWh_{th}	0.03
SF_K	Solarer Deckungsanteil Wärme zum Antrieb TKM	0.90

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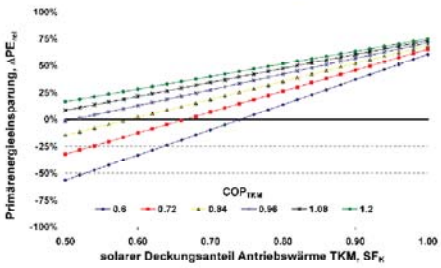
Task 38 Solar Air-Conditioning and Refrigeration

Influence of solar fraction for driving heat



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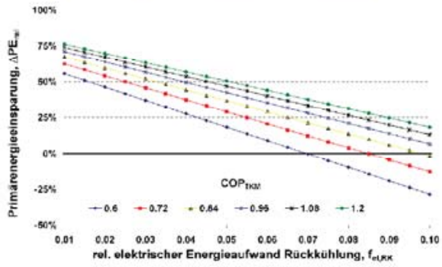
Task 38 Solar Air-Conditioning and Refrigeration

Influence of electricity demand for heat rejection



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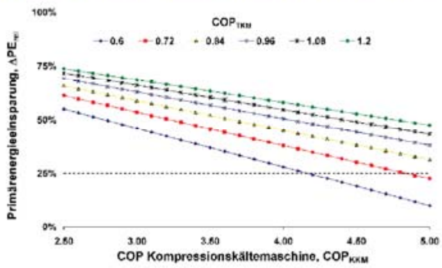
Task 38 Solar Air-Conditioning and Refrigeration

Influence of COP of conventional reference chiller



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Task 38 Solar Air-Conditioning and Refrigeration

... thank you for your attention!

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Task 38 Solar Air-Conditioning and Refrigeration

Conference: Sustainable Cooling Systems
TECHbase Vienna
31st of March 2008

Overview of Solar Cooling Technologies

Marcello Aprile, Politecnico di Milano, piazza Leonardo da Vinci, 32 - 20133 Milano, Italy, marcello.aprile@polimi.it

Key words: solar cooling, absorption, adsorption, solar collectors

Abstract

Two types of solar cooling systems are available today: closed cycle (chilled water system) and open cycle (air system). Within closed cycle systems, both market available and newly developed chilled water systems are briefly presented. Market available thermally driven chillers include single effect absorption, double effect absorption and adsorption systems. New developments include prototypes, pre-commercial and commercial absorption and adsorption systems. The basic working principle of absorption and adsorption chillers is illustrated: in particular, the functioning of the intermittent adsorption cycle is explained and its operational data are commented. Within open cycle systems, market available desiccant wheels are briefly presented. Desiccant wheels are commonly used in conjunction with indirect and direct evaporative coolers, so to realise a desiccant and evaporative cooling cycle. An example is presented on the psychrometric chart. New developments of desiccant systems include liquid sorption systems and highly efficient indirect evaporative solid adsorption heat exchanger: the working principle of these novel systems is illustrated. Finally, an overview of market available solar collectors is presented, including new developments in the medium temperature range. The selection of a suited collector type depending on the thermally driven cooling system is briefly discussed.

Overview of Solar Cooling Technologies

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International Conference "Solar Cooling" – TECHbase
Vienna, 31-3-2008

POLITECNICO DI MILANO

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Contents

2

- **Heat driven cooling technologies (open systems, closed cycles)**
  - market available components
  - new developments
- **Solar collectors**
  - the appropriate collector
  - new developments
- **Conclusions**

Mario Motta – mario.motta@polimi.it POLITECNICO DI MILANO

Open and closed cycles

3

- open cycles (desiccant cooling or desiccant and evaporative cooling)
  - are employed for direct conditioning of fresh air (or a mixture of fresh and return air)
  - generally consist of a combination of sorptive dehumidification and evaporative cooling by air humidification
  - systems are air handling units (supply/return air) with the necessity to have appropriate air duct systems for air distribution in the building
- closed cycles (thermally driven chillers)
  - are used for production of chilled water
  - can be combined to any type of air-conditioning equipment such as centralized air-handling units, fan-coil systems, chilled ceilings etc.

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Market available chilled water systems

4

Single effect absorption – many products for operation with hot water or steam in the capacity range > 100 kW; only few products < 100 kW; typical operation temperatures 85°C - 110°C

Double effect absorption – often directly fired systems; few products in the capacity range below 100 kW; typical operation temperatures 130°C - 160°C

Adsorption – only two commercial products from Japanese manufacturers; typical operation temperatures 60°C - 95°C

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New developments of heat driven water chillers

5

- many new activities to develop water chillers suitable for solar heat have been implemented in the last years
- priority small power range (< 20 kW), since few commercial products are available:
  - Commercial water-LiBr absorption chillers (not complete): EAW in Germany (15 kW); Rotartica (Spain 4.5 kW) air-cooled rotating system; prototype: Phönix (10 kW);
  - Commercial ammonia water systems (with mechanical solution pump): Pink/Joanneum Reserach (Austria) (10 kW); Prototypes: AOSOL in Portugal (air cooled,6 kW); *University of Applied Research in Gelsenkirchen (Germany - 25 kW);* Robur, air cooled (Italy - 17.5 kW).

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New developments of heat driven water chillers

6

- Prototypes ammonia water systems (without mechanical solution pump): University of Applied Research in Stuttgart (Germany) (appr. 3-5 kW); SolarFrost in (Austria);

- Commercial: Adsorption chillers two manufacturers offer machines with capacities starting at 50 kW (Nishyodo, Mayekawa/Mycom)
- Commercial: adsorption heat pump (water, zeolite): Sortech in (Germany) (7.5 kW)

- Commercial: salt water system (LiCl-water): ClimateWell AB in Hägersten/Sweden (10 kW; includes chemical storage); Prototype: SWEAT b.v. in the Netherlands (includes chemical storage)

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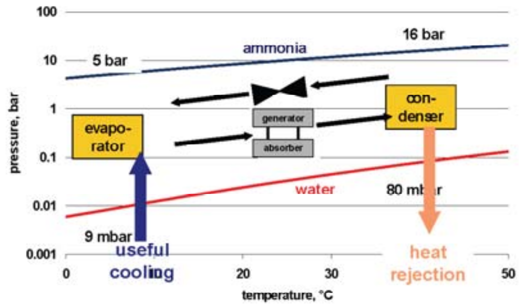
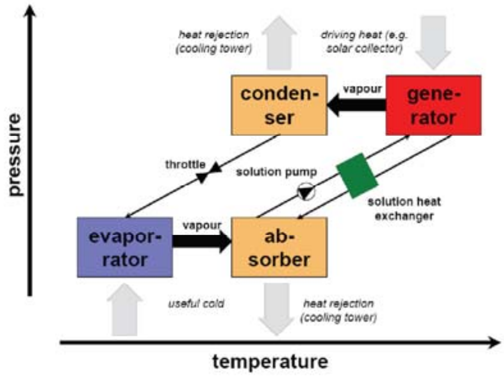
Solar cooling applications

- Majority of the systems in the small capacity range
- the dominating system used in the small capacity range is the WFC 10 from Yazaki (Japan) with a nominal cooling capacity of 35 kW
- it worked without mechanical solution pump using a bubble pump until 2003, new systems are operated with a mechanical solution pump

Basic process - closed cycles

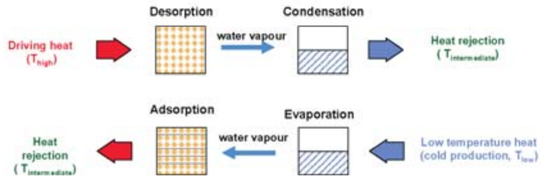


Working principle of an absorption chiller

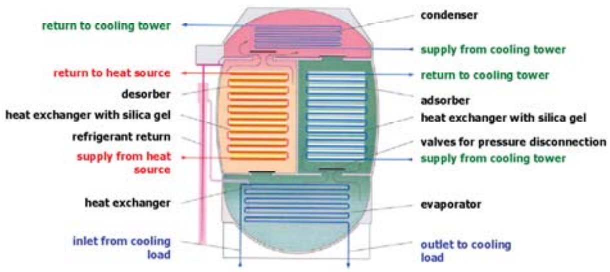


Working principle of an adsorption chiller

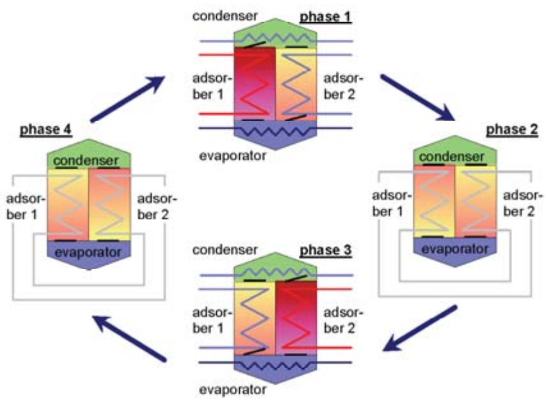
- Adsorption is the bonding of gas molecules on the internal surface of highly porous materials
- This bonding is reversible, i.e., it the working fluid (refrigerant) can be removed and adsorbed periodically
- The equilibrium vapour pressure of the working fluid (refrigerant) is lowered in presence of the adsorption material
- This effect can be employed to realise a technical process of subsequent adsorption and desorption



Scheme of an adsorption chiller

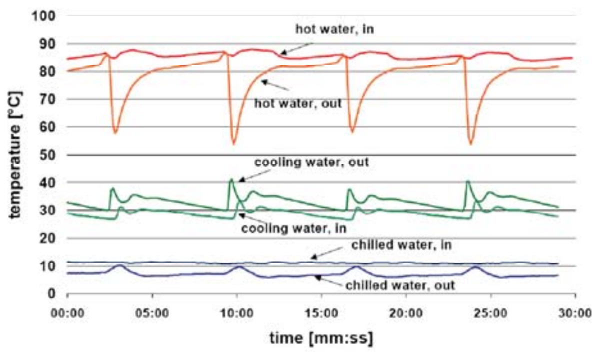


Full cycle of an adsorption system



Periodic operation ==> periodic temperature fluctutations

13



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Market status of desiccant systems

14

Systems using solid sorbent: desiccant rotors desiccant rotors are available in a broad range of sizes from several manufacturers; based either on silica gel or lithium-chloride

Systems using liquid desiccants some systems in pilot plant operation

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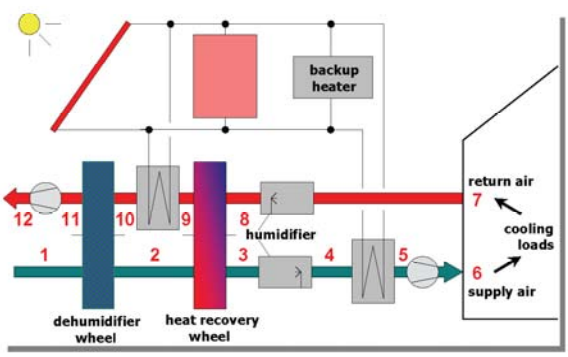
Basic cycle using a sorption wheel

15



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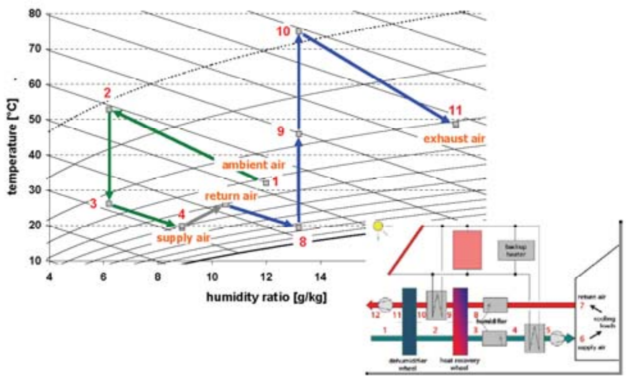
Working principle of the basic cycle

16



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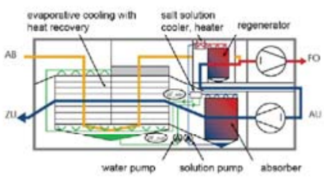
New developments of desiccant cooling systems

17

- Menerga (Germany): new air handling unit using liquid sorption; dehumidifier in combination with a standard indirect evaporative cooler; prototype tested in different sites in Germany
- ZAE Bayern (Germany): advanced open cooling system using liquid sorption; concentrated solution used as high energy density storage;
- Other liquid sorption developments: Technion Haifa (Israel); *Queens University (Canada); Kassel University (Germany); University of South Australia.*



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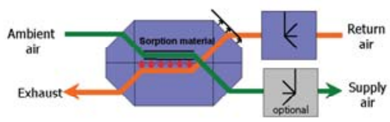
New developments of desiccant cooling systems

18

- ECOS - indirect Evaporative COoling counter-flow heat exchanger with Sorption: high efficient indirectly evaporative cooled sorption dehumidifier using a plate heat exchanger coated with zeolite; FhG-ISE (Germany) and ENER-POLIMI (Italy)
- ambient air is simultaneously dehumidified and cooled
- the released sorption heat is CONTINOUSLY transferred to the return air
- regeneration is realized with heated ambient air
- **periodical process** ==> two heat exchangers in order to realize a quasi-continuous operation air-to-air counter-flow hx with a sorptive coating on the supply air side



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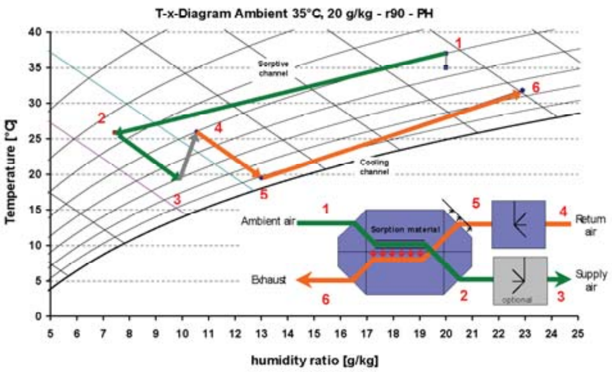
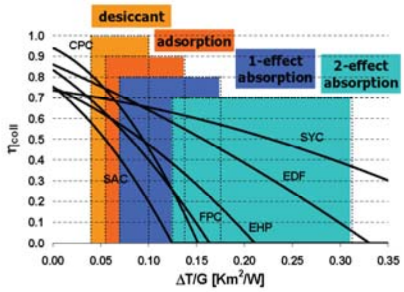
ECOS process path



Solar collectors and thermally driven cooling

- SAC = solar air coll.
- CPC = stationary CPC
- FPC = selectively coated flat plate
- EHP = evacuated heat-pipe
- EDF = evacuated, direct flow
- SYC = stationary concentrated, Sydney-type



New developments of solar collector

- For solar cooling and air-conditioning solar collectors working in the temperature range of 80-150°C are of particular importance
- Approaches
  - Collectors using transparent insulation materials
  - Collectors using two covers with anti-reflective coatings
  - Stationary, concentrating collectors (flat construction, evacuated tubes)
  - Tracking CPC-collectors at lower cost
- Extensive review in IEA SHC Task 33 SHIP

Conclusions

- The market of small scale heat driven absorption chillers is growing steadily. Many are the systems available and under development.
- Adsorption chillers available only in medium-large capacity. Small scale under development.
- Solid desiccant cooling systems: for solid commercial systems are available for medium to large capacity systems and small scale are object of R&D activities; Liquid desiccant cooling systems under development worldwide, forseen commercial application soon.
- The peculiarities of the systems require a rigorous approach to design (see Design tools) and the choice of the proper coupling heat driven cooling technology+distribution system+solar collector

Thank you for your attention!!

Conference: Sustainable Cooling Systems
TECHbase Vienna
31st of March 2008

Overview of existing large scale solar cooling installations in Europe.

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Key words: solar cooling, state of the art, practices

1. Introduction

Within the activities of the Task 38 project [1], a list has been draft including known worldwide solar cooling installations with a cooling capacity over then 20 kW [2]. In order to define the state of the art of the existing large scale solar cooling systems, relevant data have been collected and statistics have been elaborated. The present work shows the results derived from statistic elaborations of significant data concerning European installations and illustrates some applications.

2. Method

For each solar cooling installation, the following data have been collected and elaborated:
- building uses;
- technologies applied;
- cooling capacities and solar collectors surfaces.

Those data have been collected through:
- direct contact to task 38 participants following single systems;
- contact of the institutions who own the systems;
- contact of installation firms;
- international projects like (e.g. IEA-Task 25 [3]).

3. Results

The list counts 76 large scale solar cooling systems installed in Europe, mainly in Spain and in Germany. 60% of these installations are office blocks, 12% industries, 9% laboratories and education centres; the left percentage consists in buildings with different uses (hospitals, schools, sport centre, etc). In 69% of installations absorption chillers are used, in 18% DEC (Desiccant Evaporative Cooling) systems and in 13% adsorption chillers. Among the DEC installations, only 1 system uses a liquid absorber (DEC liquid). The overall cooling capacity of the solar thermally driven chillers amounts to 8,6 MW and it is assisted by 21.860 m² solar collectors. 38% of the solar installations for cooling purposes is made off FPC (Flat Plate Collectors), 36% of ETC (Evacuated Tube Collectors), 10 % of CPC (Compound Parabolic Collectors) and 11% of AH (Air Heaters). Not all the possible combinations

between solar collectors and thermally driven cooling machines have been applied yet: the most spread one includes absorption chillers and evacuated tube collectors.
Going more in details with some installations, a huge diversification in final uses, in applied technologies and in design features can be observed.

4. Conclusion

The data collection about solar cooling installations has been useful to define the state of the art of the technology in Europe. Statistics have revealed that large differences occur among the installations in final uses, technologies applied and design features. This reveals, on one hand, that solar cooling technology is suitable for various applications and integration with different conventional heating and cooling systems, on the other hand, that a very limited standardization has been reached up to now.

5. Sources

[1] www.iea-sch.org

[2] W. Sparber, A. Napolitano, P. Melograno, Overview on world wide installed solar cooling systems. 2nd International Conference Solar Air-Conditioning, Tarragona, October 200

[3] www.iea-shc-task25.org

EURAC research

Existing solar cooling installations in Europe

EURAC Research - Institute for Renewable Energy
Wolfram Sparber, Assunta Napolitano

EURAC research

AGENDA

1. Introduction
2. Overview on European solar cooling installations
3. Statistics
4. Specific cases
   - EURAC, a research centre in Bolzano - Italy
   - A multipurpose Building at AUDI logistic center- Ingolstadt, Germany
   - An industrial application, the FESTO technology center - Esslingen, Germany
   - An offices block for the Renewable Energy House - Brussels, Belgium
5. Conclusions

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Introduction

- Among the activities of Task 38, a list has been draft including known worldwide solar cooling installations with a cooling capacity over then 20 kW.
- For each installation, data such as geographical distribution, building uses, cooling and solar thermal technologies applied, components sizes and plant layouts, have been collected and analyzed.
- The data about existing solar cooling plants have been collected through:
  - direct contact to task 38 participants following single systems;
  - contact of the institutions who own the systems;
  - contact of installation firms;
  - international projects like IEA-Task 25, RoCoCo and SACE.

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Overview

- 88 worldwide solar cooling plants have been listed, 86% being installed in Europe.
- The data collected show:
  - diversified applications;
  - various design solutions and energy strategies;
  - large possibility of integration with conventional and/or preexistent solar and heating facilities.

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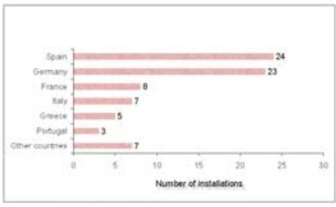
European solar cooling installations Statistics

- 76 solar assisted cooling plants
- 8.670 kW heat driven cooling power
- 21.860 m² solar thermal collectors



European installations distribution

- "Other Countries" include: Kosovo, Denmark, Belgium, Austria and Netherlands.

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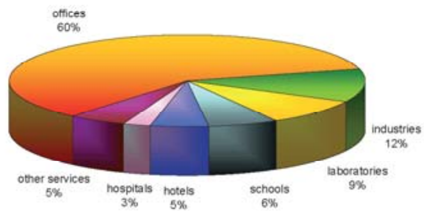
Applications



Final uses of European installations

- Some applications included in "Other services" are: an auditorium, a sport center, a library and a canteen.

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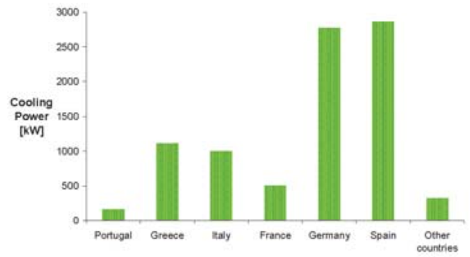
Heat driven cooling power



- "Other Countries" include: Kosovo, Denmark, Belgium, Austria and Netherlands.

Heat driven cooling capacity installed in different European Countries

Existing solar cooling installations in Europe 31 March 2008 7

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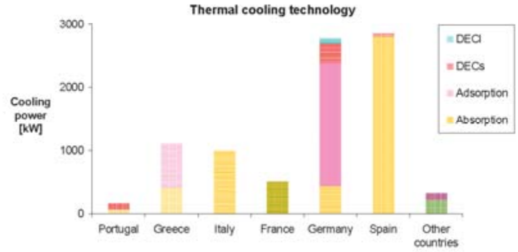
Heat driven machines



Cooling Machines Type	Absorption	Adsorption	DEC Solid	DEC Liquid
Number of installations	53	10	13	1

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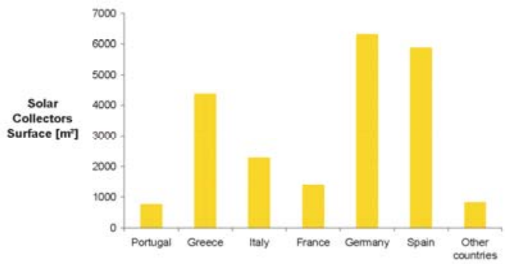
Solar thermal fields



- "Other Countries" include: Kosovo, Denmark, Belgium, Austria and Netherlands.

Solar thermal collectors installed for cooling purposes in different European Countries

Existing solar cooling installations in Europe 31 March 2008 9

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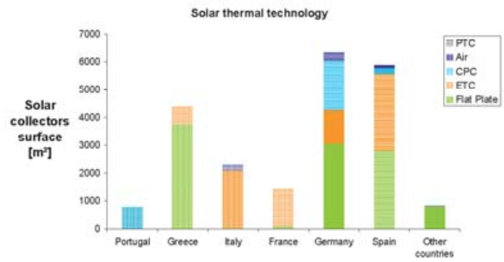
Solar collectors for cooling purposes



Solar Collectors Type	FP	ETC	CPC	Air	PTC
Number of installations	33	34	8	5	0

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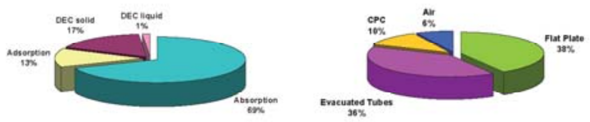
Technologies combinations



Combination	Absorption	Adsorption	DEC solid	DEC liquid
FP	18	6	4	1
ETC	27	1	0	0
CPC	3	2	3	0
AIR	0	0	5	0

- 5 hybrid systems are not included in the table

Existing solar cooling installations in Europe 31 March 2008 11

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EURAC, research center Bolzano-Italy

A Combined Heating, Cooling and Power system including absorption chiller and evacuated tube collectors.

Data provided by courtesy of:
Eurac research


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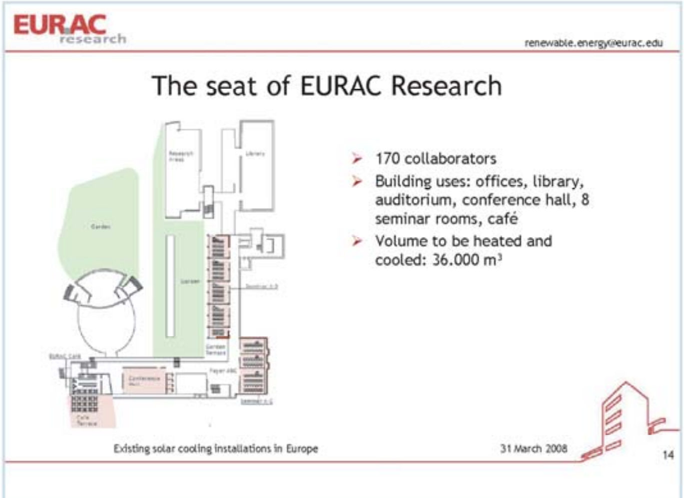
The seat EURAC Research
Built in 1936 and listed since 1987 as example for Italian rationalism
Founded as private research institute in 1992
Refurbished to a solar active and passive building in 2002
Existing solar cooling installations in Europe
31 March 2008
13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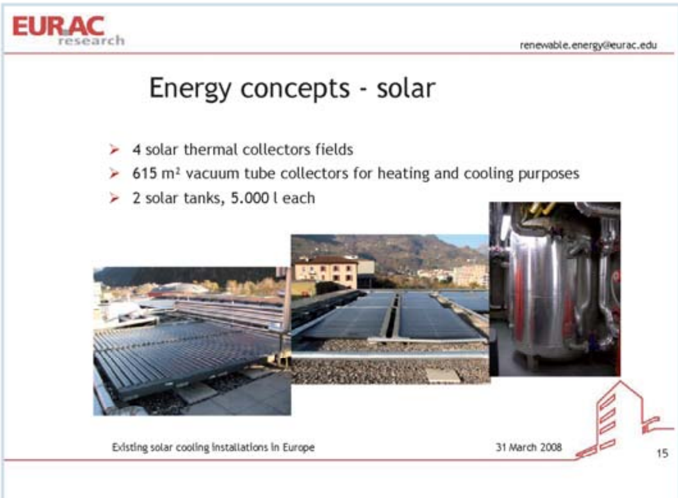
The seat of EURAC Research
170 collaborators
Building uses: offices, library, auditorium, conference hall, 8 seminar rooms, café
Volume to be heated and cooled: 36.000 m³
Existing solar cooling installations in Europe
31 March 2008
14


EURAC research
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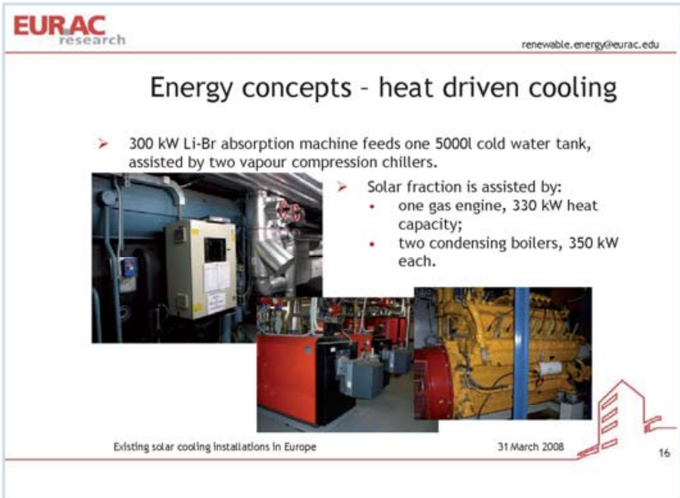
Energy concepts - solar
4 solar thermal collectors fields
615 m² vacuum tube collectors for heating and cooling purposes
2 solar tanks, 5.000 l each
Existing solar cooling installations in Europe
31 March 2008
15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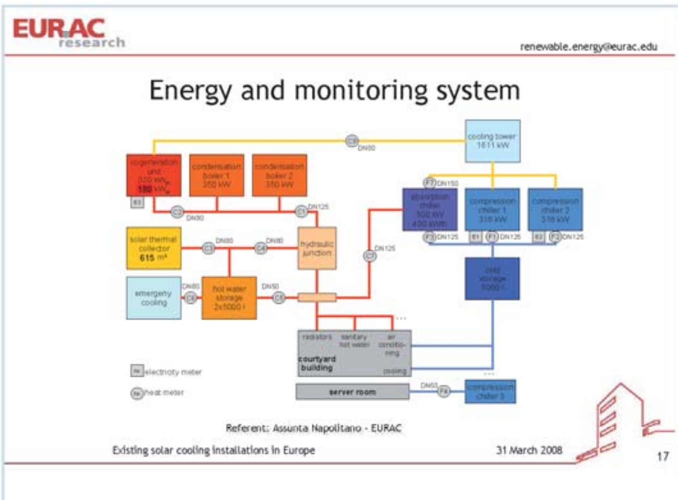
Energy concepts – heat driven cooling
300 kW Li-Br absorption machine feeds one 5000l cold water tank, assisted by two vapour compression chillers.
Solar fraction is assisted by:
one gas engine, 330 kW heat capacity;
two condensing boilers, 350 kW each.
Existing solar cooling installations in Europe
31 March 2008
16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Energy and monitoring system
cooling tower 1611 kW
solar thermal collector 615 m²
hydraulic junction
emergeny cooling
courtyard building
server room
Referent: Assunta Napolitano - EURAC
Existing solar cooling installations in Europe
31 March 2008
17

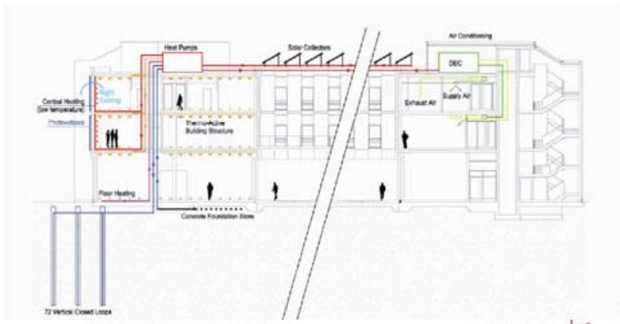

EURAC research
Multipurpose building at AUDI logistic center Ingolstadt, Germany
DEC technology and flat plate collectors
Data provided by courtesy of:
Christoph Trinkl - University of Applied Sciences Ingolstadt

Multipurpose building


- In use since 2004
- Building uses: a training centre (ground floor), an office environment, a film studio (second floor) and a hotel (third floor).
- Volume: 45.000 m³

Existing solar cooling installations in Europe — 31 March 2008 — 19

Multipurpose building, plant scheme



Existing solar cooling installations in Europe — 31 March 2008 — 20

Energy concepts - solar

- 2 fields of solar thermal flat plate collectors, per 280 m² total area
- 2 thermal tanks of 3.000 l each and a thermal ground storage (approx. 15.000 m of piping in the building's foundation,72 vertical closed loops of 40 m depth).

Existing solar cooling installations in Europe — 31 March 2008 — 21

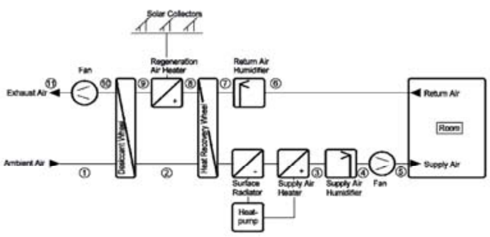
Energy concepts – heat driven cooling

- Base-load cooling is supplied by two heat pumps (320 kW heating power, 240 kW cooling power) and effected through a thermo-active building structure.


- The peak-load cooling is met by 2 solar-driven DEC units with approximately 38 kW each.
- Ventilation air flow: 8.000 m3/h each DEC system

Existing solar cooling installations in Europe — 31 March 2008 — 22

DEC system



- Heat pump is used as back-up system to cool down the supply air in the surface radiator in summer, to heat up the supply air in winter.

Existing solar cooling installations in Europe — 31 March 2008 — 23

FESTO Technology Center Esslingen, Germany

Adsorption chillers and CPC collectors

Data provided by courtesy of:
Antoine Dalibard - University of Applied Sciences Stuttgart

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FESTO, the building

- Building use: offices
- Conditioned area: 25.000m²

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Energy concepts – solar energy

- Compound Parabolic Collectors, per 1.218 m² field for heating and cooling purposes.
- Collectors feed 2 solar tanks, in series connected, 7.000 l each.

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Energy concepts – heat driven cooling

- 3 adsorption chillers, 350 kW each

- Solar fraction is assisted by gas boilers and waste heat recovery from compressors involved in the manufacturing processes.

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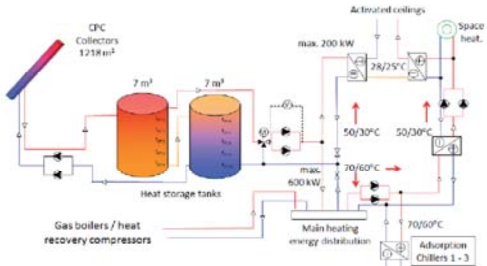
FESTO, plant scheme



Renewable Energy House
Brussels, Belgium

Flat plate and evacuated tube collectors for an absorption machine

Data provided by courtesy of:
Roel De Coninck - 3E Brussels

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Renewable Energy House, the building

- Building use: offices
- Volume: 9.900 m³

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Energy concepts – solar energy

- Two solar thermal fields: the first one is made of 42,8m² evacuated tube collectors whereas the second one is made of 38,3 m² flat plate collectors.
- Solar energy is stored in 2 tanks per 2m³ each one , in series connected.

Existing solar cooling installations in Europe 31 March 2008 31

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Energy concepts – heat driven cooling

- A LiBr absorption chiller with a cooling capacity of 35 kW is installed.
- The solar fraction is assisted by: one 80 kW pellet boiler and one ground coupled heat pump. The last one provides heat during winter while during summer it is used as heat rejection system for the absorption chiller.

Existing solar cooling installations in Europe 31 March 2008 32

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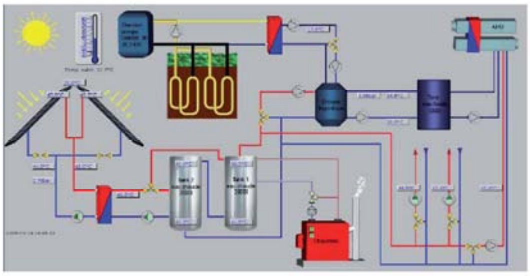
REH, plant scheme

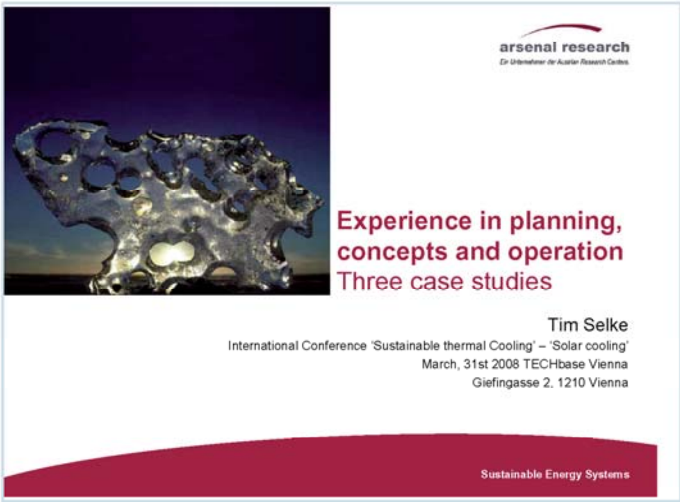


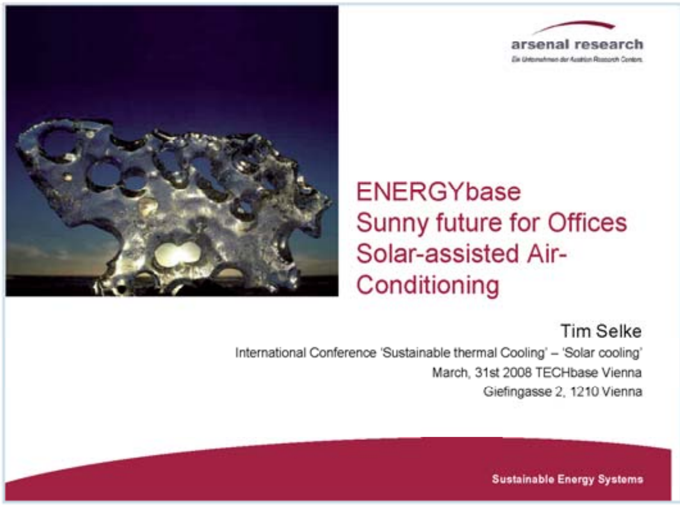
Existing solar cooling installations in Europe 31 March 2008 33

EURAC research

Conclusions

- Statistics have shown that solar cooling technology fits for various applications and different building uses.
- The installations have highlighted large differences in design choices and control strategy.
- Monitoring and optimisation in the first years of operation is highly recommended
- Establishment of rools of thumb derived from experiences lead to improvements of the solar cooling installations and thus to a faster market introduction.


arsenal research
Experience in planning, concepts and operation
Three case studies
Tim Selke
International Conference 'Sustainable thermal Cooling' – 'Solar cooling'
March, 31st 2008 TECHbase Vienna
Giefingasse 2, 1210 Vienna
Sustainable Energy Systems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ENERGYbase
Sunny future for Offices
Solar-assisted Air-Conditioning
Tim Selke
International Conference 'Sustainable thermal Cooling' – 'Solar cooling'
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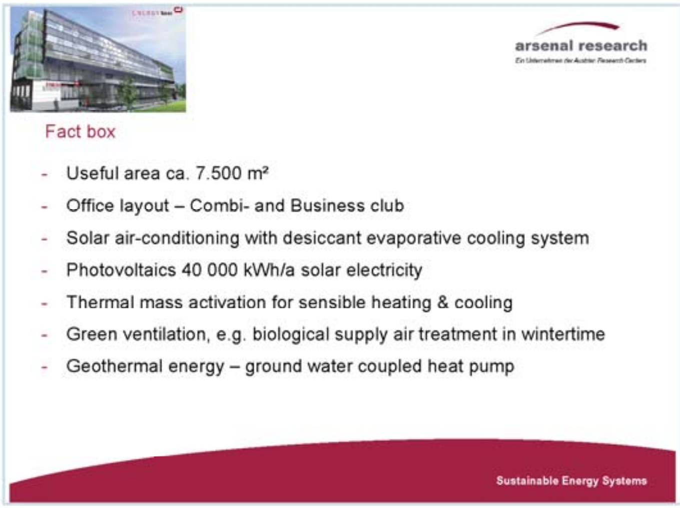
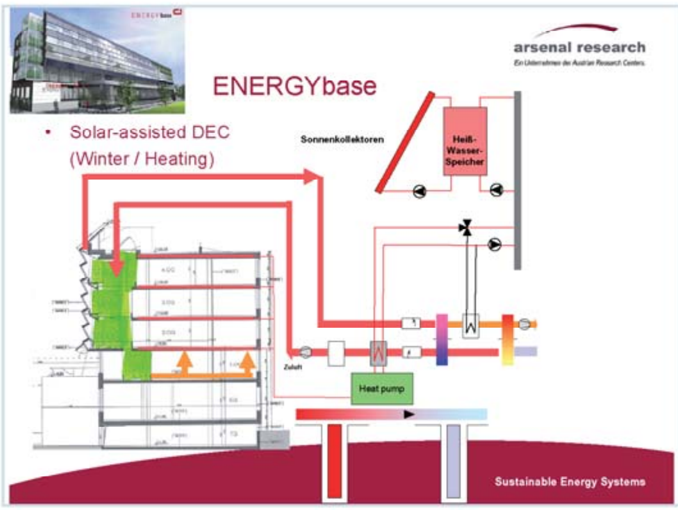
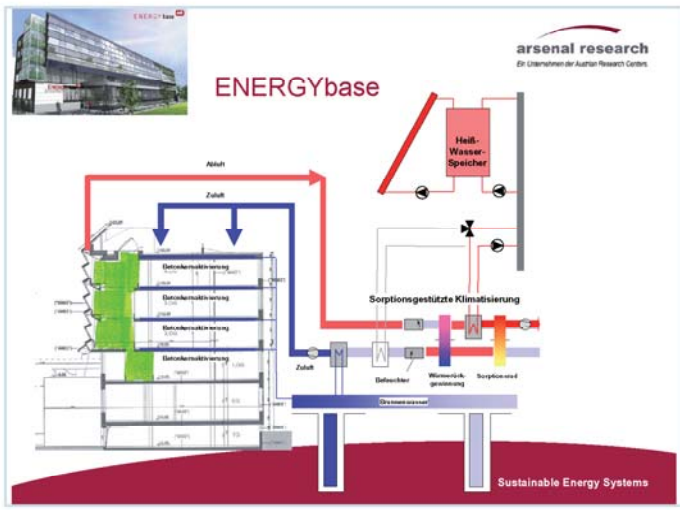
ENERGY base


arsenal research
Fact box
- Useful area ca. 7.500 m²
- Office layout – Combi- and Business club
- Solar air-conditioning with desiccant evaporative cooling system
- Photovoltaics 40 000 kWh/a solar electricity
- Thermal mass activation for sensible heating & cooling
- Green ventilation, e.g. biological supply air treatment in wintertime
- Geothermal energy – ground water coupled heat pump
Sustainable Energy Systems


arsenal research
ENERGYbase
• Solar-assisted DEC (Winter / Heating)
Sonnenkollektoren
Heiß-Wasser-Speicher
Heat pump
Sustainable Energy Systems


arsenal research
ENERGYbase
Heiß-Wasser-Speicher
Sorptionsgestützte Klimatisierung
Sustainable Energy Systems

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Ein Unternehmen der Austrian Research Centers

- 2nd generation

CONCEPT FOR Desiccant Cooling System Design

- Is applied for supply air treatment (temperature and humidity)
- Operates in moderate climate (35°C/ 15 g/kg)
- Operates with constant volume flow due to the hygienic requirements
- Operates with moderate set values for supply air (20°C /10 g/kg)

Main task: Control of latent loads of the office building

Thermal concrete activation

- Covers the sensible cooling load (30W/m²)
- Use of ground water

Sustainable Energy Systems

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- 2nd generation

Standard desiccant cooling system (slightly adapted)

- Two separate air handling units (east and west unit)
- Design volume flow rates : 8 240 m³/h (east) and of 8 880 m³/h (west)
- Flat plate collectors : 285 m² (South/ 30°)
- Hot water storage : 15 m³
- Two regeneration heat exchanger : 80 kW
- Sorption wheel use for dehumidification (summer operation) as well for humidity recovery (winter operation)

Sustainable Energy Systems

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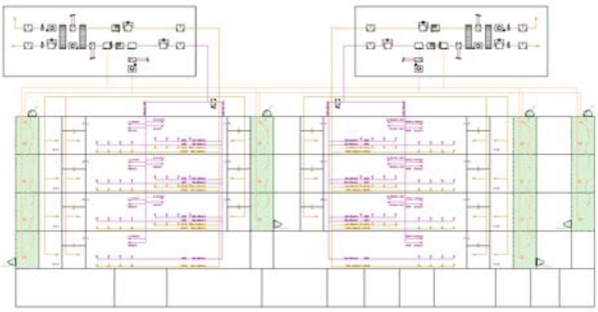
ENRGYbase - air handling system



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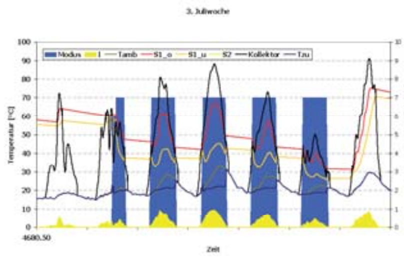
Solar DEC Design



One week in July

Low solar radiation

Ambient temperature > 30°C

Results

- Collector field generates temperatures up to 70°C (DEC mode operation) Weekend 90°C
- Storage temperature >=60°C
- Supply temperature > 22°C

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Summary

- Concept for solar DEC system for office building
  - Humidity control by solar DEC system (dehumidification in summer and humidity recovery in winter)
  - Thermal mass activation covers sensible heating & cooling load
  - Solar thermal heat assists heat pump system in winter operation
- HVAC planning was supported by transient system simulation results
- Some advanced control strategies are developed
- Comprehensive monitoring is foreseen in order to evaluate the overall HVAC system performance

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WEBsite

www.energybase.at

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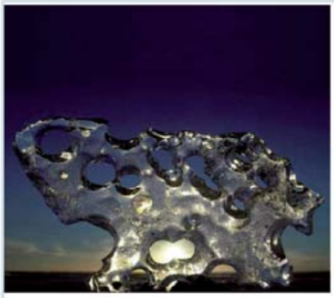

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Solar assisted air-conditioning at the University Hospital in Freiburg/ Germany

Edo Wiemken*), Hans-Martin Henning*), Kay Teckenburg*)
Tim Selke

International Conference 'Sustainable thermal Cooling' – 'Solar cooling'
March, 31st 2008 TECHbase Vienna
Giefingasse 2, 1210 Vienna

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Solar assisted air-conditioning at the University Hospital in Freiburg/ Germany

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System description

- Solar assisted air-conditioning of a laboratory building (approx. 360 m² floor area)
- Two central supply air systems, provided with chilled / heated water, to cool / heat the supply air stream
- Chilled water supply: Adsorption chiller of 70 kW chilling capacity
- Hot water supply for heating and operation of Adsorption chiller:
  - steam heat exchanger supplied by local steam network of University Hospital;
  - 171 m² vacuum tube solar collectors

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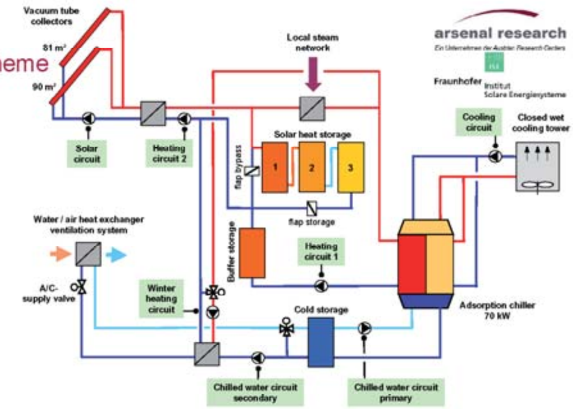
Scheme



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System control

- **Solar circuit:**
  pump starts at radiation level 250 W/m²; volume flow controlled to allow constant high collector output temperature (65-70°C)
- **Heating circuit 1:**
  pump is primarily operated according to the position of the A/C supply valve (thus, according to the cooling demand). Additionally, it is matched to the volume flow in heating circuit 2
- **Heating circuit 2:**
  pump runs in principle parallel with solar circle pump. If temperatures at secondary stage of solar heat exchanger exceed the temperature levels in solar circle due to high temperatures from steam backup, this pump is stopped

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Solar assisted air-conditioning at the University Hospital in Freiburg/ Germany

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System control

- **Chilled water circuit primary and cooling circuit:**
  controlled internal by the adsorption chiller (to avoid freezing of the evaporator). Both pumps are operated simultaneously
- **Cycle length of chiller**
  (switching period from adsorption to regeneration):
  the originally internal control of a fixed period length of 7 minutes was altered to an external control:

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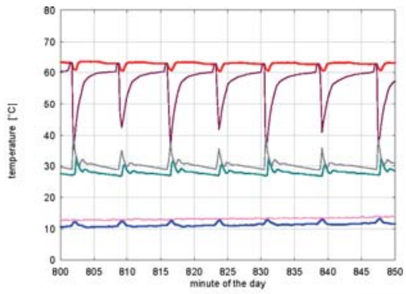
Adsorption machine temperature levels



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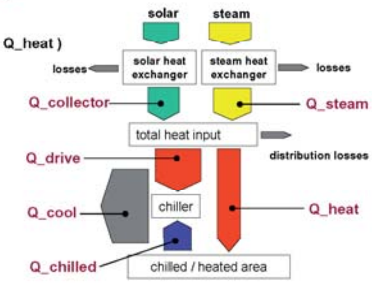
Solar assisted air-conditioning at the University Hospital in Freiburg/ Germany

Monitoring/ Measurement problems

Definition of terms

Q_drive = (Q_collector + Q_steam - Q_heat)

by neglecting distribution losses



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Monitored data 2003

Coefficient of Performance COP:

COP_1 = Q_chilled / (Q_steam + Q_collector - Q_heat)

COP_2 = Q_chilled / Q_drive

COP_1: too low (higher heat dissipation than expected, measurement error in Q_collector)

COP_2: too high (measurement error in Q_drive)

⇒ **COP = (COP_1 + COP_2) / 2**

Solar Fraction:

Q_collector / (Q_collector + Q_steam)

Net collector efficiency:

Q_collector / Q_solar

Q_solar: radiation energy in collector plane

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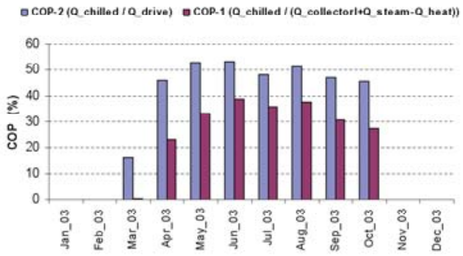
Monitored data 2003



Difference between COP_1 and COP_2

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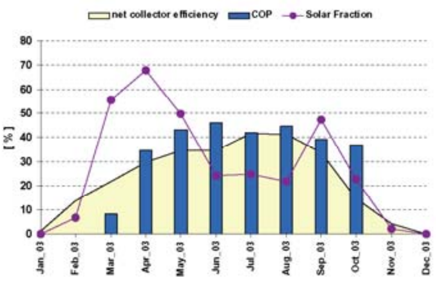
Monitored data 2003
Performance data

Annual values

COP:	43 %
net coll. eff.:	31 %
Solar Fraction:	28 %
coll. yield:	395 kWh/m²

error: ± 15% relative



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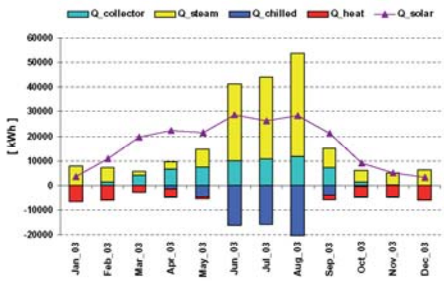
Monitored data 2003
Energy data

Annual values

Q_solar:	199400
Q_collector:	60900*
Q_steam:	155300*
Q_chilled:	-62200
Q_heat:	-38000

*error: ± 10% relative



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Monitored data 2003
Electricity consumption
(pumps, cooling tower fan)

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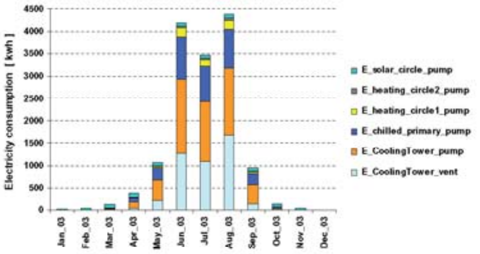
Not included:
Pump
winter heating circle;
chilled water, secondary

total annual
electricity consumption:
14800 kWh



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Monitored data 2003
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arsenal research

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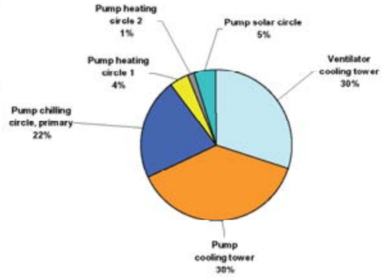

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Estimation of primary energy savings 2003

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Results of Monitoring

- Reference system without solar system
  Adsorption chiller with total heat supply from
  steam heat exchanger; heating with heat from steam heat exchanger
- Savings: 2. COP of reference system = 0.43
- Primary energy savings of solar assisted system: 29 700 kWh/a
- Avoided CO2 emissions of solar assisted system: 9.0 t/a

Conversion factors:
electricity 0.36 kWh_{el} / kWh_{PE}
heat 0.85 kWh_{th} / kWh_{PE}

Emissions:
electricity 0.8 kg / kWh_{el}
heat 0.3 kg / kWh_{PE}

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Monitored data 2004

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Changes

- **Exchange of temperature sensors:**
  finished at 12. August 2004, some more calibration actions in the subsequent days
- **Coefficient of Performance COP:**
  now calculated from: COP = Q_chilled / Q_drive

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Monitored data 2004
Day: 18 August

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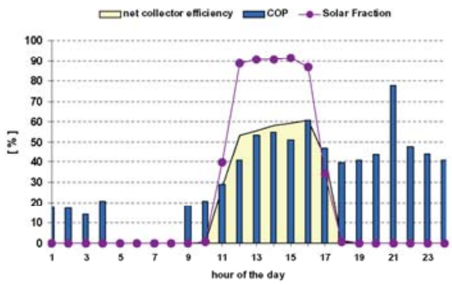
Performance data

Chilling also during night required, but with low chilling power and with low COP



Sustainable Energy Systems

Monitored data 2004
Day: 18 August

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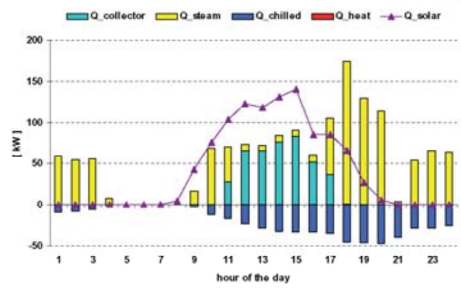
Energy data

Chilling also during night required, but with low chilling power and with low COP (high heat input)



Sustainable Energy Systems

Monitored data 2004

Day: 18 August

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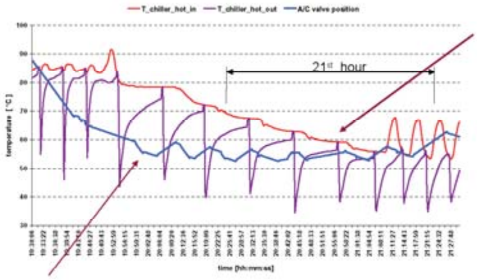

Utilising energy stored in buffer storage and hydraulic circuit; no additional heat.
For a period of approx. 1 hour, the system is in part-load operation close to shut-down (decreasing driving temperature, rising chilled water temperature). Due to the thermal inertia, evaporation is still effective and in combination with the extended cycle length, high COP values are achieved.

AC valve position (%) indicates reduced cooling demand

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Monitored data 2004

Performance data of 31 days

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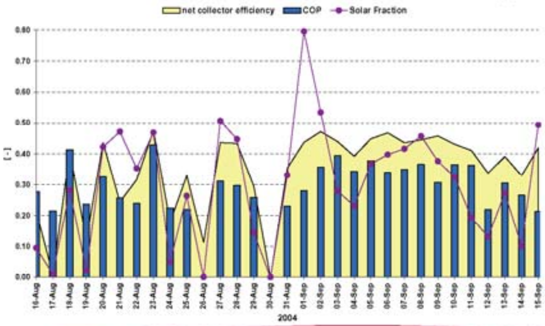

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Monitored data 2004

Energy data of 31 days

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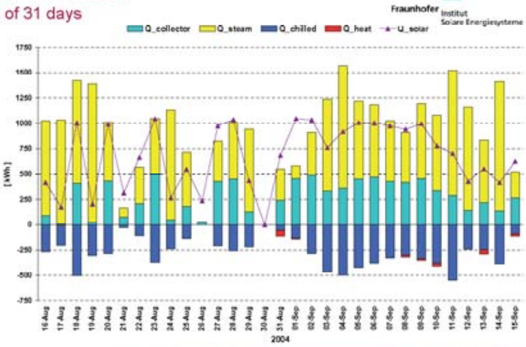

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Summary

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- Reliable system operation
  One event has been occurred:
  during a holiday period with non-use of the chiller system and simultaneous high radiation availability in 2003, the fluid of the solar circle was in part released to the air due to high system pressure. Beside this malfunction, no serious system breakdown has occurred.
- During daytime in summer, the chiller runs mainly solar driven in case of high radiation availability.
- COP values of 0.6 or above may be achieved with sufficient high driving temperatures.
  Average monthly values of COP are in the range 0.35 - 0.5

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Summary

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- To achieve higher solar fractions in the cooling season, collector and storage has to be increased, in order to use solar energy in the evening hours *(modification of system control / hydraulic system required)*
- Complex hydraulic scheme increases heat dissipation in the network
- Electricity consumption of solar circles are small compared to consumption of cooling circle
  → Optimisation potential for cooling tower operation
- Estimated primary energy savings and CO2 savings in the range of 12% compared to the system without solar collector

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Monitoring 2007 – Solar Cooling in an Office Building/ Austria

Tim Selke

International Conference 'Sustainable thermal Cooling' – 'Solar cooling'
March, 31st 2008 TECHbase Vienna
Giefingasse 2, 1210 Vienna

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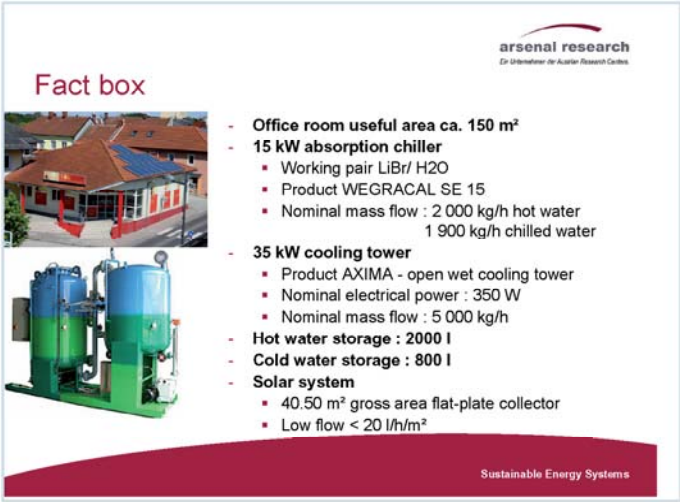
arsenal research
Fact box
- Office room useful area ca. 150 m²
- 15 kW absorption chiller
▪ Working pair LiBr/ H2O
▪ Product WEGRACAL SE 15
▪ Nominal mass flow : 2 000 kg/h hot water
1 900 kg/h chilled water
- 35 kW cooling tower
▪ Product AXIMA - open wet cooling tower
▪ Nominal electrical power : 350 W
▪ Nominal mass flow : 5 000 kg/h
- Hot water storage : 2000 l
- Cold water storage : 800 l
- Solar system
▪ 40.50 m² gross area flat-plate collector
▪ Low flow < 20 l/h/m²
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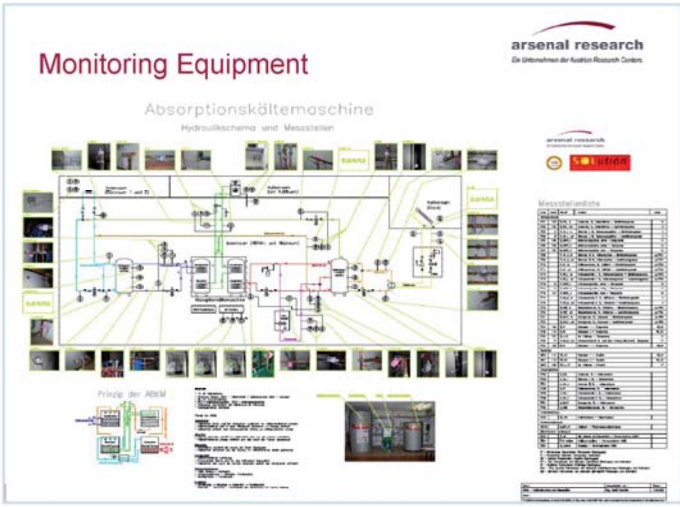
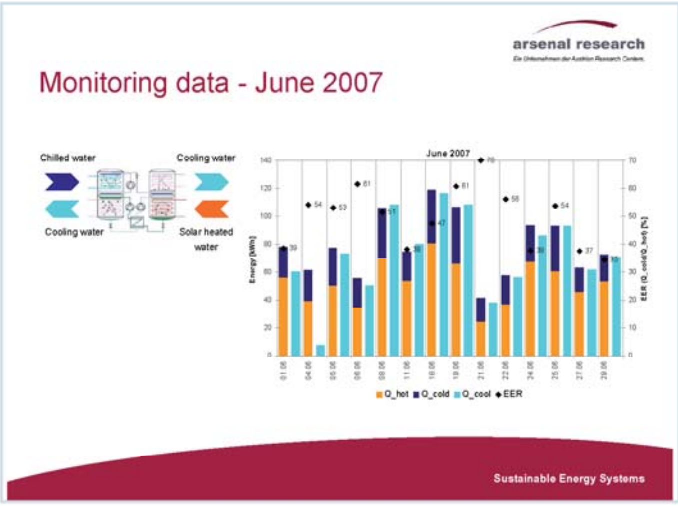
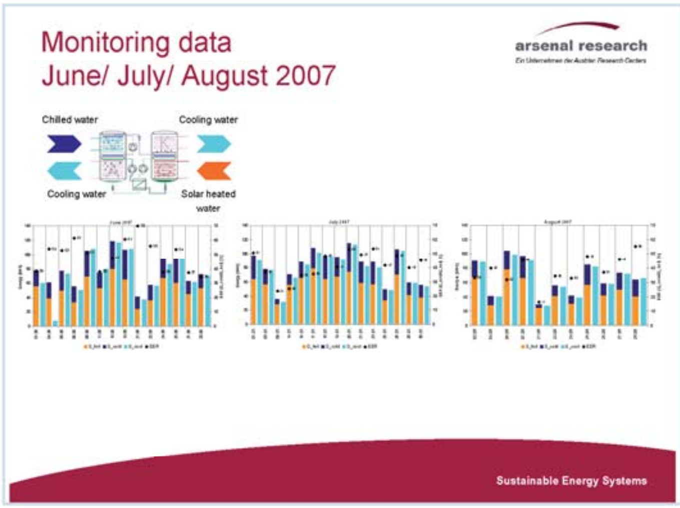
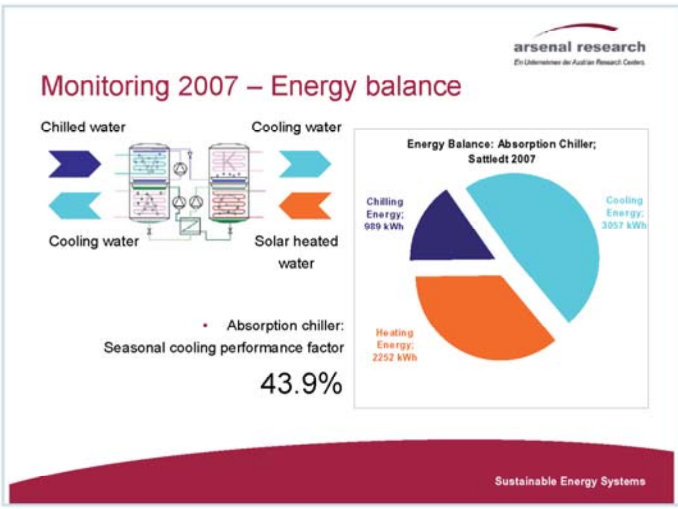

arsenal research
Monitoring Equipment
Absorptionskältemaschine
Sustainable Energy Systems


arsenal research
Monitoring data - June 2007
Chilled water
Cooling water
Cooling water
Solar heated water
June 2007
Energy [kWh]
Q_hot
Q_cold
Q_cool
EER
Sustainable Energy Systems


arsenal research
Monitoring data
June/ July/ August 2007
Chilled water
Cooling water
Cooling water
Solar heated water
Sustainable Energy Systems


arsenal research
Monitoring 2007 – Energy balance
Chilled water
Cooling water
Cooling water
Solar heated water
Absorption chiller:
Seasonal cooling performance factor
43.9%
Energy Balance: Absorption Chiller; Sattledt 2007
Chilling Energy; 989 kWh
Cooling Energy; 3057 kWh
Heating Energy; 2252 kWh
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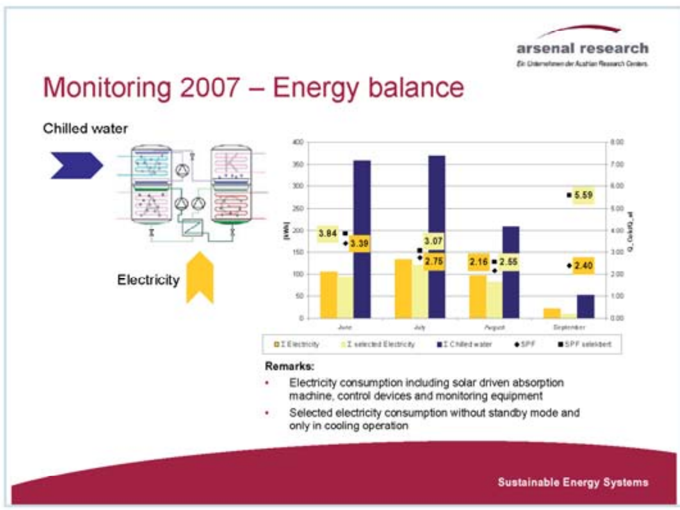
arsenal research
Monitoring 2007 – Energy balance
Chilled water
Electricity
3.84
3.39
3.07
2.75
2.16
2.55
5.59
2.40
June
July
August
September
Remarks:
Electricity consumption including solar driven absorption machine, control devices and monitoring equipment
Selected electricity consumption without standby mode and only in cooling operation
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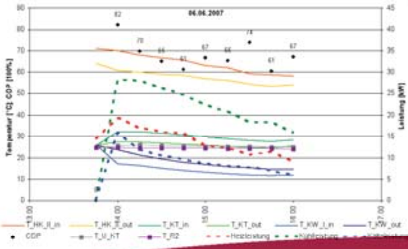
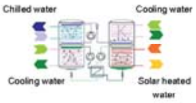
Daily Monitoring
Balance of Absorption machine
06th June 2007

- Good Performance / High COP
- Part load operation 5 – 15 kWCold
- Chilled water temperatures till 12°C
- High temperature differences in all hydraulic circuits
- Continuously decreasing solar system temperatures





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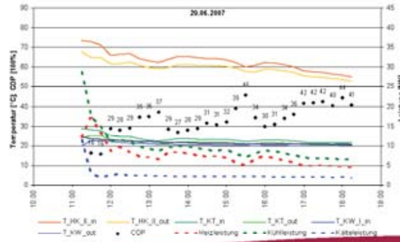
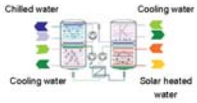
Daily Monitoring
Balance of Absorption machine
29th June 2007

- Bad Performance / Low COP
- Part load operation lower 5 kWCold
- Chilled water temperatures only 20°C
- Cooling tower works efficient
- Continuously decreasing solar system temperatures





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Summary

- **Solar autonomous absorption system** operated from June till September 2007 (temperature control by chilled ceiling)
- 2007 **office** was appropriate cooled (only a coupled of temperatures higher than Toffice < 26°C)
- **Absorption chiller**
  - Absorption chiller was 100% driven by solar energy
  - Mainly operated in part load (0 – 5 kWcold)
  - Seasonal performance factor of 43.9% (Qcold/Qhot)
- **Solar system**
  - 40.5 m² and 2000 l hot water tank supplied hot water temperatures in a range of 55°C to 75°C at a typical day

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Summary

- **Absorption chiller**
  - Mainly operated in part load (0 – 5 kWcold)
  - Despite sufficient heating capacity 21 kW the chilled water temperature did not fall below 15°C (hot water temperature of 75°C is not sufficient)
- **Control improvements**
  - The chiller should be put into operation when the solar system supplies driving temperature of around 85°C
  - Cooling tower operation mode can be incorporated to supply cooled water to the chilled ceiling
- Monitoring in 2008 planned

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Experience in planning, concepts and operation
Three case studies

Tim Selke
International Conference 'Sustainable thermal Cooling' – 'Solar cooling'
March, 31st 2008 TECHbase Vienna
Giefinggasse 2, 1210 Vienna

Sustainable Energy Systems

Conference: Sustainable Cooling Systems
TECHbase Vienna
31st of March 2008

Economic and technical potential across Europe

Laura Sisó Miró, AIGUASOL, Roger de Llúria 29 3r-2a, Spain, laura.siso@aiguasol.coop

Key words: economy, costs, primary energy savings

1. Introduction

One of the ROCOCO project aims was to generate a picture about the present situation of costs of solar cooling systems. In fact, different factors influence the costs structure in this kind of technology: climate, type of building, demand profile along day and months, other thermal uses provided by the system (heating, domestic hot water), type of solar cooling technology (absorption, adsorption, desiccant).

At the same time, the costs of solar cooling plant can be divided in investment costs and costs of operation. The operation costs are related with energy costs to support the auxiliary energy that can not be provided by solar irradiation, and maintenance costs. The costs of solar cooling plants means an increase of investment costs and maintenance costs referring to conventional system[1], and a reduction of operation costs related to energy savings in comparison with conventional system.

The results of this work will provide an identification of high-potential building sectors for the implementation of solar cooling systems, and an economic assessment of the most promising solar cooling technologies in terms of costs.

2. Method

The activities carried out to reach these results have been the following:

- The preparation of technology and market matrix (T & M) using transient simulations for obtaining energy demand values for different areas of applications: hospitals, hotels, office buildings, trade commercial centres and residential buildings.
- Setting up models of solar cooling installations using transient simulations for most promising applications (absorption, adsorption and desiccant) to analyse the energy performance.
- Collecting information from the market about costs of equipment, energy prices and maintenance services costs.
- Assessing the costs for investment (material, installation and planning) and operation (auxiliary energy, water consumption and maintenance) to analyse cost tendencies, in comparison with conventional system.

The analyses include hospitals (A[2]), hotels (B), offices (C), trade centres (D) and residential (E) buildings. The considered climates represent the regions of South, Central and North Europe with examples of Spain, France and Austria. Also extreme climates very arid-hot, in Iran, and humid-hot in Mexico has been assessed.

[1] Conventional system: plant that provides the same uses that are provided by solar cooling plant based on gas boiler, electrically driven vapour compression chiller and air-treatment units.
[2] In parenthesis there is the letter that appears in figures

3. Results

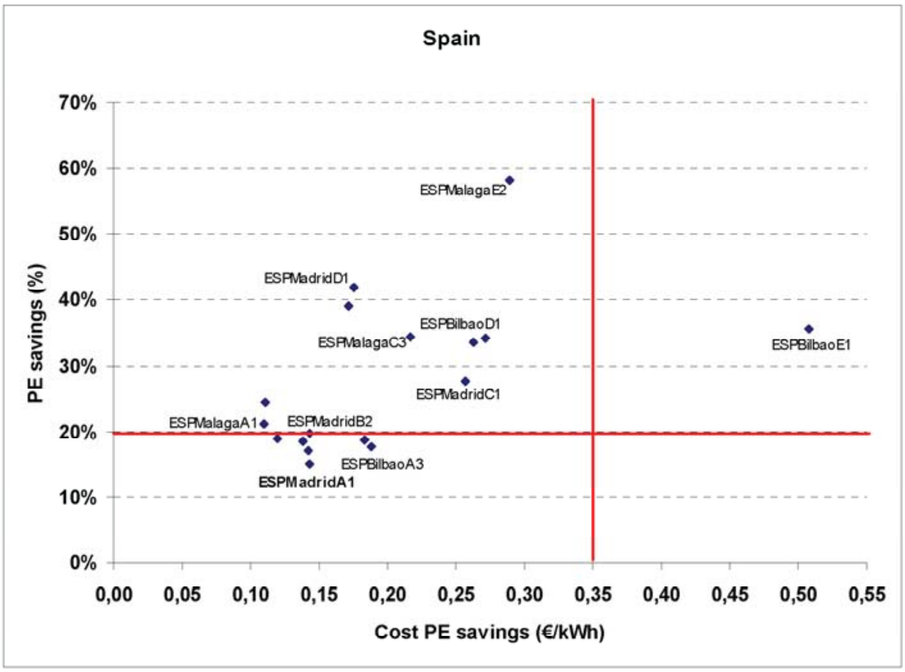
In a first step, the technologies analysed have been absorption with flat-plate collectors and desiccant with flat-plate collectors. In a second step other technologies more expensive but with better energy efficiency have been considered; this means, absorption with evacuated tube collectors and adsorption with flat-plate collectors. Besides that, also desiccant with air collectors has been analysed.

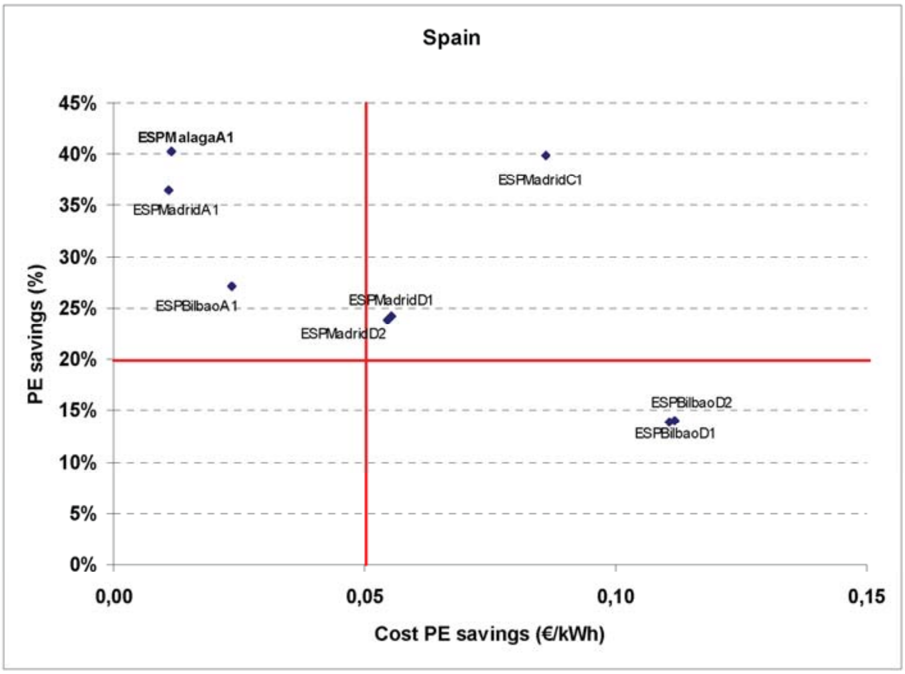
The primary energy savings gained by the solar cooling system in comparison to the reference system and the costs for one primary energy unit saved are taken here as indicators to evaluate high potential building applications.
The analyses show a different picture between the three chosen countries and the two solar cooling technologies (absorption and desiccant). The following figures divide the building applications in four quadrants:

- high PE savings/ low costs of PE savings (1)→ high promising cases
- high PE savings/ high costs of PE savings (2) →very low promising cases
- low PE savings/ low costs of PE savings (3) → potential high promising cases
- low PE savings/ high costs of PE savings (4) → low promising cases

The cases in quadrant 1 are the ones high promising for costs reduction. However it must be taken into account that the cases of quadrant 3 have the potential of cost reduction and PE savings increasing, if hypothesis on design are changed. It means to increase the system size, to increase the investment cost but to reduce the operation costs. Some cases could reach the quadrant 1 with those changes in initial design criteria. Therefore, some cases in quadrant 1 with higher costs of PE savings than other cases in quadrant 3 could be most unfavourable.

The following figures shows the results for absorption and desiccant for the country with the better opportunities for cost reduction from the different analysed regions.





4. Conclusion

Considering the relative increase on investment costs and annual costs of the two analysed solar cooling technologies absorption and desiccant, different characteristics and tendencies for the chosen building applications offices, hospitals, hotels and commercial can be identified.

The initial level of investment costs is much higher for absorption systems in all building applications in a range of 311% to 745% compared to desiccant systems with 96% to 129% (without funding) over a reference system with vapour compression chillers and traditional air handling units. The relative increase in total annual costs for a period of 20 years taking also the energy and maintenance costs into account shows a different picture: 25% to 210% over reference system for absorption systems and 5% to 39% over reference system for desiccant systems. Solar cooling technologies applied in hospitals and hotels achieve the lowest annual cost values.

The situation of high promising building types for the chosen building applications differs between the two solar cooling technologies absorption and desiccant and also between the three countries Austria, Spain and France. High promising cases with absorption technology can be found in Spain for all applications, in France for hospitals and hotels and in Austria also for hospitals and hotels, although considering design optimization is needed to increase the primary energy savings and therefore reduce the operation costs. The cost level is for all absorption cases much higher than in desiccant systems, which means a higher development demand for absorption technology itself than for desiccant. High promising cases with desiccant technology can be found in all of the three countries, which are mainly hospitals and hotels also for all three countries. But also offices with desiccant technology can achieve high primary energy savings and the prices are not that far away from competitive systems.

5. Sources

[1] Duffie, Beckman: Solar Engineering of Thermal Processes, 1991, USA.

[2] Henning, H.M. (Ed): Solar-Assisted Air-conditioning in Buildings. A Handbook for Planners. SpringerWienNewYork. Austria 2003

[3] Henning, H.M.: Decision scheme for the selection of the appropriate technology using solar thermal air-conditioning. IEA Solar Heating and Cooling Programme. Task 25: Solar-assisted air-conditioning of buildings.2004

[4] Henning, H-M.; Wiemken, Edo: SACE-Solar Air Conditioning in Europe. Economic study results report. EU project NNE5/2001/00025. 2003

[5] METEONORM. Global meteorological database for solar energy and applied climatology. Version 5.1

[6] Mugnier, D; Quinette, J.Y.: Check-list method for the selection and the success in the integration of a solar cooling system in buildings. 61st ATI National Congress – International Session "Solar Heating and Cooling. 2007

[7] TRNSYS, Transient System Simulation Program, SEL, Solar Energy Laboratory, University of Wisconsin, Madison (USA), Version 16.0


Title : Reduction of costs of Solar Cooling systems
Acronym: ROCOCO
Economic and technical potential across Europe
Laura Sisó
AIGUASOL
aiguasol
SIXTH FRAMEWORK PROGRAMME
International Conference Sustainable Cooling Systems
31st March 2008 – Vienna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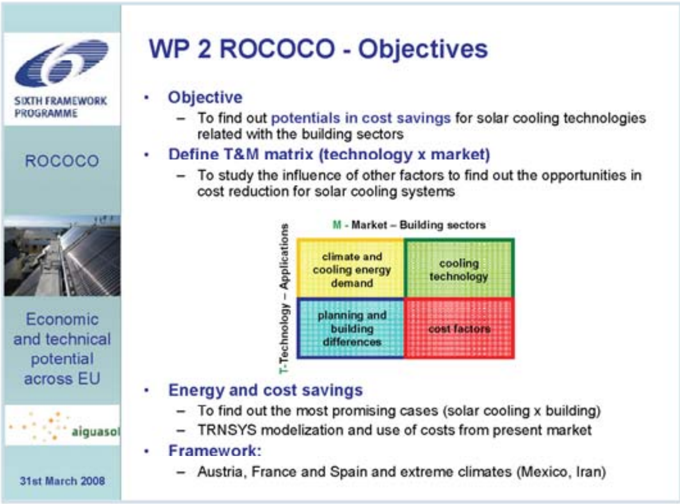
contents
WP 2 ROCOCO – Objectives
WP 2 ROCOCO – Methodology
WP 2 ROCOCO – Results for AB/ADsorption solar cooling systems
Conclusions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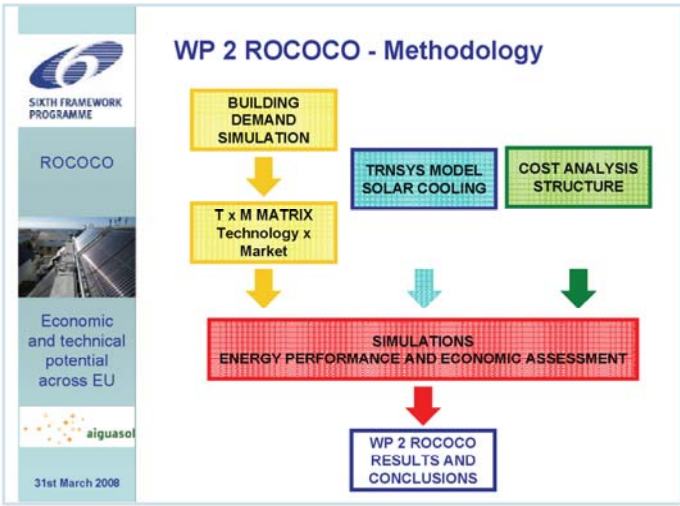
WP 2 ROCOCO - Objectives
Objective
– To find out potentials in cost savings for solar cooling technologies related with the building sectors
Define T&M matrix (technology x market)
– To study the influence of other factors to find out the opportunities in cost reduction for solar cooling systems
M - Market – Building sectors
T-Technology – Applications
climate and cooling energy demand
cooling technology
planning and building differences
cost factors
Energy and cost savings
– To find out the most promising cases (solar cooling x building)
– TRNSYS modelization and use of costs from present market
Framework:
– Austria, France and Spain and extreme climates (Mexico, Iran)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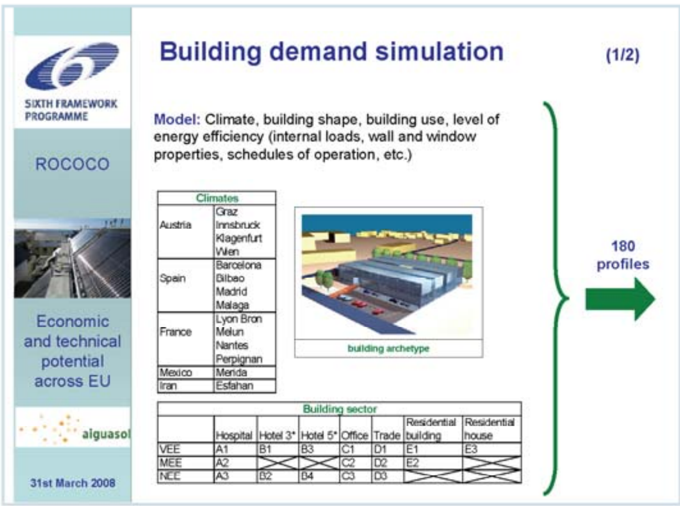
WP 2 ROCOCO - Methodology
BUILDING DEMAND SIMULATION
TRNSYS MODEL SOLAR COOLING
COST ANALYSIS STRUCTURE
T x M MATRIX Technology x Market
SIMULATIONS ENERGY PERFORMANCE AND ECONOMIC ASSESSMENT
WP 2 ROCOCO RESULTS AND CONCLUSIONS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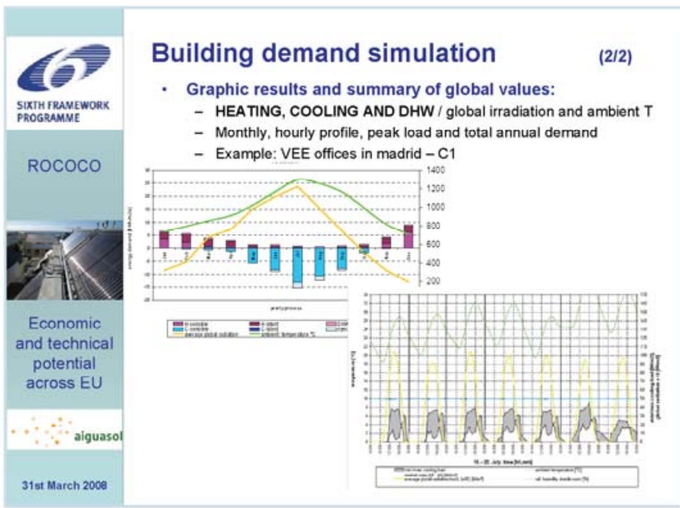
Building demand simulation (1/2)
Model: Climate, building shape, building use, level of energy efficiency (internal loads, wall and window properties, schedules of operation, etc.)
Climates
Austria: Graz, Innsbruck, Klagenfurt, Wien
Spain: Barcelona, Bilbao, Madrid, Malaga
France: Lyon Bron, Melun, Nantes, Perpignan
Mexico: Merida
Iran: Esfahan
building archetype
Building sector
Hospital, Hotel 3*, Hotel 5*, Office, Trade, Residential building, Residential house
VEE: A1, B1, B3, C1, D1, E1, E3
MEE: A2, C2, D2, E2
NEE: A3, B2, B4, C3, D3
180 profiles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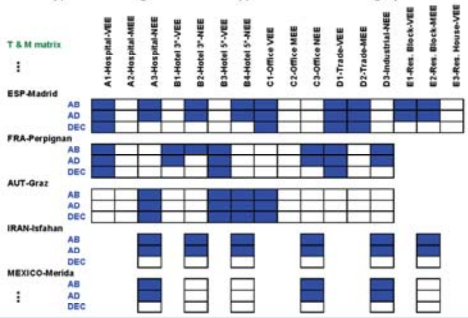
Building demand simulation (2/2)
Graphic results and summary of global values:
– HEATING, COOLING AND DHW / global irradiation and ambient T
– Monthly, hourly profile, peak load and total annual demand
– Example: VEE offices in madrid – C1

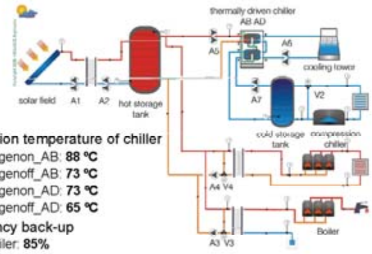
T x M matrix

- Methodology: 60 cases selected from 192
  - Simultaneity in daily profile between cooling load and irradiation
  - Energy demand all year long
    - with balance between energy demand on summer and winter
    - very few months without it
  - Type of building + climate → type of air-conditioning system



Solar cooling model – AB/AD (1/2)

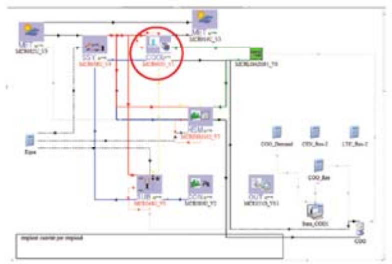
- Pre-design of the solar cooling system
  - COOLING + HEATING + DHW
  - AB/AD capacity: **50-60%** max. cooling load→**70-350 kW**
  - Collector surface: **3 m²/kW** FPC - **2.6 m²/kW** ETC
  - Storage: **0.045 m³/m²** HOT – **0.015 m³/m²** COLD



  - Operation temperature of chiller
    - T_genon_AB: **88 ºC**
    - T_genoff_AB: **73 ºC**
    - T_genon_AD: **73 ºC**
    - T_genoff_AD: **65 ºC**
  - Efficiency back-up
    - Boiler: **85%**
    - Vapour compression chiller: **2.5**

Solar cooling model – AB/AD (2/2)

- Model features
  - Software for transient simulation: TRNSYS
  - Macros structure
  - EXCEL Macros to treat the annual results



Solar cooling model – DEC

- Pre-desing and hypothesis
- Model features

Cost analysis structure (1/2)

- Investment Specific Costs
  - Basis: manufacturer prices and offers from engineering Cos.
  - All countries together. Data from WP1 "demonstration cases"

Sub-system	Cost structure per each sub-system
SC – solar collectors SCA – SC auxiliaries AHS – auxiliary heating system SCP – solar cold production REC – re-cooling STG – storage BCP – back-up cold production CME – control system, monitoring and electricity	• Investment in MATERIAL – **Main equipment** – **Auxiliaries hydraulics** – **Auxiliaries civil** • Investment in INSTALLATION – **Hours x personnel costs** – **(Transport costs not included)**
DSP – design, planning and commissioning	• Investment in DESIGN and PLANNING

Specific costs related to unit of equipment capacity (kW, m², m³)

Costs analysis structure (2/2)

- Maintenance costs
  - From partners experience and WP1 "demonstration cases"
- Energy and water prices
  - Per country: Austria, France, Spain, Mexico and Iran
  - Electricity and gas
- Energy performance analysis parameters
  - PRIMARY ENERGY SAVINGS $$PE_{ZAV} = \frac{PE_{REF} - PE_{SOL}}{PE_{REF}}$$
- Economic analysis parameters
  - RELATIVE INCREASE IN INVESTMENT $$\Delta I_{tot} = \frac{I_{tot-SOL} - I_{tot-REF}}{I_{tot-REF}}$$
  - RELATIVE INCREASE IN TOTAL ANNUALIZED COSTS $$\Delta C_{an} = \frac{C_{an-SOL} - C_{an-REF}}{C_{an-REF}}$$
  - COST OF PRIMARY ENERGY SAVED $$C_{PE-ZAV} = \frac{C_{an-SOL} - C_{an-REF}}{PE_{REF} - PE_{SOL}}$$
  - INCREASE IN COST OF PRIMARY ENERGY $$\Delta C_{PE} = \frac{\frac{C_{an-SOL}}{PE_{SOL}}}{\frac{C_{an-REF}}{PE_{REF}}} - 1$$

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Analysis of results

- Austria, France and Spain
- AB + FPC / DEC + FPC
- Name of buildings

	Building sector						
	Hospital	Hotel 3*	Hotel 5*	Office	Trade	Residential building	Residential house
VEE	A1	B1	B3	C1	D1	E1	E3
MEE	A2			C2	D2	E2	
NEE	A3	B2	B4	C3	D3		

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Investment costs – AB+FPC

Concept	unit	Group 1	Group 3	Group 5	Group 7	Group 8
Solar cooling capacity	kW	70	133	214	329	462
Solar collector surface	m2	210	400	642	987	1 386
Investment solar cooling plant	k€	360	530	727	994	1 268
Relative increase in solar cooling plant	%	311%	417%	511%	591%	745%
Specific costs (solar collector)	€/m2(sc)	**1 724**	1 328	1 133	1 007	**915**
Specific costs (building surface)	€/m2(bui)	113	166	227	310	396
Specific costs (solar cooling-capacity)	€/kW	5 173	3 983	3 398	3 021	2 745

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Investment costs – DEC+FPC

Concept	unit	Group 1 office	Group 2 hotel	Group 3 hospital	Group 4 commercial
Desiccant air flow to supply	m³/h	21 800	29 826	33 901	44 810
Solar cooling capacity	kW	125	175	242	232
Solar collector surface	m2	250	500	500	500
Investment solar cooling plant	€	550 548	793 279	836 604	890 795
Relative increase solar cooling plant	%	96%	127%	119%	106%
Specific costs (m² solar collector)	€/m2	**2 202**	1 587	1 673	**1 782**
Specific costs (m² building surface)	€/m2	172	248	261	278
Specific costs (solar cooling-capacity)	€/kW	4 404	4 533	3 457	3 839

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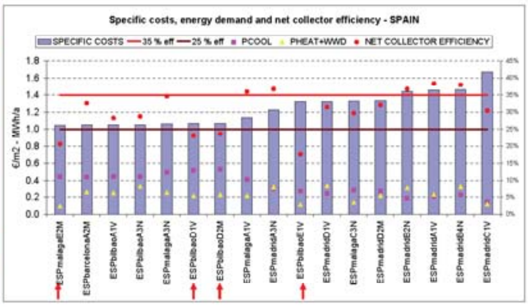
Specific cost and energy performance

- Collector efficiency higher when higher PHEAT+WWD and long operation
  - High eff.: Hospitals and Hotels
  - Low eff. Residential VEE-Bilbao (**E1**) or Malaga (**E2**) and commercial in Bilbao (**D1, D2**)



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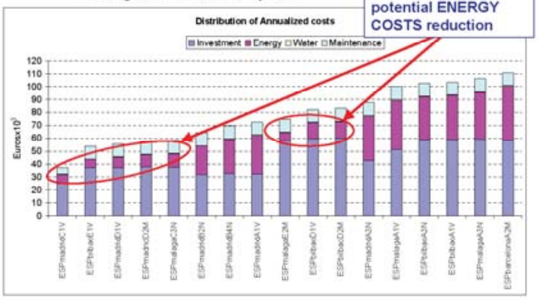
Annualized costs

- Higher contribution of energy costs in buildings with higher PHEAT+DHW → Higher potential for costs reduction
- Relative increase to reference system
  - 3.5 – 6.5 times higher costs in solar cooling than in reference system

Office, commercial, residential low potential ENERGY COSTS reduction



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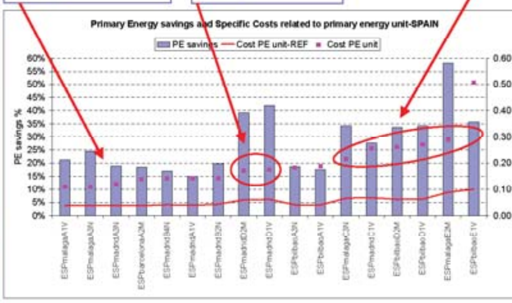
Cost of primary energy saved

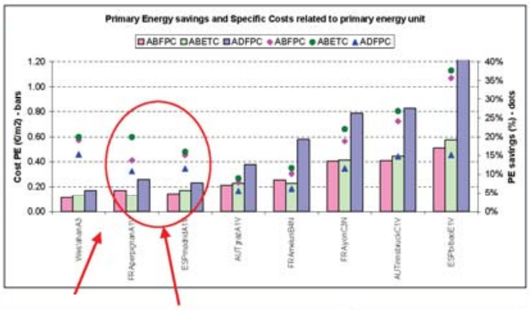
Hospitals and hotels lower costs and higher potential to reduce increasing PE savings

Commercial: low potential to reduce cost increasing PE savings

Office, commercial, residential higher costs of PE



Other technologies



Hospitals in Esfahan, Perpignan and Madrid has promising low costs

Small differences FPC - ETC

Adsorption technology higher costs lower savings

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Conclusion

- **Building Type**
  - **Hospitals and Hotels:** high and continuous demand of both cooling and heating+DHW →lower costs; increasing the solar field surface higher energy savings are expected → **PROMISING APPLICATIONS**
  - **Offices, commercial and residential:** cooling demand higher than heating+DHW demand and less operation time than the other buildings → higher costs; difficulty to reduce due to the most of the costs are related to investment
  - Same results for the other countries
- **Climate**
  - **Perpignan, Madrid and Esfahan** have the **MOST PROMISING CONDITIONS** from the ones studied
- **Cost reduction opportunities**
  - Reduce **specific cost** in **solar collectors** and **chillers** markets
  - **Standarization of engineering**, tools, knowledge of technology
  - **Standarization of control**

SOLAR COOLING HAS TODAY PROMISING MARKETS IN BUILDINGS AND CLIMATES WHERE THERE IS A CONTINOUS HEAT DEMAND

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THANKS FOR YOUR ATTENTION !

For additional information contact:
laura.siso@aiguasol.coop

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31st March 2008

Title : **Reduction of costs of Solar Cooling systems**
Acronym: **ROCOCO**
Target prices for solar cooling systems
Reinhard Ungerböck **CONNESS** **31/03/2008**

SIXTH FRAMEWORK PROGRAMME

Target prices - methodology

1. Optimization of the circumstances of solar cooling systems
2. Expectations of stakeholders, where prices of components and market will lead to

Target prices for solar cooling systems

15/11/07

CONNESS

parametric optimization

Target: to show the different influence in type and scale of certain changes of the circumstances for Solar cooling

1. Increase of electricity and gas prices
2. Increase in performance of SAC
3. Reduction of engineering costs
4. Reduction of control and monitoring costs
5. Reduction of maintenance costs
6. Reduction of solar collector investment cost
7. Reduction of solar cold production chiller investment cost
8. Different subsidies

Target prices for solar cooling systems

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parametric optimization

Basis: optimized outputs of simulations

Certain representative cases

absorption chiller:

1. Madrid, hospital, FPC
2. Innsbruck, office, ETC
3. Lyon, office, ETC

desiccant

1. Malaga, office, FPC
2. Perpignan, trade, FPC
3. Graz, hotel, FPC

Target prices for solar cooling systems

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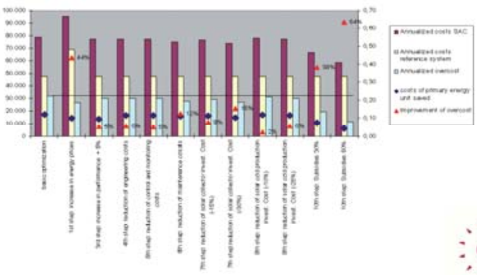
parametric optimization absorption chiller

Madrid, hospital, very efficient envelope, FPC, low primary energy savings, low costs of primary energy unit



Target prices for solar cooling systems

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CONNESS

parametric optimization absorption chiller

Madrid, hospital, very efficient envelope, FPC, low primary energy savings, low costs of primary energy unit

What are the scenarios to reach paybacks of

- 20 years
- 10 years?

Target prices for solar cooling systems

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parametric optimization absorption chiller

Madrid, hospital, very efficient envelope, FPC, low primary energy savings, low costs of primary energy unit

20 years payback:

- Electricity price: +10%/y
- Gas price: +15%/y
- Increase in performance: +10%
- Reduction of engineering costs ⇒ 6%
- Reduction of control and monitoring costs ⇒ +50% over reference
- Reduction of maintenance costs ⇒ +50% over reference
- Reduction of solar collector investment ⇒ -30%
- Reduction of solar cold production chiller investment ⇒ -25%
- Subsidies on overall investment costs: 25%

Return on investment: ~3%

Target prices for solar cooling systems

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parametric optimization absorption chiller

Madrid, hospital, very efficient envelope, FPC, low primary energy savings, low costs of primary energy unit

10 years payback:

- Increase in performance: +15%
- Reduction of engineering costs ⇒ 6%
- Reduction of control and monitoring costs ⇒ +30% over reference
- Reduction of maintenance costs ⇒ +35% over reference
- Reduction of solar collector investment ⇒ -50%
- Reduction of solar cold production chiller investment ⇒ -40%
- Subsidies on overall investment costs: 50%

Return on investment: 13%

Target prices for solar cooling systems

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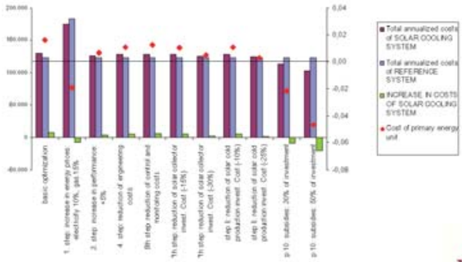
parametric optimization desiccant

Graz, hotel, FPC, high energy savings, low costs of primary energy unit



Target prices for solar cooling systems

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CONNESS

parametric optimization desiccant

- Graz, hotel, FPC, high energy savings, low costs of primary energy unit

What are the scenarios to reach paybacks of

1. 20 years?
2. 10 years?

Target prices for solar cooling systems

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CONNESS

parametric optimization desiccant

- Graz, hotel, FPC, high energy savings, low costs of primary energy unit

20 years payback:

- Reduction of solar cold production investment ⇒ -10%
- Subsidies on solar collector installation (Austrian subsidy system): 25%

Return on investment: ~5%

Target prices for solar cooling systems

15/11/07

CONNESS

parametric optimization desiccant

- Graz, hotel, FPC, high energy savings, low costs of primary energy unit

10 years payback:

- Increase in performance: +5%
- Reduction of engineering costs ⇒ 6%
- Reduction of control and monitoring costs ⇒ +50% over reference
- Reduction of solar collector investment ⇒ -15%
- Reduction of solar cold production investment ⇒ -25%
- Subsidies on solar collector installation (Austrian subsidy system): 25%

Return on investment: ~11%

Target prices for solar cooling systems

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Results of interviews with manufacturers of SAC-components
participation
Over all 19 finished interviews out of 35 tries: flow back ~55%
1. Solar collectors: 13
2. Absorption: 6
3. Adsorption: 2
4. Cooling tower: 3
Target prices for solar cooling systems
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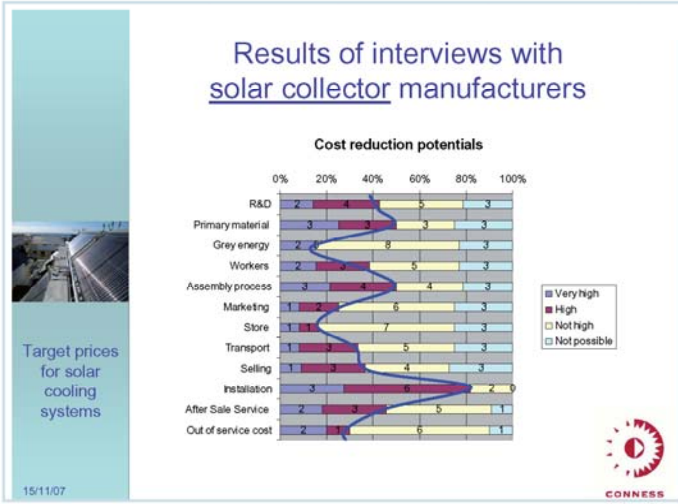
Results of interviews with solar collector manufacturers
Cost reduction potentials
0% 20% 40% 60% 80% 100%
R&D
Primary material
Grey energy
Workers
Assembly process
Marketing
Store
Transport
Selling
Installation
After Sale Service
Out of service cost
Very high
High
Not high
Not possible
Target prices for solar cooling systems
15/11/07
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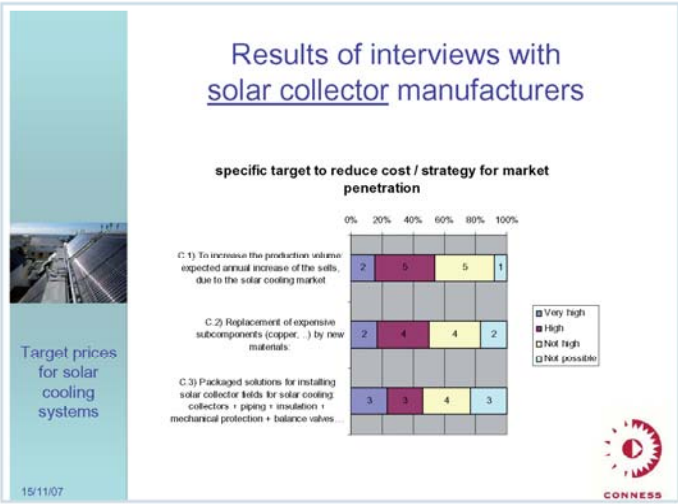
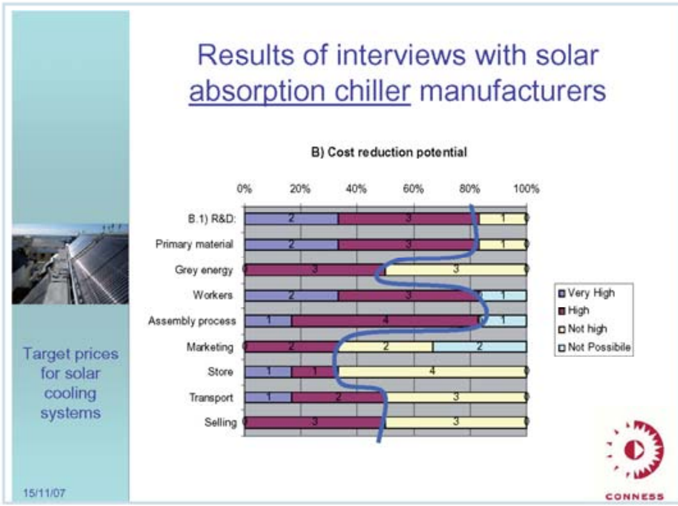
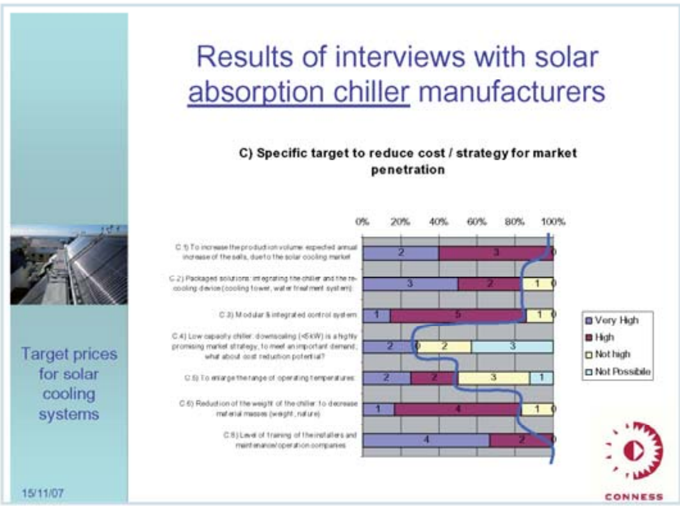

Results of interviews with solar collector manufacturers
specific target to reduce cost / strategy for market penetration
0% 20% 40% 60% 80% 100%
C.1) To increase the production volume: expected annual increase of the sells, due to the solar cooling market
C.2) Replacement of expensive subcomponents (copper, ..) by new materials:
C.3) Packaged solutions for installing solar collector fields for solar cooling: collectors + piping + insulation + mechanical protection + balance valves...
Very high
High
Not high
Not possible
Target prices for solar cooling systems
15/11/07
CONNESS


Results of interviews with solar absorption chiller manufacturers
B) Cost reduction potential
0% 20% 40% 60% 80% 100%
B.1) R&D:
Primary material
Grey energy
Workers
Assembly process
Marketing
Store
Transport
Selling
Very High
High
Not high
Not Possibile
Target prices for solar cooling systems
15/11/07
CONNESS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C) Specific target to reduce cost / strategy for market penetration
0% 20% 40% 60% 80% 100%
Very High
High
Not high
Not Possibile
Target prices for solar cooling systems
15/11/07
CONNESS

Conference: Sustainable Cooling Systems
TECHbase Vienna
31st of March 2008

Strategies for market penetration of solar-assisted cooling systems in buildings

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Key words: solar-assisted cooling systems, market situation, market penetration

1. Introduction

In the last two to five years a lot of technology development happened in the field of solar-assisted cooling technologies and yet several opportunities for solar-assisted cooling in buildings are available, which are in some cases already cost-competitive to reference system considering lifecycle costs. The identified primary energy saving potentials by using solar-assisted cooling systems showed that this technology could cover a high percentage of the rising energy demand caused by air-conditioning in buildings. The market penetration of solar-assisted cooling systems does not show the same progress due to the higher costs compared to reference systems in most of the cases and additional market barriers which comes up when a new technology substitutes another in the building sector. In the framework of ROCOCO [1] the project team tried to analyse the current market situation of solar-assisted cooling systems in the three participating countries Austria, France and Spain to get input for strategies of market penetration.

2. Method

In a first step workshops with stakeholders in different solar-assisted cooling related topics were organised in each of the three countries to get a picture of the current market situation of solar-assisted cooling systems by using the procedure shown in Figure 1.

For building stock analyses and the development until 2030 current study results [2] were taken for the Austrian market. For Spain the data have been assessed for central air-conditioning market in Spain (capacity >12 kW) in 2000 and 2020. Scenario of 2020 is expected to have absence of large regulatory actions and of significant changes in consumers' choice [3]. The analyses for existing solar cooling installations worldwide were part of the ROCOCO-project [1].

PEST analysis:

PEST stands for political, economic, social and technological instruments or basic conditions which were analysed on their importance and influence on solar-assisted cooling systems.

Procedure:

- First step: Identification of important basic conditions/ instruments for solar cooling technology

- Second step: opportunities and threats of these basic conditions/ instruments regarding market penetration of solar cooling technologies

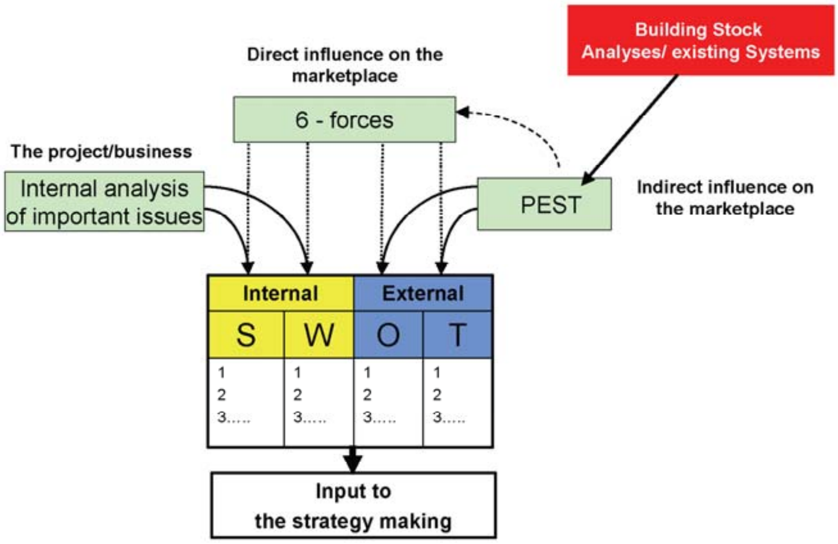

Figure 1: Procedure for analyses of current market situation of solar-assisted cooling systems in buildings

Six-forces analysis:

The influence of the market place on each market entity can be divided in six main parts: customer, supplier, competitor, potential competitor, supplementary industry, replacement; for each of these parts a SWOT analysis was made. In SWOT analyses the participants try to identify the strengths, weaknesses, opportunities and threats of each section.

Following forces on the market place of solar-assisted cooling systems were selected:

1. Customers:
   - Private house owner
   - Investors external renting
   - Investor self-occupation (office, trade, hotel)
   - Public authority
2. Supplier:
   - System supplier
   - Executive companies
   - Engineering consultants
3. Competitors:
   - Compression cooling
   - Biomass
   - District heating
   - Heat pump
4. Potential Competitors
   - Photovoltaic
   - No cooling demand in buildings (Austria)

5. Supplementary industry
- Component producer
- Research
- Facility Manager and contracting organisations
6. Replacement → included in competitors and potential competitors

After these analyses, goals were set for market penetration in the three countries with several actions behind.

3. Results

Overall 25 people participated on the workshops in the three countries and represented component manufacturers, engineering consultants, contracting organisations, research institutions, public authorities and energy agencies.

All of the workshop results can be found in the final report of ROCOCO project [1], following a compilation of common customer characteristics for the three countries set up by the workshop participants is shown.

Private house owner:

- Innovative technologies in the building sector often came from private house owners (solar thermal heating, "Passivhaus" standard, biomass)
- Simple decision finding process
- Cost relevance is not that important point (emotional decisions), neighbour has → also want to have
- Operation and maintenance of installation must be assured
- Opportunity of awareness raising

Investors external renting:

- Responsible for big construction volume
- Quite good quality of projects
- Little interest in operation costs, just for large building volume and high occupation the energy demand may be relevant, otherwise only "marketing interest" in operation costs
- Can be big multiplier
- Wide range of users → flexibility in buildings requested
- Selling of kWh cooling may be interesting in the future

Investors self-occupation:

- CI-strength, image
- Interest in lifecycle costs, operation costs
- Very good quality of projects, want to invest in quality
- Critical and difficult customer → lot of convincing necessary to change from their used technology with a lot of experience to a new technology
- Demonstration projects possible
- Request on control, verification if promised goals can be achieved
- Can be multiplier for whole sectors (supermarket, hotels, hospitals)

- ESCO (Energy service companies) may provide solar cooling
- Lot of competitive technologies by other energy efficient or renewable energy technologies

Public authority:

- Want to be good example
- Political goals for technologies
- Possibility of establishment
- Influence of other lobbies
- Complex way of decision finding
- Can set action for awareness rising

From the previous analyses goals for market penetration were set for each of the three countries and afterwards merged to common goals.

Common goals: (The number in brackets shows in how many of the three countries that was a goal)

- Demonstration plants (3)
- Dissemination/Network (3)
- Training (3)
- Design Tools (2)
- Legislation for standards (2)
- Public funding (investments/ €/kWh) (2)
- Communication/ Marketing actions (2)
- Study of technology comparison (2)

It has to be mentioned that these results only represent the opinion of the participating people of the workshops, therefore is has to be taken as a fist step to see the most relevant topics for market penetration in solar-assisted cooling systems. There couldn't be found any goals which would be specific only for one of the three countries, therefore common action should be preferred in the realisation of market penetration strategies.

4. Conclusion

The workshops for market penetration of solar-assisted cooling systems in the three countries Austria, France and Spain was a first step of discussions to get a picture of the current market situation of solar-assisted cooling and the potential market related to the customer structure. A great interest on the technology has been noticed in all of the three workshops, the most interest came from absorption machine and solar collector manufacturers. The workshops also made clear, that a lot of tasks are necessary to do, not only on technology development, but also on customer-specific preparation of the whole topic by setting up information material, realisation of demonstration sites and getting package solutions. The supplier of the solar-assisted cooling plants which are mainly engineering consultants and executive companies will also need support by training, pre-selection tools, planning tools, pre-defined control strategies and monitoring data of running installations. Besides solar-assisted cooling, there are also some other sustainable cooling technologies in the market as passive cooling, geothermal usage, biomass and district cooling. It has to be evaluated in a proper way by a comparison of technologies, which positions solar-assisted cooling could have in the rapid rising cooling demand in buildings. A roadmap for solar-assisted cooling systems on national level and on European level should be one of the next tasks in that field. There couldn't be found any goals for market penetration of solar-assisted cooling systems which would be specific only for one country, therefore common action should be preferred in the realisation of market penetration strategies.

5. Sources

[1] ROCOCO - Reduction of costs of Solar Cooling systems, TREN/05/FP6EN/S07.54855/020094, Specific Support Action in 6th Framework Programme of the European Commission, 2008

[2] R.Haas et al: Wärme und Kälte aus Erneuerbaren 2030, Wien, 10/2007

[3] EECCAC, "Energy Efficiency and Certification of Central Air Conditioners", study for D.G. Transportation-Energy (DGTREN) of the European Commission, Co-ordinator: J.ADNOT, September 2002

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New concepts and promising technologies

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Key words: Absorption Chiller, Adsorption Chiller, Solar Cooling Kits, System provider

1. Introduction

In Europe various new sorption chillers with small-scale capacity have been developed during the last few years. Many of these absorption and adsorption chillers have now passed over from prototype stadium into field tests and production, so that a rising amount of products is expected within the next few years. The market potential for solar cooling with small-scale capacity is very large, so that different companies are developing solar cooling kits for the product business. The sale figures of conventional electrically driven compressor chillers (split-units) with a cooling capacity range up to 5 kW are rising rapidly. In Europe the number of sold units has risen about 84% from 4.4 million in 2003 to predicted 8.1 million in 2007 [1]. Therefore an all-season use of renewable energy sources for hot water, space heating and solar cooling is here indispensable. Therefore the latest sorption chiller and solar cooling kit developments are presented.

2. Small-Scale Cooling Technologies on the Market

The company Yazaki from Japan has been offering water/lithium bromide (LiBr) absorption chillers with 35, 70 and 105 kW cooling capacity since 1977 [2], whereas the 35 kW machine is the most used absorption chiller for solar cooling projects worldwide until now. In 2008 a new 17.5 kW LiBr chiller is going to be offered in Europe, e.g. by SolarNext as chillii® WFC 18. Further water/LiBr absorbers with 15 kW to 200 kW cooling capacity are offered by EAW from Germany, which were developed for solar cooling and CHP applications, respectively. The company Sonnenklima, Germany carries out field tests on different European locations with a 10 kW LiBr chiller, the suninverse 10. A further LiBr chiller with low cooling capacity is being developed and analyzed through field tests by Rotartica, Spain since a few years. With measured 4.2 to 5.1 kW cooling capacity COPs of approximately 0.42 were achieved [3], whereas the used rotating absorber enables working with dry re-cooling – an important advantage at small-scale installations. The table 1 shows the different technical specifications and performance data of these chillers.

Avoiding crystallization in conventional absorption chillers causes high effort, but the company Climatewell in Sweden uses exactly this principle of crystallization of high concentrated lithium chloride solution (LiCl) to arise the internal storage tightness. To expel the refrigerant water out of the salt solution and to crystallize out two boxes with salt solution, totally 88 kWh thermal heating is needed. First chillers with a cooling capacity range of 7 to 10 kW have been in the field test in Spain since 2005 [4].

Table 1: Comparison of different market available small-scale ab-/adsorption chillers

Company	Yazaki	EAW	Sonnenklima	Rotortica
Product name	WFC-SC5, chillii® WFC 18	Wegracal SE15	suniverse	Solar 045
Technology	Absorption	Absorption	Absorption	Absorption
Working pair	H_2O/LiBr	H_2O/LiBr	H_2O/LiBr	H_2O/LiBr
	 (source: Yazaki)	 (source: Schüco)	 (source: Sonnenklima)	 (source: Rotartica)
Cooling capacity [kW]	17.6	15	10	4.5
Heating temperature [°C]	88 / 83	90 / 80	75 / 65	90 / 85
Recooling temperature [°C]	31 / 35	30 / 35	27 / 35	30 / 35
Cold water temperature [°C]	12.5 / 7	17 / 11	18 / 15	13 / 10
COP	0.70	0.71	0.77	0.67
Dimensions (WxDxH) [m x m x m]	0.60 x 0.80 x 1.94	1.75 x 0.76 x 1.75	1.13 x 0.80 x 1.96	1.09 x 0.76 x 1.15
Weight [kg]	420	660	550	290
Power [W]	72	300	120	1,200 (incl. ventilator)

Company	Climatewell	SolarNext	SorTech	SJTU
Product name	Climatewell 10	chillii® PSC10	ACS 08 chillii® STC8	SWAC-10
Technology	Absorption	Absorption	Adsorption	Adsorption
Working pair	H_2O/LiCl	NH_3/H_2O	H_2O/Silica gel	H_2O/Silica gel
	 (source: Climatewell)	 (source: Pink/SolarNext)	 (source: SorTech)	 (source: SJTU)
Cooling capacity [kW]	10	10	7.5	10
Heating temperature [°C]	83 / -	85 / 78	75 / 67	85 / 79
Recooling temperature [°C]	30 / -	24 / 29	27 / 32	30 / 36
Cold water temperature [°C]	- / 15	12 / 6	18 / 15	15 / 10
COP	0.68	0.63	0.53	0.39
Dimensions (WxDxH) [m x m x m]	1.20 x 0.80 x 1.60	0.80 x 0.60 x 2.2	0.79 x 1.06 x 0.94	1.80 x 1.20 x 1.40
Weight [kg]	875	350	260	1,600
Power [W]	170	300	57	200

Since the end of the year 2006 the company SolarNext, Germany exclusively distribute a 10 kW ammonia/water (NH_3/H_2O) absorption chiller, the chillii® PSC as shown in Table 1. The chiller is a product of the company Pink in Austria, which uses a newly developed membrane pump. The driving temperatures are according to cold water temperature and possibility of re-cooling (wet cooling tower or dry cooler) in the range of 75 to 85°C.

One problem of closed adsorption chillers is the poor heat transfer between the solid adsorber like packages around a heat exchanger and the heat transfer medium. A construction of adsorption chillers with very short cycle times in the area of minutes is only possible using coated heat exchangers with adsorption material. The German company SorTech has developed a new water/silica gel adsorption chiller with 7.5 kW cooling capacity, which is for example being distributed as chillii® STC8 by SolarNext. A further 10 kW water/silica gel adsorber was developed by the Shanghai Jiao Tong University, China. The adsorber is produced by the Chinese company Jiangsu Shuangliang Air Conditioner Equipments [5].

3. Current Prototype Developments

Several prototypes of small-scale absorption chillers are developed in the last few years, especially air-cooled absorbers. At the University Polytechnic Catalonia, Spain a laboratory prototype of an air-cooled water/LiBr absorption chiller has been developed. The experimental results showed a maximum cooling capacity of 3.8 kW and a COP of 0.68 [6]. The company Abakus, Germany has developed a water/LiBr absorption chiller, which runs without a mechanical solution pump, because of using a thermo siphon pump [7]. The cooling capacity is 3 to 4.5 kW and the driving temperatures are in the range of 85 to 100°C.

A directly air-cooled NH_3/water absorption chiller of the company Robur in Italy with 17 kW cooling capacity is driven by pressurized water of a Fresnel collector [8]. The chiller is a modified version of Robur's standard gas fired product, which requires driving temperature of 180 to 200°C. The institute INETI of the University Lisbon developed together with company AoSol from Portugal also an air-cooled ammonia/water absorber prototype with 6 kW cooling capacity for the South-European market [9]. The Technical University Graz, Austria just developed for the company Heliotherm/Helioplus, Austria a prototype of an ammonia/water absorption heat pump/chiller with 5 kW cooling capacity [10]. At the ITW Stuttgart in Germany a further NH_3/water absorption chiller prototype with 10 kW cooling capacity is developed [11]. The lifting of the solution to the required high pressure level is achieved by a membrane pump. At driving temperatures of 90°C and re-cooling temperatures of 27/32°C, cold water temperatures of 15°C could be achieved with a cooling capacity of 7.2 kW and a COP of 0.66. Different diffusion absorption chiller prototypes with the working pair ammonia/water and helium as auxiliary gas are developed at the zafh.net of the Stuttgart University of Applied Sciences, Germany [12]. The chiller has no mechanical solution pump, but an indirectly driven bubble pump. The latest reached cooling capacity of the third prototype is 3 kW.

At present there are some small-scale adsorption chiller prototypes developed in Europe, each of them with a different working pair. The ECN (Energy Research Centre of the Netherlands) has developed within the EU research project SoCool a prototype of a water/silica gel adsorber with 5 kW cooling capacity [9]. The company InvenSor, Germany has also developed a water/silica gel adsorption chiller; in 2007 a first prototype with a cooling capacity of 10 kW has been finished [11]. A further water/silica gel adsorber is developed within the Sunsorber project by EEE Güssing in Austria [13]. Some adsorption chiller prototypes all with 5 kW cooling capacity are developed by the RWTH Aachen, Germany based on water/zeolith [14]. Besides the working pair water/silica gel or water/zeolith other working pairs like ammonia/ active carbon or methanol active carbon are investigated. The University of Warwick, UK has developed a prototype of a very compact ammonia-carbon adsorption chiller with 1.4 kW cooling capacity and a COP of 0.20 [15].

4. Solar Cooling Kits

During the last years a few European solar companies have established themselves on the market as system providers for solar cooling kits. These are in the small-scale cooling capacity range up to 30 kW the following companies:

- CitrinSolar, Germany with the SorTech adsorber,
- Schüco International, Germany with the LB 15 and LB30 (both absorbers of EAW),
- Sol-ution, Austria with the adsorption chiller of SorTech and Alaska-Sets based on the absorption chiller of EAW
- and SolarNext, Germany with its chillii® Solar Cooling & Heating Kits based on the chillii® PSC10, chillii® STC8 and chillii® WFC 18. SolarNext also use absorption chillers of EAW and Yazaki for its chillii® Solar Cooling Systems.

These solar cooling kits basically include solar thermal collectors with attachments, hot water storage, pump-set, chiller, re-cooler, partly cold water storage and system control. Further European solar companies are considering to enter the solar cooling market as system providers or just testing solar cooling systems, e.g. like Paradigma, Saunier Duval (Vaillant), Schott, Solvis.
The specific total costs of installed solar cooling systems in Europe are so far between 5,000 and 8,000 EUR/kW. For 2008 system prices of 4,500 EUR/kW are reached, in the next two years 3,000 EUR/kW are expected for solar cooling kits.

5. Conclusion

Worldwide the energy consumption for cold and air-conditioning is rising rapidly. Thermal cooling by solar energy or district heating or waste heat from CHP units could be lead to a considerable reduction of energy consumption and CO_2 emissions. In the small-scale capacity range up to 30 kW several water/lithium bromide absorption chillers, one ammonia/water absorber as well as two water/silica gel adsorption chillers are market-ready available in Europe. Different prototypes are under development, especially air-cooled chillers.

Assumptions for single-effect sorption chillers is above all a very high solar fraction (more than 70%) or, even better a complete solar cooling and heating system, because low COPs lead rapidly to higher primary energy consumptions, if an additional heating system has to be used. Because of the general trend in Europe to larger solar thermal plants for the heating support, small-scale sorption chillers offer good opportunities to use efficiently the summery heat. First system suppliers are acting on the market with small-scale capacity solar cooling kits and during the next few years more suppliers can be expected.

6. Sources

[1] 71 Mio. Klimageräte – neuer Weltrekord. *cci* (2007) No. 9, p. 30

[2] Niemeyer J., Absorption technology for solar air-conditioning. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 342-345

[3] Izquierdo M., Lizarte R., Marcos J.S., Palacios E. and Burguete A., Cooling with a 4.5 kW air-cooled single effect LiBr/H_2O absorption unit (Rotartica 045v). *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 612-617

[4] Bales C., Bolin G., Nordlander S. and Settenwall F., Solar driven chemical heat pump with integral storage – the thermo-chemical accumulator. *Proceedings of the 1st Int. Conference Solar Air-Conditioning* (2005) Bad Staffelstein, 6-7 October 2005, pp. 63-67

[5] Wang D. Z., Xia Z. Z., Wu J. Y., Wang R. Z., Zhai H. and Dou W. D., Study of a novel silica gel-water adsorption chiller. Part I. Design and performance prediction. *International Journal of Refrigeration* (2005) Vol. 28, pp. 1073-1083

[6] Gonzàlez, J.C., Simulation of heat and mass transfer phenomena in the critical elements of H_2O-LiBr absorption cooling machines. Experimental validation and application to design. *PhD Thesis* (2005) University Polytechnic Catalonia

[7] Dassler I., Dietrich M. and Hebecker D., Entwicklungsstand und eigene Ergebnisse zur solaren Sorptionsklimakälteerzeugung. *VDI-Berichte* (2006) No. 1924, pp. 313-328

[8] Häberle A., Luginsland F., Zahler C., Berger M., Rommel M., Henning H.-M., Guerra M., De Paoli F., Motta M. and Aprile M., A linear concentrating Fresnel collector driving a NH_3-H_2O absorption chiller. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 662-667

[9] Pink W., Eignung der Absorptionskältetechnik als neues Geschäftsfeld der Pink GmbH. *Diploma Thesis* (2007) Fachhochschule Joanneum Gesellschaft mbH Graz, Studiengang Produktionstechnik und Organisation

[10] Moser H. and Rieberer R., Small-capacity ammonia/water absorption heat pump for heating and cooling - used for solar cooling applications. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 51-61

[11] Zetzsche M., Koller T., Brendel T. and Müller-Steinhagen H., Solar cooling with an ammonia/water absorption chiller. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 536-541

[12] Jakob U., Eicker U., Schneider D. and Teußer A., Experimental investigation of bubble pump and system performance for a solar driven 2.5 kW diffusion absorption cooling machine. *Proceedings of the Heat SET 2007* (2007) Chambery, 18-20 April 2007, pp. 789-796

[13] Projekt Sunsorber – Solares Kühlen. *Project info* (2006) Europäisches Zentrum für Erneuerbare Energie Güssing GmbH (EEE), www.eee-info.net

[14] Dubbelfeld D., Solares Kühlen hydraulische und regelungstechnische Beschreibung einer Adsorptionskältemaschine. *Diploma Thesis* (2007) Fachhochschule Augsburg, Fachbereich Maschinenbau

[15] Critoph R.E., Metcalf S.J. and Tamainot Telto Z., Development of a compact ammonia-carbon adsorption chiller for solar air conditioning. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 606-611

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R&D activities on components and examples

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Key words: 3 – 5 key words

Absorption, cycle, working fluid, heat exchanger

1. Introduction

Technological development in the field absorption refrigeration is discussed for solar cooling applications.

2. Method

Paper review

3. Results

Technological trends are described in three categories of absorption refrigeration engineering, namely, cycles, working fluids and heat-mass exchangers.

4. Conclusion

Absorption cycles
- State-of-the-art absorption chillers yields about 50% of Carnot efficiency. Most of new chiller developents are aimed at extending operating ranges rather than improving thermodynamic efficiency.

Working fluids
- Most studies are to modify conventional fluids by adding new substances for extending operating ranges or improving thermophysical properties. Ionic fluid is an exception.

Heat and mass exchangers
- Various heat transfer surfaces have been developed to improve heat and mass transfer in ab(de)sorbing flows. It is probably the easiest way to lower the driving temperature and/or manufacturing cost of an absorption chiller.

5. Sources

[1] Kim & Infante Ferreira, Int. J. Refrig. 31(2008) 3-15
[2] Ziegler, F. Int. J. Therm. Sci. 38(1999) 191-208
[3] Kang et al, Int. J. Refrig. 23(2000) 388-401
[4] Ishibashi, T. Silver Jubilee Congress of ISES, Atlanta, USA, 1979
[5] Lamp, P. and Ziegler, F. Int. J. Refrigeration, 21 (1998) 89-99
[6] Wilbur, P.J., Mitchell, C.E. Solar Energy, 17(1975)193-199

[7] Kaushik et al, Energy Conversion & Management, 32(1991)197-206
[8] Product description, ClimateWellTM DB220
[9] Iedema, P.D. Int. J. Refrig. 5(1982) 262-273
[10] Kim & Infante Ferreira, Int. J. Refrig., http://dx.doi.org/10.1016/j.ijrefrig.2007.12.014
[11] Flamensbeck et al. Applied Therm. Eng. 18 (1998) 413-425
[12] Herold et al. Int. J. Refrig. 14 (1991) 156-167.
[13] Niebergall, W. Handbuch der Kältetechnik, Band 7, Springer-Verlag Berlin, 1981
[14] Bourouis et al. Int. J. Therm. Sci. 44(2005)491-498
[15] Killion, J. and Garimela S. Proc. ISHPC '02, Shanghai, China, 2002
[16] Ausner, I., Dissertation, TU Berlin 2006
[17] Gavriilidis, A. University College London
[18] Saisorn, S. and Wongwises, S. Exp. Therm. Fluid Sci., 32(2008) 748-760
[19] Kim & Infante Ferreira, to be published
[20] Koziol K. and Broniarz, L. Int. Chem Eng. 20 (1980)143-149
[21] Kunugi et al. Trans. Japan Assoc Refrig. 1 (1984) 133-139
[22] Nagaoka et al. Proc. 17th Congress Refrig. Vienna, Austria, 1987
[23] Davies J.T. and Warner, K.V. Chem Eng. Sci. 24 (1969) 231-240
[24] Fijita et al. Trans. Japan Soc. Mech. Eng. 44 (1978) 135-143
[25] Zhao, L. and Cerro, R.L. Int. J. Multiphase Flow 18 (1992) 495-516
[26] Raach, H. and Mitrovic, J. Desalination 183 (2005) 307-316

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Contents

- Overview of solar cooling technologies
- Absorption cycles
- Working fluids
- Heat and mass exchangers
- Conclusions

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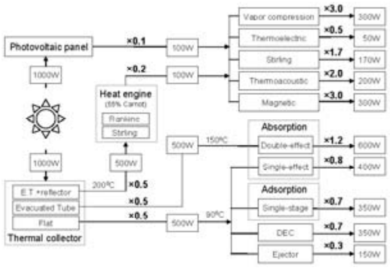
Solar cooling overview – available technologies

Various technologies are availabe for transformation of solar energy to cooling effect [1].



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Solar cooling overview – absorption cooling

Efficiencies of solar absorption cooling systems range from 10 to 60% [1].

Table 1 Overview of solar absorption refrigeration studies

Ref.	Application	Q_c [kW]	A_c [m²]	$\eta_{solar\,cool}$ [-][4]
	Single effect LiBr-water chillers			
23–25	space cooling/heating			
26	space cooling	4	36[1]	0.11
27	space cooling	210	1,577[2]	0.31
28	space cooling	90	316[1]	0.26–0.36
29	space cooling	35	49.9[1]	0.34
30,31	prototype chiller	10		0.37
32	prototype chiller	16		0.40
	Double effect LiBr-water chillers			
33, 2	fuel-fired solar-assisted prototype			
34	cooling/steam (144°C) generation	140	180[3]	0.5–0.6
	Ammonia-water chillers			
35–37	diffusion-absorption prototype	<2.5		0.1–0.25
38–42	refrigeration/heat pump			
43	wine cooling	10	100[1]	
44	space cooling	15		0.27

1. flat plate collectors
2. evacuated tube collectors (no. of tubes)
3. trough collectors (aperture area)
4. where not given, a collector efficiency of 0.50 has been assumed

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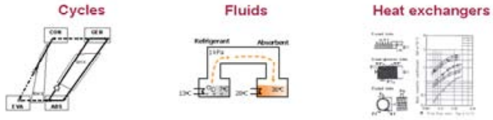
Improvement of absorption chillers – options

High COP and/or low T_H

Cycles | Fluids | Heat exchangers



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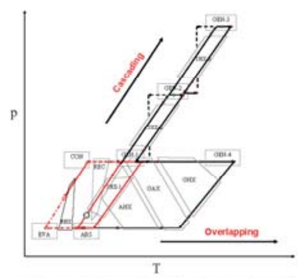
Absorption cycles – overview

Most absorption cycles are cascaded and/or overlapped single-effect cycles [2,3]. Can we improve thermodynamic efficiency of an absorption cycle by cascading or overlapping?



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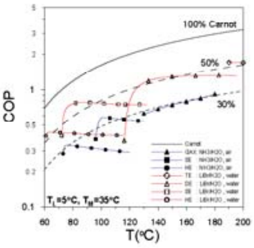
Absorption cycles – limits of thermodynamic efficiency

Maximum efficiency of a heat-driven refrigeration cycle is limited by the product of Carnot engine and refrigeration cycle efficiencies



$$\eta^{id}_{heat-cool} = \eta^{id}_{heat-pow} \times \eta^{id}_{pow-cool} = \frac{T_L}{T_H}\left(\frac{T_H - T_M}{T_M - T_L}\right)$$

Max. COP of a water-cooled chiller is c.a. **50%** η_{Carnot}

Max. COP of an air-cooled chiller is c.a. **30%** η_{Carnot}

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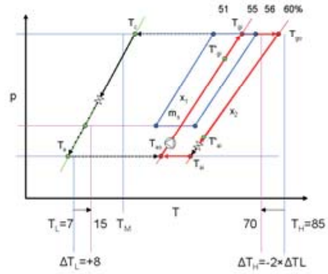
Absorption cycles – practical solution: use of cold ceiling

Evaporation temperature has great influence on driving temperature (T_H). Use of elevated cold medium temperature (T_L) should be actively excercised whenever possible.



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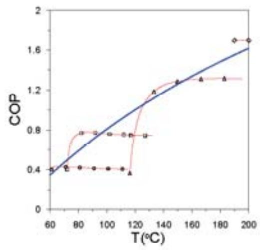
Absorption cycles – practical solution: variable effect cycles

Every absorption chiller has a cut-off temperature below which operation is impossible. Variable or continuous-effect chiller may be interesting for combionation with high-temperature solar collectors [4,5].



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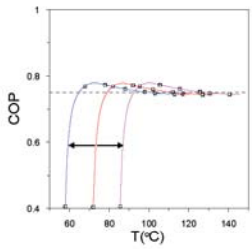
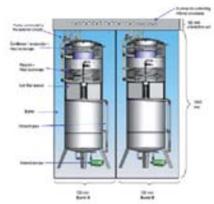
Absorption cycles – practical solution: controlled absorbent composition

A system with active control of absorbent composition may allow effective use of wide operating temperature ranges [6]. Such a system includes refrigerant/solution buffers and control means. The system can also serve as a PCM storage [7]. ClimateWell™ [8] is an extreme example.





Intermittent absorption heat pump ClimateWell™ [8]

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Working fluids – overview

Choice of a working pair is the single most important factor that influences COP [9].

An ideal working pair should be/have;

high latent heat, low pressure (high solubility), low heat of dilution, low specific heat, low viscosity, high conductivity, high diffusivity, low freezing point,....

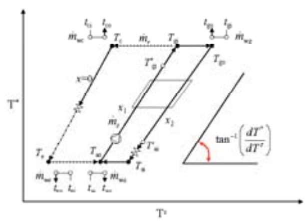
chemically stable, non-toxic, non-corrosive, non-flammable,.....

Refrigerants	Absorbents
water	metalic salts
ammonia	water
alcohols	glycols
hydrocarbons	amines
fluorocarbons	ethers
amines	.....
.....	

Sustainable Energy Systems

Working fluids – electrolyte solutions

COP of an absorption chiller based on electrolyte solution is mainly a function of the gradient of an isostere (**dT^{-1}/dT^{s-1}**) and the ratio of specific- and leatent heats (**Cp/h_{fg}**) [10].



$$COP \approx \frac{1}{\Delta_{des} + \Delta_{loss}}$$

$$\Delta_{des} = \frac{d\left(1/T^{*}\right)}{d\left(1/T^{s}\right)}$$

$$\Delta_{loss} = \frac{C_p}{h^{fg}} \times \left(\dot{m}_s / \dot{m}_r\right)\left(T_{go} - T'_{gi}\right)$$

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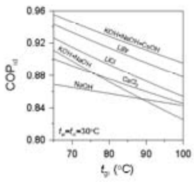
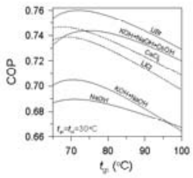
Working fluids – aqueous electrolyte solutions

Superiority of LiBr-water originates from its very low **Cp/h$_{fg}$** [10]. To obtain high COP, new absorbent development should be directed to find or synthesize one with low **Cp**.

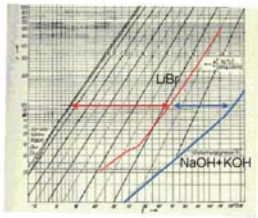
$$COP^{ideal} \approx \frac{1}{\Delta_{des}} \qquad COP^{real} \approx \frac{1}{\Delta_{des} + \Delta_{loss}}$$



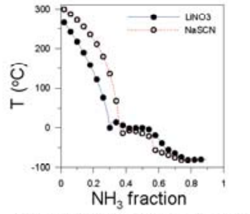


Working fluids – drawbacks of electrolyte solutions

Narrow operating range (crystallization, dissociation,..) of existing absorbents has been the biggest barrier in some applications. Some substances have wider operating ranges but high **corrosion** potential is a common problem (e.g. NaOH/KOH [11], NaOH/KOH/CsOH [12],..).



Operating ranges of water-LiBr & NaOH/KOH [13]



Crystallization of ammonia-salt solutions

Working fluids – additives

Additives

- Operating ranges (crystallization retardant): ternary- or -quarternary metal salts [14], hydroxide
- Thermal/fluid properties: alcohols (surface tension), polymers (viscosity), nano particles (Cp and..)
- Chemical properties: molibdates (corrosion inhibition),..

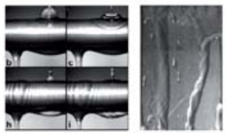
New absorbents

- Ionic fluids

Heat and mass exchangers – overview

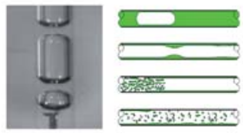
Two-phase heat exchanegrs in an absorption chiller may be largely classified into film and bubble types depending on whether it is flooded or not.

Film



hor. tube [15] ver. plate [16]

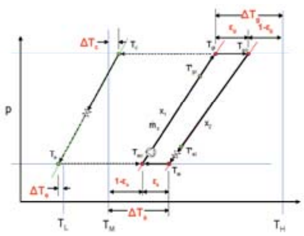
Bubble



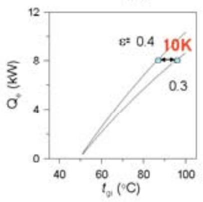
ver. mini tube [17] hor. mini tube [18]

Heat and mass exchangers – effect on driving temeprature

Enhanced heat and mass exchangers lower internal temperatures consequently bringing down driving temperature. High effectiveness of absorber/generator is most desirable.

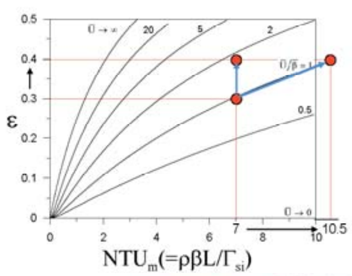


Increase from ε_a=ε_g=0.3 to 0.4 decreases T$_H$ by 10K



Heat and mass exchangers – theory

Effectiveness of a falling film absorber is a function of NTU$_h$(=UL/ΓCp)and NTU$_m$(=ρβL/Γ) [19].



$$\bar{U} = UL/(\Gamma_{si} Cp_s)$$

$$\bar{\beta} = \rho\beta L/\Gamma_{si}$$

U=2 kW/m^{2}K, β=6x10^{-4} m/s

Cp$_s$=2 kJ/kgK, ρ=1,600 kg/m^3

→ $\bar{U}/\bar{\beta} \approx 1$

For 180kg/h, W=1m, μ=4x10^{-3}Pa s

→ Γ=0.05kg/ms (Re=50)→

NTU=7 → L=1.2m

NTU=10.5 → L=1.8m

→ **50% increase in L or 100% in U**

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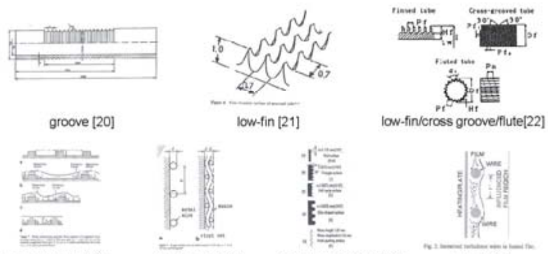
Heat and mass exchangers – augmented surfaces

In the past, various surface geometries were developed for absorbers with varying degree of success [20-26].



groove [20] · low-fin [21] · low-fin/cross groove/flute[22]
periodic weir [23] · wire/gauze [24] · engraved patterns[25] · wire [26]

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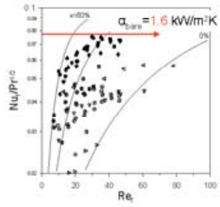
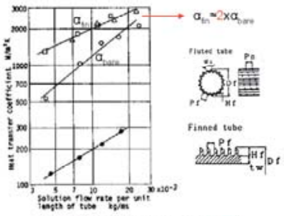
Heat and mass exchangers – experiments

Doubling heat transfer coefficient is easily achieved by using a micro-fin. Mass transfer can be, however, decreased by the surface structure [22].



Heat transfer in horizontal bare tube falling film absorbers [various sources]



Heat transfer in horizontal bare & extended tube falling film absorbers [22]

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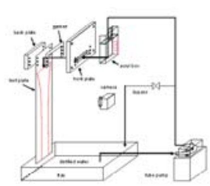
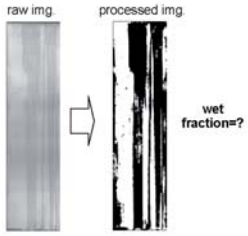
Heat and mass exchangers – R&D at arsenal research

Micro-patterned SS plate heat exchangers are being developed for low-cost absorption chillers. Focus is given to wettability and heat & mass transfer enhancement.



Flow visualization



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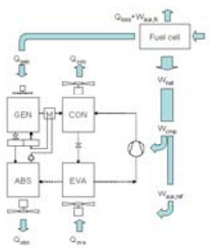
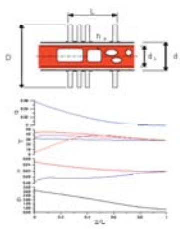
Heat and mass exchangers – R&D at arsenal research

A bubble absorber is being developed for a fuel cell-driven hybrid compression-absorption heat pump. Focus is given to charge minimization.





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Conclusions

Technology development in the field absorption refrigeration was briefly discussed for solar cooling applications. Followings are conclusions.

Absorption cycles

- State-of-the-art absorption chillers yields about 50% of Carnot efficiency. Most of new chiller developents are aimed at extending operating ranges rather than improving thermodynamic efficiency.

Working fluids

- Most of studies are to modify conventional fluids by adding new substances for extending operating ranges or improving thermophysical properties. Ionic fluid is an exception.

Heat and mass exchangers

- Various heat transfer surfaces have been developed to improve heat and mass transfer in ab(de)sorbing flows. It is probably the easiest way to lower the driving temperature and/or manufacturing cost of an absorption chiller.

* Small absorption chillers (Q_e<35kW) are currently very expensive, which is detrimental to the growing solar cooling market. R&D should be focused on cutting down the cost.

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References

[1] Kim & Infante Ferreira, Int. J. Refrig. 31(2008) 3-15
[2] Ziegler, F. Int. J. Therm. Sci. 38(1999) 191-208
[3] Kang et al, Int. J. Refrig. 23(2000) 388-401
[4] Ishibashi, T. Silver Jubilee Congress of ISES, Atlanta, USA, 1979
[5] Lamp, P. and Ziegler, F. Int. J. Refrigeration, 21 (1998) 89-99
[6] Wilbur, P.J., Mitchell, C.E. Solar Energy, 17(1975)193-199
[7] Kaushik et al, Energy Conversion & Management, 32(1991)197-206
[8] Product description, ClimateWell™ DB220
[9] Iedema, P.D. Int. J. Refrig. 5(1982) 262-273
[10] Kim & Infante Ferreira, Int. J. Refrig., http://dx.doi.org/10.1016/j.ijrefrig.2007.12.014
[11] Flamensbeck et al. Applied Therm. Eng. 18 (1998) 413-425
[12] Herold et al. Int. J. Refrig. 14 (1991) 156-167.
[13] Niebergall, W. Handbuch der Kältetechnik, Band 7, Springer-Verlag Berlin, 1981
[14] Bourouis et al. Int. J. Therm. Sci. 44(2005)491-498
[15] Killion, J. and Garimela S. Proc. ISHPC '02, Shanghai, China, 2002
[16] Ausner, I., Dissertation, TU Berlin 2006
[17] Gavriilidis, A. University College London
[18] Saisorn, S. and Wongwises, S. Exp. Therm. Fluid Sci., 32(2008) 748-760
[19] Kim & Infante Ferreira, to be published
[20] Koziol K. and Broniarz, L. Int. Chem Eng. 20 (1980)143-149
[21] Kunugi et al. Trans. Japan Assoc Refrig. 1 (1984) 133-139
[22] Nagaoka et al. Proc. 17th Congress Refrig. Vienna, Austria, 1987
[23] Davies J.T. and Warner, K.V. Chem Eng. Sci. 24 (1969) 231-240
[24] Fijita et al. Trans. Japan Soc. Mech. Eng. 44 (1978) 135-143
[25] Zhao, L. and Cerro, R.L. Int. J. Multiphase Flow 18 (1992) 495-516
[26] Raach, H. and Mitrovic, J. Desalination 183 (2005) 307-316

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Einsatz von thermisch angetriebenen Kältemaschinen in Nah- und Fernwärmenetzen

Auswirkungen auf die Netze am Beispiel Mureck

Olivier Pol, Gernot Haslinger

Nachhaltig Thermisch Kühlen 2008, Kühlen mit Fernwärme

Wien, 1. April 2008

ENERGIE SYSTEME der Zukunft

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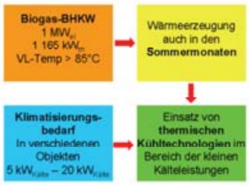
Kühlen mit Nah- und Fernwärme
Einleitung: Hintergründe

- **Vermehrter Einsatz der Kraftwärmekopplung im Groß- und Kleinleistungsbereich**
- **Nutzungsmöglichkeit der bereitgestellten Wärme in thermisch angetriebenen Kühlprozessen**
- **Nutzung von Strom in Anwendungen, wo es keine alternative Antriebsmöglichkeit gibt**
- **Für die Wirtschaftlichkeitsberechnung, unterschiedlicher Ansatz als bei der solaren Kühlung:**
  - *Solare Kühlung:* Die Systemevaluierung berücksichtigt alle Komponenten der Wärme- und Kältebereitstellung inklusiv das Nutzen für Heizen und Kühlen.
  - *Nah- oder Fernwärme:* Die Systemevaluierung schließt die Investitionen für das BHKW aus und die Wärme hat einen Preis.



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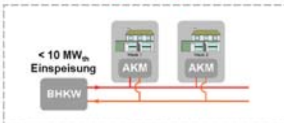
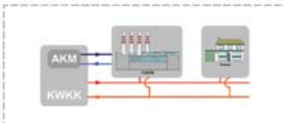
Kühlen mit Nah- und Fernwärme
Einleitung: mögliche Konfigurationen



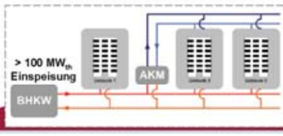
a) Nahwärmenetze und dezentrale Kühlung
- Niedrige Dichte an Kühlbedarf
- Verschiedene verfügbare Sorptionstechnologien
- Verschiedene mögliche Anbindungsvarianten

Beispiel:
Güssing, (Ostfildern: in Bau), (Mureck: Studie)



b) Direkte Kraftwärme-Kältekopplung
- Kühlbedarf in unmittelbarer Nähe des BHKW
- Mögliche Einspeisung in ein Fernkältenetz

Beispiel:
Fussach



c) Fernkälte
- Hohe Dichte an Kühlbedarf

Beispiel:
Wien

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Kühlen mit Nah- und Fernwärme
Einleitung: die Kühltechnologien

- **ABsorptionskältemaschinen (zentral und dezentral)**
- **ADsorptionskältemaschinen (zentral und dezentral)**
- **Sorptionsgestützte Klimatisierung (dezentral)**
  - Integration in Be- und Entlüftungsanlagen
  - Flüssigsorption in Kombination mit Sorptionsspeichern
- **Die Studie hat sich auf den Einsatz von ABsorptionskältemaschinen konzentriert:**
  - Größte Anzahl an marktverfügbaren Produkten
  - Größte Erfahrung im Bereich der solaren Kühlung
  - Komplexe Modellierung einer sorptionsgestützten Klimatisierungsanlage

Nachhaltige Energiesysteme

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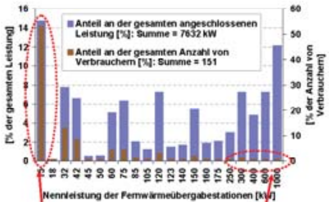
Fallbeispiel Mureck
Ausgangslage und Eckdaten

- **Name**
  Projekt Multi-Mukli, Gemeinde Mureck
- **Region**
  verstreutes ländliches Gebiet, gemischte Nutzung (Wohngebiet, Landwirtschaft, kleine Industrie- und Dienstleistungsgebiete), lokale Biomasseressourcen, bestehendes Nahwärmenetz für ein schon gebautes Gebiet
- **Netztyp**
  kleines auf Biomasse basierendes Nahwärmenetz
- **Netzlänge**
  ca. 12 km
- **Sommerliche Wärmeeinspeisung**
  Biogas-Blockheizkraftwerk mit 1 MW$_{el}$ / 1,2 MW$_{th}$
- **Thermische sommerliche Abnahmeleistung**
  ca. 250 kW$_{th}$
- **Abnahme**
  Die Nahwärme wird fast ausschließlich zur Warmwasserbereitung verwendet.

Nachhaltige Energiesysteme

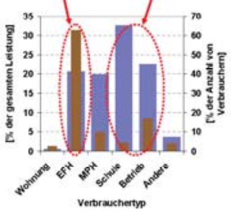
Fallbeispiel Mureck
Netzcharakterisierung: Nahwärme



- Mehr als 50% aller Verbraucher: 15 kW FWÜST, 15% der angeschlossen Leistung
- 3% aller Verbraucher: > 250 kW FWÜST, 30% der angeschlossen Leistung

Einfamilienhäuser machen 60% aller Verbraucher und 20% der gesamten angeschlossenen Leistung aus.

Im Sommer: keine Schulen und wenige Betriebe



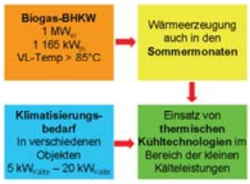
Fragestellungen

Im Sommer kann ein Teil der erzeugten Wärme dafür genützt werden, **Absorptionskältemaschinen** zu betreiben, um die **Abwärme** des Biogas-Blockheizkraftwerkes besser **auszunützen**:

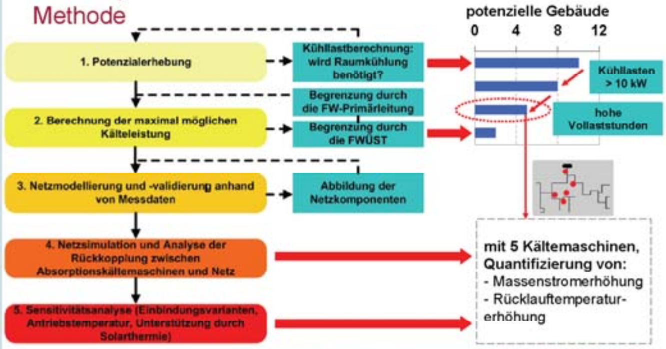
- **Wo** im Nahwärmenetz und mit **welcher Leistung** können Absorptionskältemaschinen eingesetzt werden?
- **Wie** wirken sich Absorptionskältemaschinen auf das Netz?
- **Wann** ist die Einbindung von Absorptionskältemaschinen **wirtschaftlicher und ökologischer** als die Nutzung von konventionellen Kältemaschinen und Raumklimageräten?

Das Projekt Multi-Mukli
Ziele

- Die Partner
  - arsenal research
  - Technisches Büro Ing. Gerhard Repnik, enerep schöner Tag
  - Conness Energieberatungs- Planungs- und Betriebs GmbH
  - Nahwärme Mureck GmbH, Ökostrom Mureck GmbH, Südsteirische Energie- und Eiweißerzeugungs regGenmbH
- Langfristige Ziele
  - **Optimierung des sommerlichen Wärmenetzbetriebs** zur Erreichung eines möglichst hohen Wirkungsgrades des Biogas-Blockheizkraftwerkes und eines wirtschaftlichen Betriebes des Wärmenetzes
  - **Reduzierung der Stromspitzenlasten** aufgrund des Betriebs von Raumklimageräten

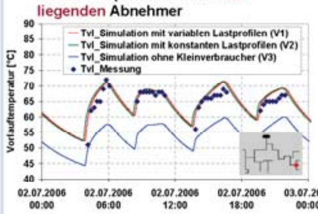


Das Projekt Multi-Mukli
Methode

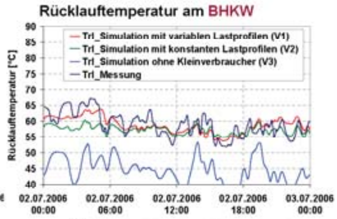


Validierung des Netzmodells
Variation der Lastprofile der Kleinabnehmer

Vorlauftemperatur am weitest liegenden Abnehmer

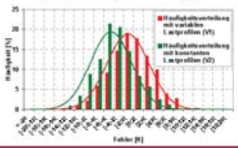


Rücklauftemperatur am BHKW



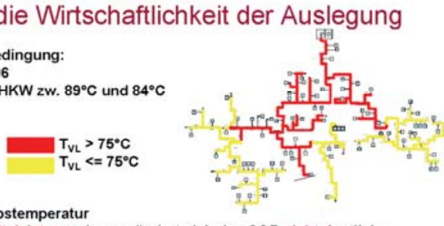
Validierung bei 47% der Anschlussleistung mit dynamischen Lastprofilen hinterlegt.

Bei konstanten Lastprofilen wird die Rücklauftemperatur unterschätzt.

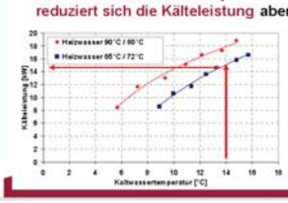


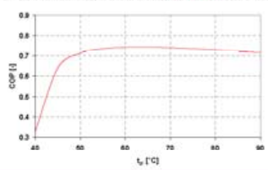
Höhe der Netzvorlauftemperatur
Einfluss auf die Wirtschaftlichkeit der Auslegung

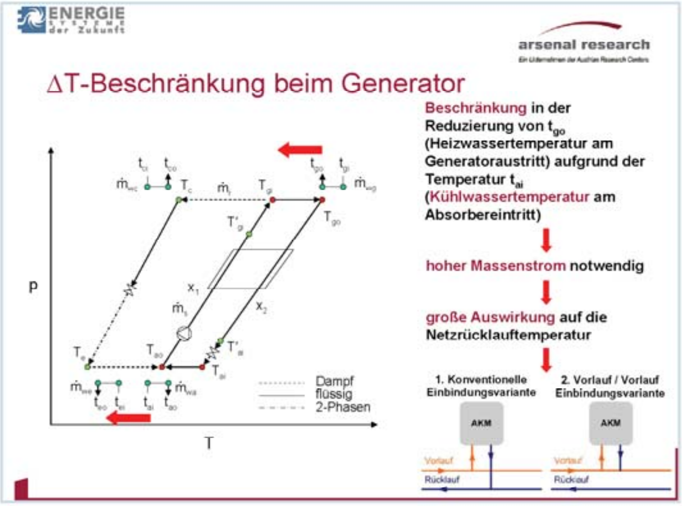
Rahmenbedingung:
- 02.07.2006
- T_{VL} am BHKW zw. 89°C und 84°C



Mit sinkender Antriebstemperatur reduziert sich die Kälteleistung aber verändert sich das COP nicht deutlich:






ENERGIE SYSTEME der Zukunft
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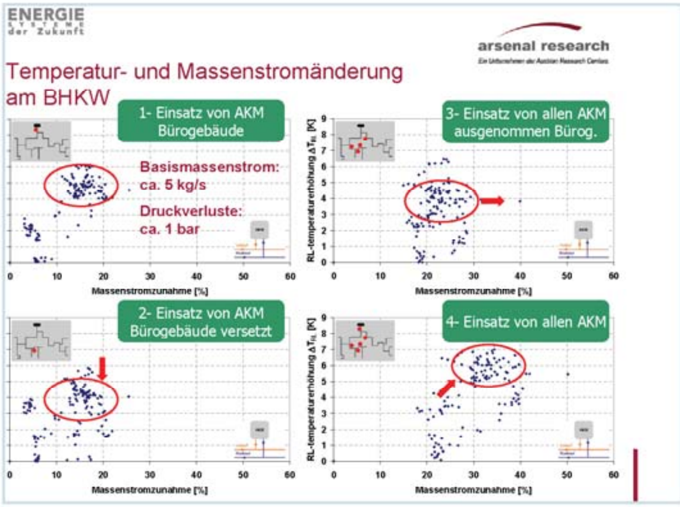
ΔT-Beschränkung beim Generator
Beschränkung in der Reduzierung von t_go (Heizwassertemperatur am Generatoraustritt) aufgrund der Temperatur t_ai (Kühlwassertemperatur am Absorbereintritt)
hoher Massenstrom notwendig
große Auswirkung auf die Netzrücklauftemperatur
1. Konventionelle Einbindungsvariante
2. Vorlauf / Vorlauf Einbindungsvariante
AKM
Vorlauf
Rücklauf
p
T
Dampf
flüssig
2-Phasen


ENERGIE SYSTEME der Zukunft
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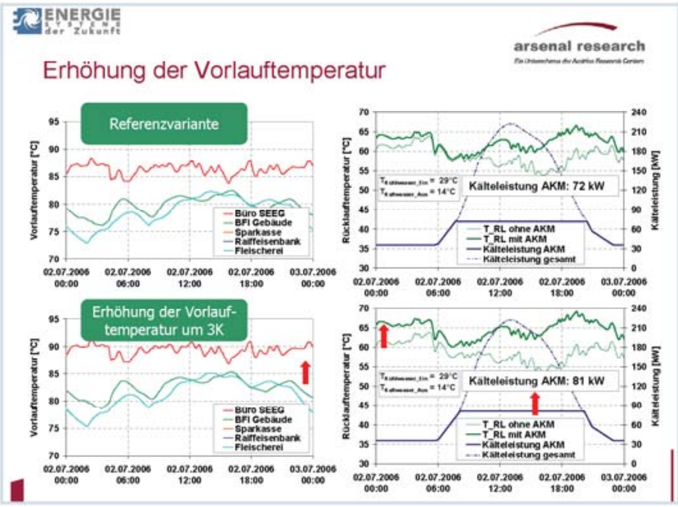
Temperatur- und Massenstromänderung am BHKW
1- Einsatz von AKM Bürogebäude
Basismassenstrom: ca. 5 kg/s
Druckverluste: ca. 1 bar
2- Einsatz von AKM Bürogebäude versetzt
3- Einsatz von allen AKM ausgenommen Bürog.
4- Einsatz von allen AKM
Massenstromzunahme [%]
RL-temperaturerhöhung ΔT_RL [K]


ENERGIE SYSTEME der Zukunft
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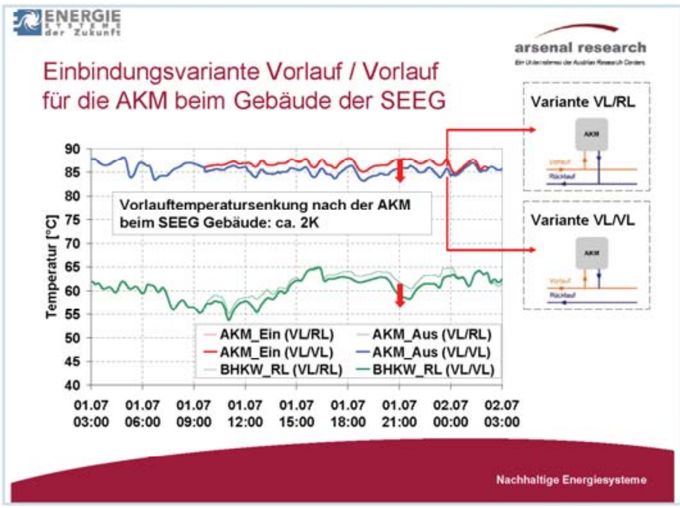
Erhöhung der Vorlauftemperatur
Referenzvariante
Erhöhung der Vorlauftemperatur um 3K
Vorlauftemperatur [°C]
Rücklauftemperatur [°C]
Kälteleistung [kW]
Kälteleistung AKM: 72 kW
Kälteleistung AKM: 81 kW
Büro SEEG
BFI Gebäude
Sparkasse
Raiffeisenbank
Fleischerei
T_RL ohne AKM
T_RL mit AKM
Kälteleistung AKM
Kälteleistung gesamt


ENERGIE SYSTEME der Zukunft
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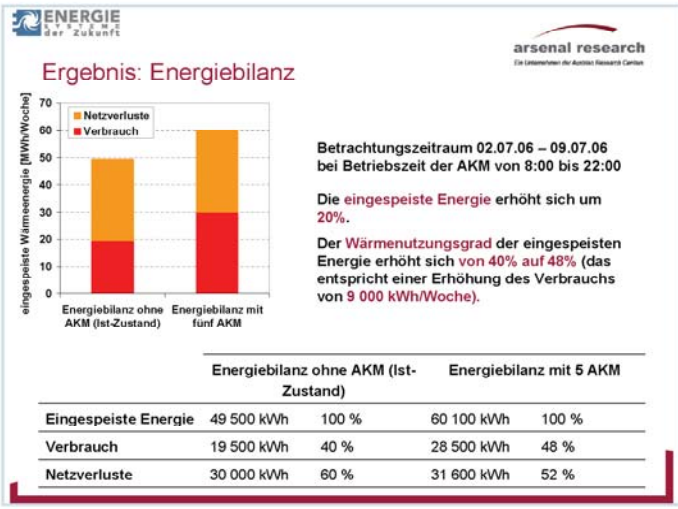
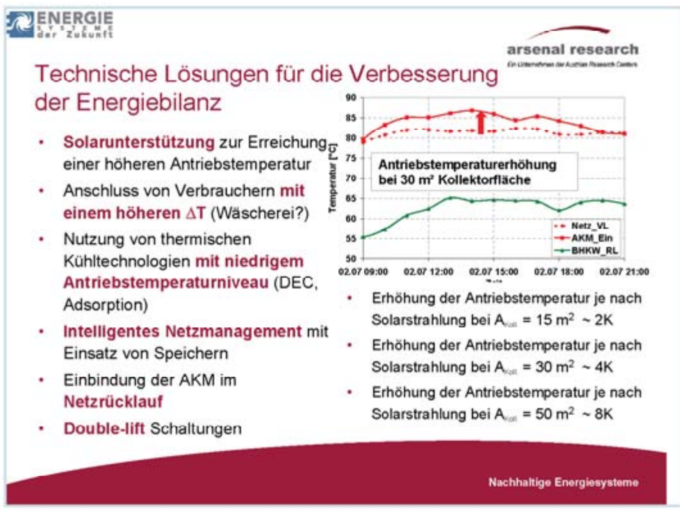
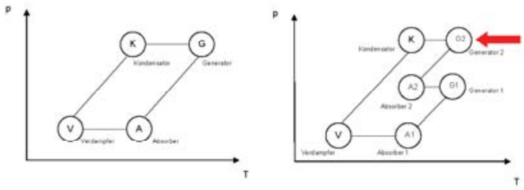
Einbindungsvariante Vorlauf / Vorlauf für die AKM beim Gebäude der SEEG
Variante VL/RL
Variante VL/VL
Vorlauftemperatursenkung nach der AKM beim SEEG Gebäude: ca. 2K
Temperatur [°C]
AKM_Ein (VL/RL)
AKM_Aus (VL/RL)
AKM_Ein (VL/VL)
AKM_Aus (VL/VL)
BHKW_RL (VL/RL)
BHKW_RL (VL/VL)
01.07 03:00
01.07 06:00
01.07 09:00
01.07 12:00
01.07 15:00
01.07 18:00
01.07 21:00
02.07 00:00
02.07 03:00
Nachhaltige Energiesysteme


ENERGIE SYSTEME der Zukunft
arsenal research
Ergebnis: Energiebilanz
eingespeiste Wärmeenergie [MWh/Woche]
Netzverluste
Verbrauch
Energiebilanz ohne AKM (Ist-Zustand)
Energiebilanz mit fünf AKM
Betrachtungszeitraum 02.07.06 – 09.07.06 bei Betriebszeit der AKM von 8:00 bis 22:00
Die eingespeiste Energie erhöht sich um 20%.
Der Wärmenutzungsgrad der eingespeisten Energie erhöht sich von 40% auf 48% (das entspricht einer Erhöhung des Verbrauchs von 9 000 kWh/Woche).
Energiebilanz ohne AKM (Ist-Zustand) | Energiebilanz mit 5 AKM
Eingespeiste Energie | 49 500 kWh | 100 % | 60 100 kWh | 100 %
Verbrauch | 19 500 kWh | 40 % | 28 500 kWh | 48 %
Netzverluste | 30 000 kWh | 60 % | 31 600 kWh | 52 %


ENERGIE SYSTEME der Zukunft
arsenal research
Technische Lösungen für die Verbesserung der Energiebilanz
Solarunterstützung zur Erreichung einer höheren Antriebstemperatur
Anschluss von Verbrauchern mit einem höheren ΔT (Wäscherei?)
Nutzung von thermischen Kühltechnologien mit niedrigem Antriebstemperaturniveau (DEC, Adsorption)
Intelligentes Netzmanagement mit Einsatz von Speichern
Einbindung der AKM im Netzrücklauf
Double-lift Schaltungen
Antriebstemperaturerhöhung bei 30 m² Kollektorfläche
Temperatur [°C]
Netz_VL
AKM_Ein
BHKW_RL
Erhöhung der Antriebstemperatur je nach Solarstrahlung bei A_koll = 15 m² ~ 2K
Erhöhung der Antriebstemperatur je nach Solarstrahlung bei A_koll = 30 m² ~ 4K
Erhöhung der Antriebstemperatur je nach Solarstrahlung bei A_koll = 50 m² ~ 8K
Nachhaltige Energiesysteme

Double-lift Schaltungen



COP bei ca. 0.4

Größeres ΔT

Niedrige Antriebstemperatur

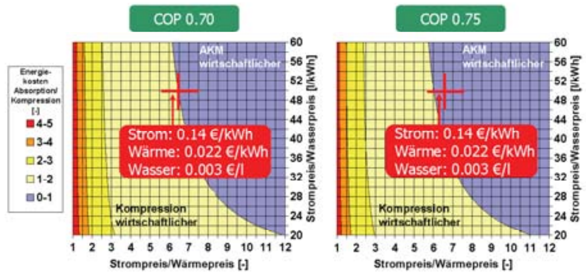
Nachhaltige Energiesysteme

Zulässige Energiepreise für einen wirtschaftlichen Betrieb einer AKM

Annahmen AKM (15 kW):
- Konstanter COP
- el. Leistung: 0,3 kW_{el}
- offener KT: 0.37 kW_{el}, 50 l/h

Annahmen Referenzvariante (15 kW):
- Splitklimageräte mit konstantem COP von 3

Volllaststunden (Messung): 1160 h/Jahr



Zulässige primäre Ressourcenfaktoren für einen „ökologischen" Betrieb einer AKM

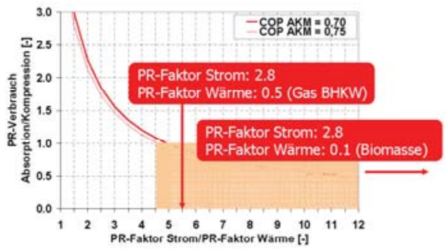
Annahmen AKM (15 kW):
- Konstanter COP
- el. Leistung: 0,3 kW_{el}
- offener KT: 0.37 kW_{el}

Annahmen Referenzvariante (15 kW):
- Splitklimageräte mit konstantem COP von 3

Volllaststunden (Messung): 1160 h/Jahr

PR-Faktor (Ressourcenfaktor):

Anteil der nicht erneuerbaren Energien in eine eingesetzte Endenergieeinheit (unter Berücksichtigung von Extraktion, Umwandlung und Transport).



Fazit

- Es kann meist **nicht die gesamte verfügbare Wärmeleistung** zum Antrieb von Absorptionskältemaschinen eingesetzt werden. Dafür würde sich die Netzrücklauftemperatur zu sehr erhöhen und **weitere Kühler würden benötigt**. In Mureck:
  - Gesamte angeschlossene Leistung: **250 kW_{th}**
  - Mögliche Kältemaschinenleistung: **70 – 80 kW_{cool} (Leistungsverhältnis < 1:2)**
- Die **bestehenden Fernwärmeübergabestationen begrenzen** auch die maximale Kälteleistung der Kältemaschine, falls ein reiner Fernwärmeantrieb gewünscht ist.
- In kleinen Netzen soll berücksichtigt werden, dass in manchen Fällen die **Vorlauftemperaturen** ab einer bestimmten Entfernung von der Wärmeeinspeisung **nur noch einen Teillastbetrieb der Absorptionskältemaschinen ermöglichen.**
- In Nahwärmenetzen sollen andere Kühltechnologien (Adsorption, DEC) oder Einbindungsvarianten (Nutzung der BHKW-Abgase auf hohen Temperaturniveaus (KWKK), Solarunterstützung, double-lift Schaltungen…) untersucht werden.

Nachhaltige Energiesysteme

Danke für Ihre Aufmerksamkeit!

Kontakte

- www.arsenal.ac.at
- olivier.pol@arsenal.ac.at

- Diese Arbeit wurde im Rahmen des von der Programmlinie Energiesysteme der Zukunft geförderten Projektes **Multi-Mukli** durchgeführt.
  www.energiesystemederzukunft.at

Nachhaltige Energiesysteme

Multi Mukli

Wirtschaftlichkeit der Einbindung von Absorptionskältemaschinen in das Nahwärmenetz Mureck

Reinhard Ungerböck

CONNESS GMBH 1

CONNESS
We Create Future

Wirtschaftlichkeit Eingangsdaten

AKM (zentrales System)

Investitionskosten:

• AKM	€22.773
• Rückkühler	€9.290
• Umluftkühler	€6.681
• Fernleitung	€4.871
• Kälteübergabe Anbindung	€3.672
• Puffer mit Pumpe	€1.872
• Primärseitige Verrohrung	€1.538
• Allgemein	€1.734
• +Planung 10%	€5.252
• Summe	€57.776

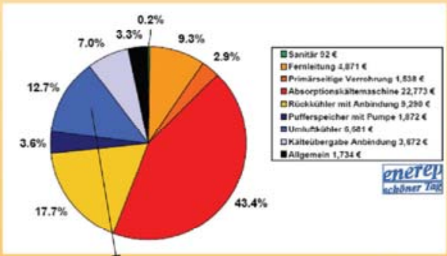
Referenz: Split-Klima
(Bestand, dezentrales System)

Investitionskosten: €16.500

CONNESS GMBH 2

CONNESS
We Create Future

Wirtschaftlichkeit Eingangsdaten



Distributionssystem muss neu errichtet werden, da keine zentrale Klimaanlage vorhanden ist.

CONNESS GMBH 3

CONNESS
We Create Future

Wirtschaftlichkeit Eingangsdaten

Laufende Kosten

AKM
- FW: 750 €/a
  (~0,043 €/kWh$_{Kälte}$)
  (Tarif: 0,03021 €/kWh)
- Strom, Wasser: 220 €/a
- Wartung: 750 €/a

Split-Klima
- Strom: 650 €/a
  (~0,037 €/kWh$_{Kälte}$)
- Wartung: 500 €/a

Preissteigerung laufende Kosten (Energie, Wartung): 3%
entspricht ungefähr VPI, hat aber keinen großen Einfluß

CONNESS GMBH 4

CONNESS
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Wirtschaftlichkeit Szenarien

1. Szenario: bestehende Split-Klima-Anlage wird ersetzt durch AKM
   - Darlehen: 6%, 10 Jahre
   - Lebenszyklus: 20 Jahre
   - 30% Förderung durch KPC für AKM

CONNESS GMBH 5

CONNESS
We Create Future

Wirtschaftlichkeit Szenarien

2. Szenario: Vergleich beider Technologien

Neue Fragestellung:
1. erforderlicher Wärmepreis für gleiche laufende Kosten
2. Erforderliche Investitionskosten für Gleichwertigkeit

CONNESS GMBH 6

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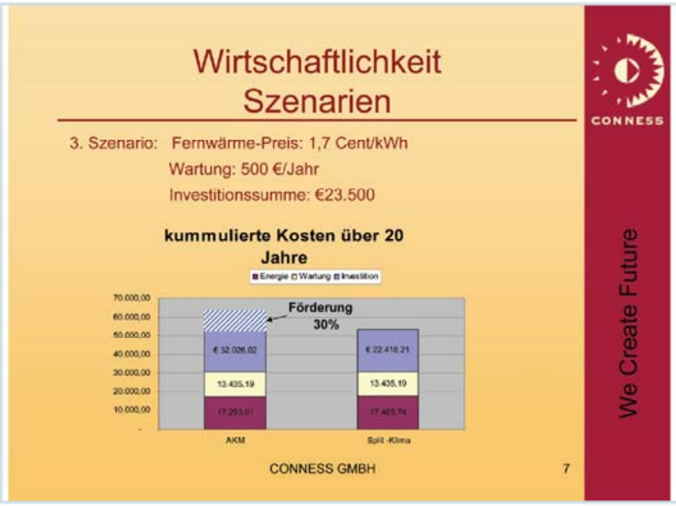
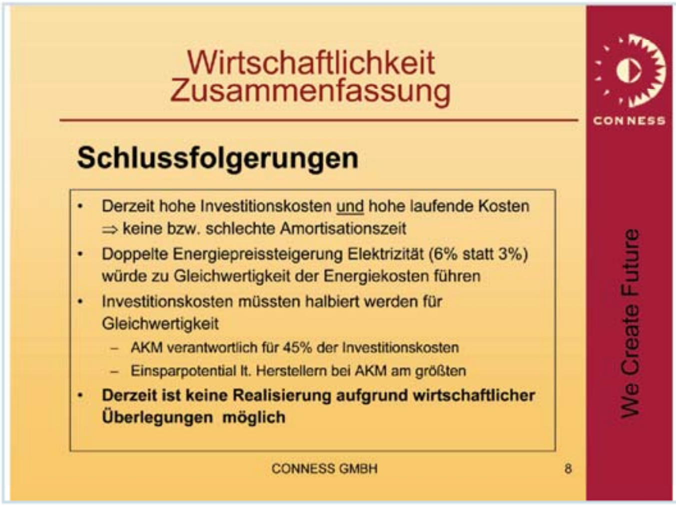

Wirtschaftlichkeit
Szenarien
CONNESS
3. Szenario: Fernwärme-Preis: 1,7 Cent/kWh
Wartung: 500 €/Jahr
Investitionssumme: €23.500
kummulierte Kosten über 20 Jahre
Energie Wartung Investition
70.000,00
60.000,00
50.000,00
40.000,00
30.000,00
20.000,00
10.000,00
Förderung 30%
€ 32.026,02
13.435,19
€ 22.418,21
13.435,19
AKM
Split -Klima
CONNESS GMBH
7
We Create Future


Wirtschaftlichkeit
Zusammenfassung
CONNESS
Schlussfolgerungen
• Derzeit hohe Investitionskosten und hohe laufende Kosten ⇒ keine bzw. schlechte Amortisationszeit
• Doppelte Energiepreissteigerung Elektrizität (6% statt 3%) würde zu Gleichwertigkeit der Energiekosten führen
• Investitionskosten müssten halbiert werden für Gleichwertigkeit
– AKM verantwortlich für 45% der Investitionskosten
– Einsparpotential lt. Herstellern bei AKM am größten
• Derzeit ist keine Realisierung aufgrund wirtschaftlicher Überlegungen möglich
CONNESS GMBH
8
We Create Future

Arsenal Workshop 1.April 2008

Kühlen mit Fernwärme

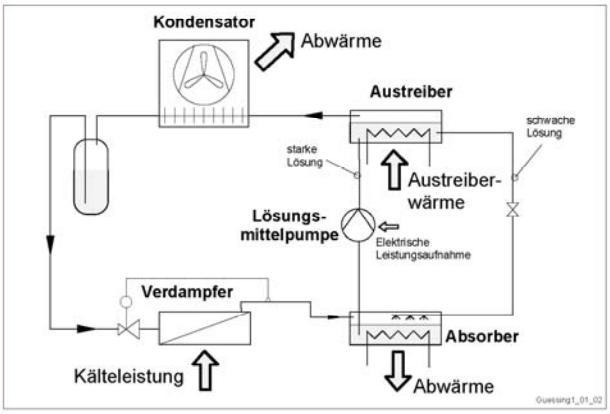
DI Dr. Richard Zweiler

GÜSSING GMBH

1

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Absorptionskältemaschine - Funktionsprinzip



Richard Zweiler – arsenal – 1.April 2008

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Absorptionskältemaschine

Auslegungs- bzw. Betriebsdaten:

Kälteleistung: 210 kW (3 mal 70 kW)
erforderliche Wärmeleistung: 234 kW

Kaltwasser: 10°C / 14°C
Fernwärme: 95°C / 85-90°C
Kühlturm: 35°C / 25°C

Pufferspeicher: 3000 Liter

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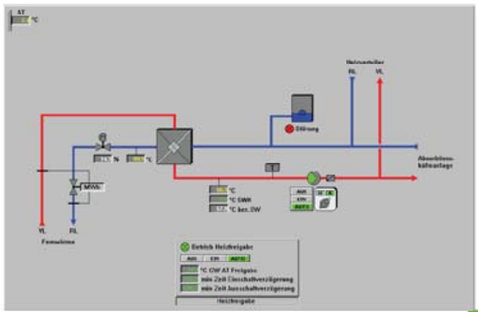
GÜSSING GMBH 3

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Fernwärmeverteiler



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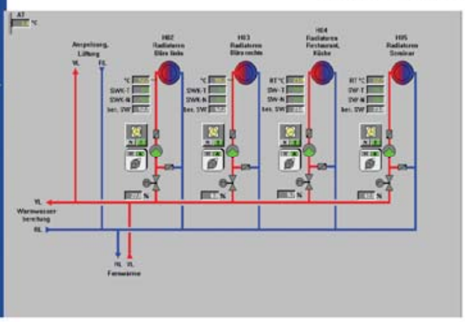
GÜSSING GMBH 4

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Heizungsverteiler

Warmwasserbereitung Küche	35,0 kW
Anspeisung, Lüftung	75,6 kW
H02	92,1 kW
H03	81,2 kW
H04	5,8 kW
HO5	7,0 kW



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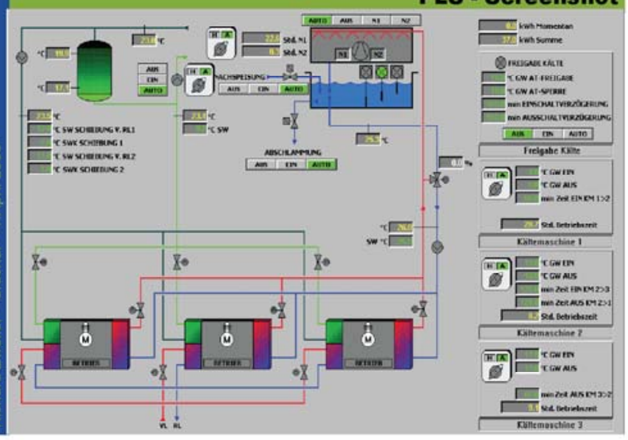
GÜSSING GMBH 5

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

PLS - Screenshot



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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Rückkühler

Offener Kühlturm:
- Effektive Kühlung durch Verdunstung
- Wasseraufbereitung erforderlich

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reNet GÜSSING GMBH 7

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Probleme während Inbetriebnahme

Heizwassermenge:

Zu gering Im Absorber- und Austreiberkreis während der Inbetriebnahme.

Pumpenregelung wurde korrigiert.

Kaltwassermenge:

Lüftungsgeräte waren nicht korrekt eingeregelt.

In Zeiten geringer und sehr hoher Kältelast wurden daher unverhältnismäßig hohe Wassermengen registriert.

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reNet GÜSSING GMBH 8

Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Probleme während Inbetriebnahme

Rückkühlkreis (Kühlturm):

- Wassermenge um 30% zu gering (Umbau Pumpe)
- Ansaugung von Luft (Analyse Leitungsführung)
- Ablagerungen (Wasseraufbereitung)

Aufgrund dieser zahlreichen hydraulischen Unzulänglichkeiten während der Inbetriebnahme wurde nur ein sehr geringer COP erzielt.

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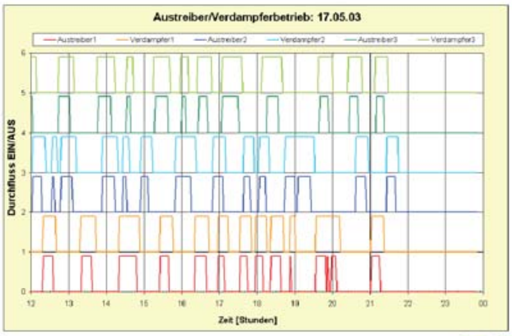
Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Schaltzeiten vor Optimierung



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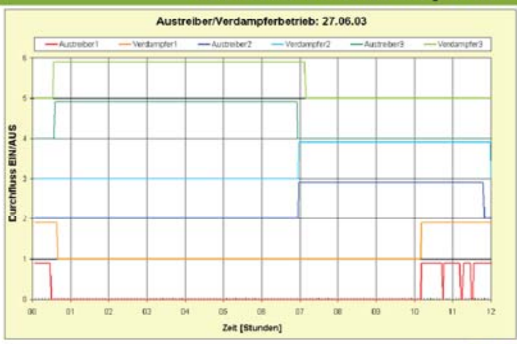
Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Schaltzeiten nach Optimierung



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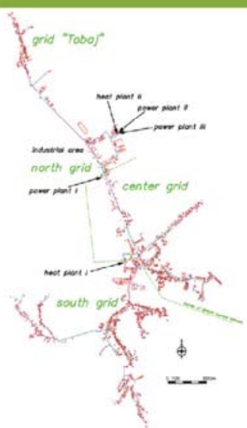
Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Fernwärmenetz



Temperaturniveau:

120°C / 70°C

Abnahmestruktur:

Sehr speziell durch Industrieabnehmer (Dampfkämmern Parkettwerk)

Konstante Bandlast: 2 MW

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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Fernwärmenetz

Sommerbetrieb:
120°C / 70°C für Industrieabnehmer
95°C / 85°C für **A**bsorptions**K**älte**M**aschine

Leistung AKM: ca. 200 kW
Leistung FW-Netz: ca. 2000 kW

Leistungsverhältnis AKM / übrigen Verbraucher ~ 1:10
Verhältnis Massenstrom AKM / übrigen Verbraucher ~ 1:2

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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Einbindung FW-Netz

Rahmenbedingungen der exemplarischen Darstellung von Jahreslastkurven

- Kühllast in Abhängigkeit der Außentemperatur 20°C – 36°C
- Max. Leistungsaufnahme AKM 250 kW_{therm}
- Spitzenlast FW-Netz 1500 kW
- Nennleistung Biomassekessel 750 kW
- Minimallast Biomassekessel 30%

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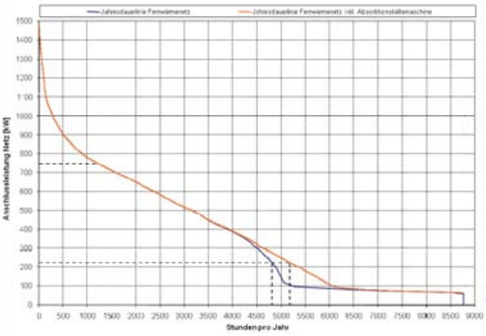
Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

AKM 250 kW - Einbindung FW-Netz

3295 MWh gesamt
2680 MWh Biomasse
615 MWh Öl

3414 MWh gesamt
2804 MWh Biomasse
610 MWh Öl



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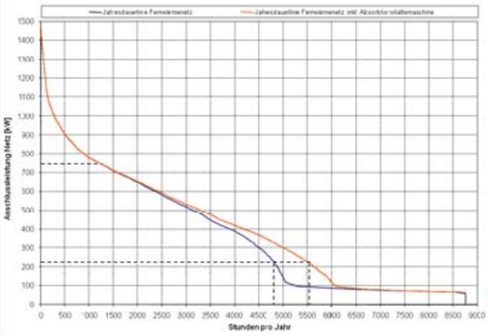
Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

AKM 500 kW - Einbindung FW-Netz

3295 MWh gesamt
2680 MWh Biomasse
615 MWh Öl

3533 MWh gesamt
3191 MWh Biomasse
559 MWh Öl



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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Wirtschaftlichkeit

Basis für Wirtschaftlichkeitsberechnung:

- Berechnung für das Jahr 2003
- Wärmepreis 33,4 €/MWh
- 15-min. max. Spitzenleistung AKM 18 kW
- Spitzenleistung Kompr.kältem. 45 kW

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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Wirtschaftlichkeit - Strompreis

Bezeichnung	Cent/kWh	€/kW u. Monat
Business-Energieverbrauch	3,0523	_
Elektrizitätsabgabe	1,5	_
Stranded Costs	0,092	_
Ökoenergiezuschlag	0,32	_
Netznutzungskosten	4,28	_
Netzverlust	0,17	_
Summe Strompreise	**9,41**	_
Netznutzung Leistung	_	**5,45**

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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Spez. Betriebsk. Kompressionskältemaschine

Kostenaufstellung Kompressionskältemaschine (01.04.2003 - 30.09.2003) Kälteleistung 120 kW	
Leistungszahl (COP)	**2,76**
Kühlenergiebedarf [kWh]	47730
Netznutzungskosten-leistungsbezogen [€]	2943
Stromkosten [€]	1628
Gesamtkosten Kälteerzeugung [€]	**4571**
Kälteenergiekosten [€/kWh]	**0,095**

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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Spezifische Betriebskosten AKM

Kostenaufstellung Absorptionskältemaschine (01.04.2003 - 30.09.2003) Kälteleistung 120 kW

Leistungszahl (COP)	**Anlagen-COP 2003**	**COP**	**COP**	**COP**
	0,36	**0,5**	**0,6**	**0,7**
Kühlenergiebedarf [kWh]	47730	47730	47730	47730
Netznutzungskosten [€]	1149	1149	1149	1149
Stromkosten [€]	450	450	450	450
Fernwärmekosten [€]	4491	3188	2657	2277
Gesamtkosten [€]	**6090**	**4787**	**4256**	**3876**
Spez. Kosten [€/kWh]	**0,127**	**0,100**	**0,089**	**0,081**

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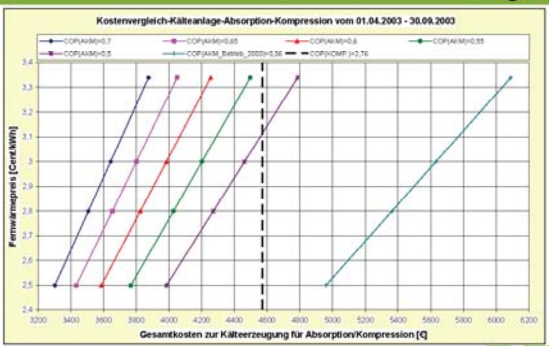
Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Wirtschaftlichkeitsvergleich



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Kühlen mit Fernwärme — Betriebserfahrung: Anlage In Güssing

Fragen & Antworten

Vielen Dank für die Aufmerksamkeit!

DI Dr. Richard Zweiler
e-mail: r.zweiler@renet-info.net

Richard Zweiler – arsenal – 1. April 2008

reNet GÜSSING GMBH 22

zafh net

Thermische Kühlung in Biomasse Nahwärmenetzen

Prof. Dr. Ursula Eicker

Forschungszentrum Nachhaltige Energietechnik - zafh.net
Hochschule für Technik Stuttgart

Folie 1

zafh.net
Prof. Dr. Ursula Eicker
www.zafh.net

Zentrum für angewandte Forschung an Fachhochschulen
Nachhaltige Energietechnik

zafh net

POLYCITY: Stadtentwicklung mit geringem Energiebedarf und erneuerbarer Energieversorgung

Konversionsgebiet Scharnhauser Park: 10000 Einwohner

80% erneuerbare Energieversorgung durch Biomasse BHKW und Photovoltaik

Gebäude: 30% Verbrauchsreduktion

Folie 2

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Nachhaltige Energietechnik

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Biomasse Kraftwerk

Folie 3

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Nachhaltige Energietechnik

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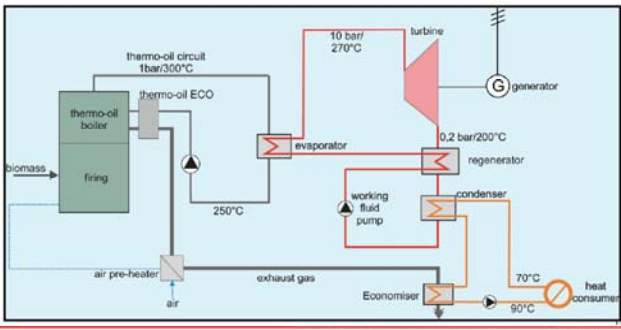
ORC Prozess, 1 Mwel, 6 MW thermisch



Folie 4

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Nachhaltige Energietechnik

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ORC Kraft-Wärmekopplung

	Th. Power (gr.)	Gas	Biomass	El. Gen.	Biomass
	[MWh/year]	[MWh/year]	[MWh/year]	[MWh/year]	[%]
2004	19,899	9,097	10,802	1,103	54.3%
2005	23,306	6,086	17,220	1,212	73.9%
2006	24,255	4,539	19,716	278	81.3%
2007	23,544	4,464	19,080	3,308	81.0%

Folie 5

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Nachhaltige Energietechnik

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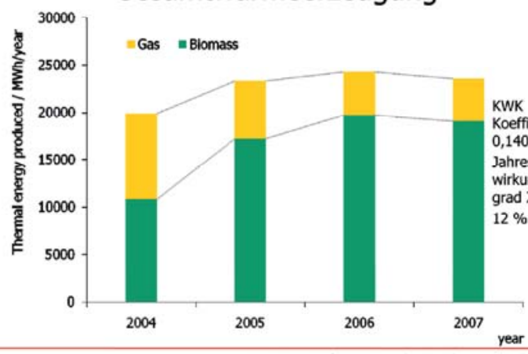
Gesamtwärmeerzeugung



KWK Koeffizient: 0,1405
Jahresstrom wirkungsgrad 2007: 12 %

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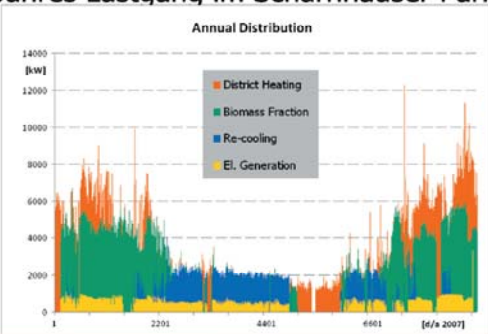
Jahres Lastgang im Scharnhauser Park



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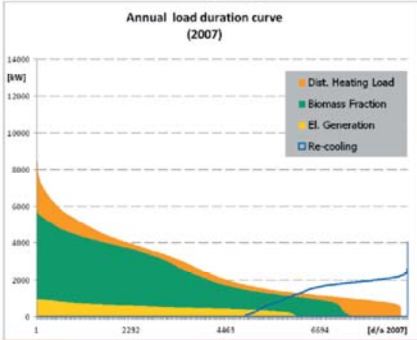
Jahreslastgang Wärme



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Dezentrale Thermische Kühlung im Bauprojekt Elektror

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Kosten und Wirtschaftlichkeit aus Betreibersicht

Kälteerzeugung: 54.000,00 €
Elektrische Kompressionskälteanlage
mit Nasskühlturm (COP = 4,0) ***(entfällt bei Contracting mit SWE)***

Wärmeübergabestation:	28.000,00 €
Kälteverteilung:	165.000,00 € (Betonkernaktivierung der Geschossdecken)
Heizungsverteilung:	110.000,00 € (Unterflurkonvektoren)
Lüftungsanlage:	180.000,00 € (8500 m³/h)
Erdreichwärmetauscher:	12.000,00 € (Sole-Luft-Wärmetauscher)
Regelungstechnik (Variante 1):	78.000,00 €
Summe:	**627.000,00 €**
Summe bei Contracting SWE:	***573.000,00 €***

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Kältekosten Planungsphase

Heizenergiekosten:
- Jahresheizwärmebedarf: 73.000 kWh/a
- Energiepreis Fernwärme: 0,055 €/kWh

Kältekosten:
- Jahreskältebedarf 140.000 kWh/a
- Energiepreis für Kälte:

Variante 1:
Absorptionskälteanlage
Betreiber: Elektror ca. 0,16 €/kWh

Variante 2: Elektrische Kompressionskälteanlage
Betreiber: Elektror ca. 0,11 €/kWh

Variante 3:
Absorptionskälteanlage Betreiber Stadtwerke ca. < 0,11 €/kWh

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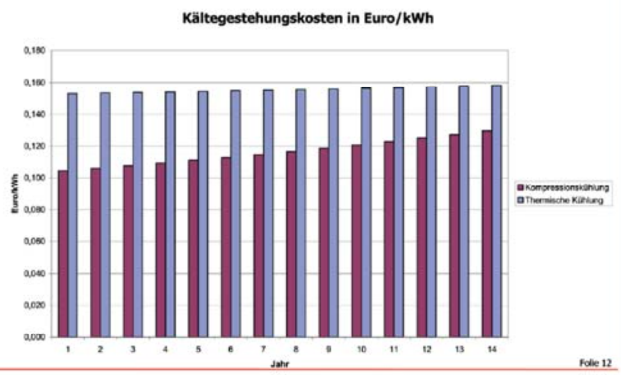

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Planung und Ausführung

erhöhte Kühlenergiemengen, höhere Investkosten

Planung:	Max. Heizleistung	Max. Kühlleistung	Heizenergie-menge	Kühlenergie-menge
	[kW]	[kW]	[MWh/a]	[MWh/a]
Hauptgebäude 3280 m²	180 (55 W/m²)	90 (28 W/m²)	72 (22 kWh/m²a)	129 (39 kWh/m²a)
Laborgebäude 280 m²	8 (29 W/m²)	15 (53 W/m²)	1 (3,5 kWh/m²a)	10 (36 kWh/m²a)

Ausgeführt: Kältebedarf						
Betonkernaktivierung	100	kW	1.200	h/a	120.000	kWh/a
EDV	5	kW	8.760	h/a	43.800	kWh/a
Büros	20	kW	400	h/a	8.000	kWh/a
Labors	40	kW	1.200	h/a	48.000	kWh/a
SUMME	165	kW		~	220.000	kWh/a
80%	über Absorption (100 kW SC 30)				176.000	kWh/a
20%	über Kompressor (60 kW)				44.000	kWh/a

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Kostenkalkulation

Energieaufwand					
bei	176.000	kWh Kälte aus Wärme mit Faktor		1,6	
	281.600	kWh Wärme nötig			
bei	44.000	kWh Kälte aus Strom mit Faktor		0,33	
	14.520	kWh Strom nötig			
plus	8	kW	2000	h/a	Strom für Pumpen + Rückkühlwerk
	16.000	kWh Strom			

Kapital-kosten	Vollkosten	Eigenanteil 65%	Annuität	Absorption Vollkosten	Kompression Vollkosten
Absorption	175.000 €	114.000 €	9,63%	18.000 €/a	
Kompressor	20.000 €	20.000 €	10,98%		2.200 €/a

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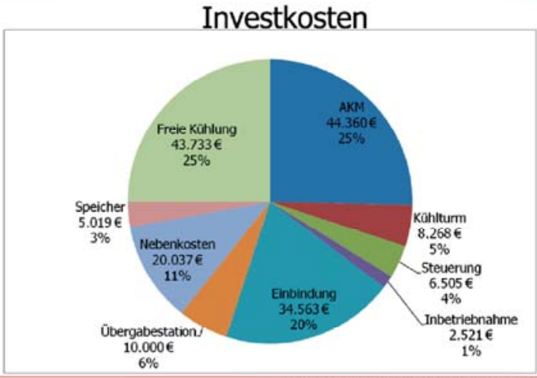
Investkosten



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Betriebskosten

Betriebskosten	Absorber		Kompressor
Wartung /Inst.haltung Absorber	1.000	€/a	
Wartung /Inst.haltung Kühlturm	360	€/a	
Wartung /Inst.haltung Einbindung	260	€/a	
Bedienung 20 h/a x 40€	800	€/a	
Verwaltung/Versicherung (1% der Investition)	690	€/a	
Summe	3.110	€/a	2200 €/a

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Energiekosten

Energiekosten				Absorber	Kompressor
Wärme	281600	kWh/a x	0,02 €/kWh	5632 €/a	
Strom	14520	kWh/a x	0,12 €/kWh		1742 €/a
	16000	kWh/a x	0,12 €/kWh	1920 €/a	
Frischwasser	450	m³/a	1,77 €/m³	796 €/a	
Abwasser	150	m³/a	1,98 €/m³	297 €/a	
Wasserzähler				37 €/a	
Summe Energiekosten				8682 €/a	1742 €/a
Gesamtsumme Absorption				28089 €/a	7912 €/a
Gesamtkosten Absorption plus Kompression				36001 €/a	
bei	220.000	kWh Kälte			
Preis	0,164	€/kWh Kälte			

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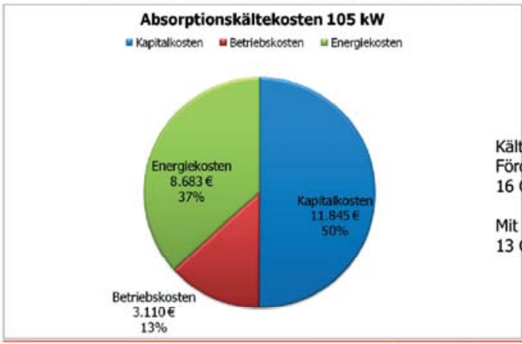
Kosten inklusive 35% Investförderung



Kältekosten ohne Förderung:
16 Cents/kWh

Mit Förderung:
13 Cents/kWh

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Gesamterlös inklusive Förderung

Gesamtkosten			28908	€/a
Gesamterlöse mit	0,073	€/kWh Kälte		
und Grundpreis von	15000	€/a	31060	€/a
Jahresergebnis Contracting			2152	€/a

Folie 19

Zusatzerlös Kraftwerksbetreiber

Wärmeverkauf:	281600 kWh mehr Wärme für 0,033 €/kWh	9292 €/a
Stromverkauf:	281600 kWh mehr Wärme mit 15% Stromwirkungsgrad	42240 kWh/a
	Stromerlös 0,2 €/kWh	8448 €/a
Summe:		17741 €/a

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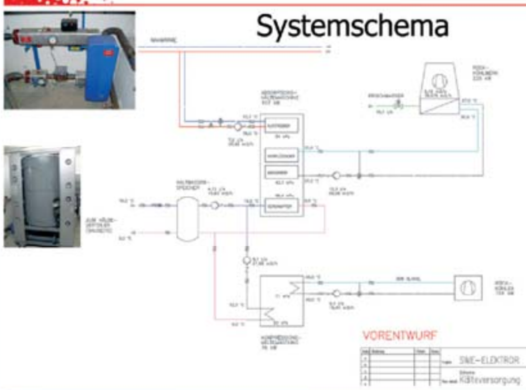
Systemschema



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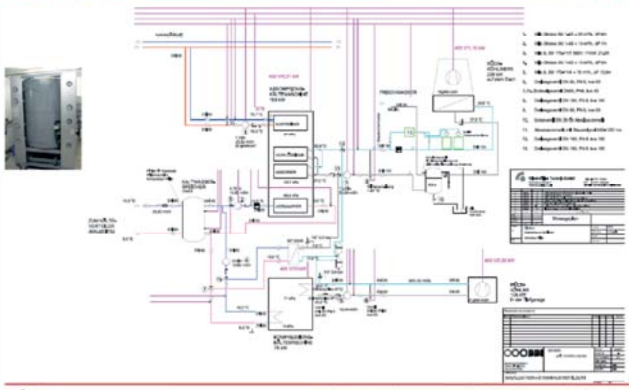

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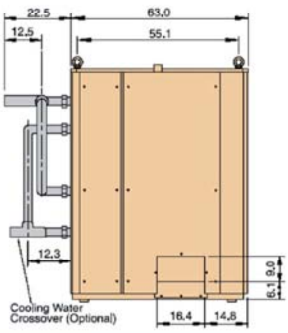
Absorption unit



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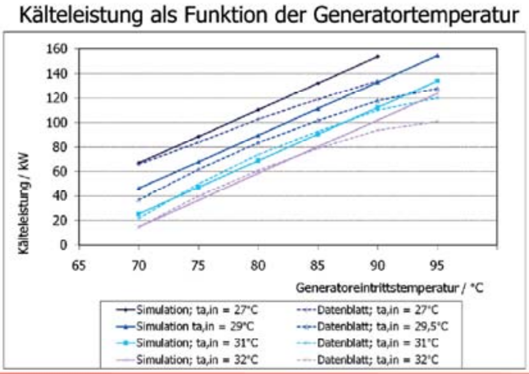
Kälteleistung als Funktion der Generatortemperatur



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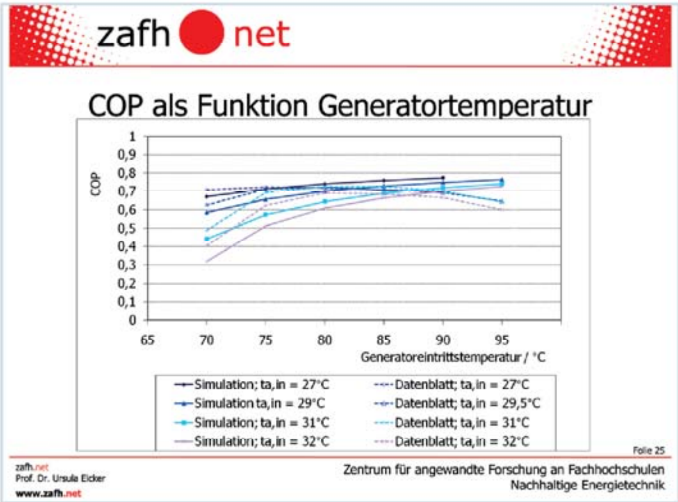
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COP als Funktion Generatortemperatur
COP
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
65 70 75 80 85 90 95
Generatoreintrittstemperatur / °C
Simulation; ta,in = 27°C
Simulation ta,in = 29°C
Simulation; ta,in = 31°C
Simulation; ta,in = 32°C
Datenblatt; ta,in = 27°C
Datenblatt; ta,in = 29,5°C
Datenblatt; ta,in = 31°C
Datenblatt; ta,in = 32°C
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Kälteverteilung durch Bauteilaktivierung
Reduktion Kälteleistung: ca. 30 - 40 %
(Speicherfähigkeit, längere Laufzeiten)
Hoher Komfort
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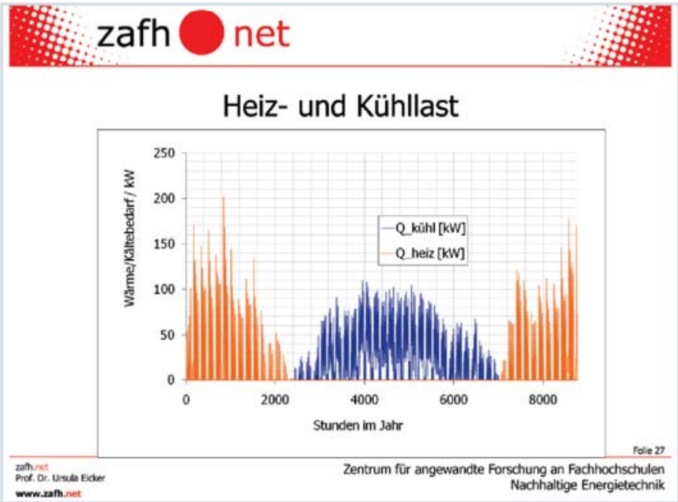
zafh net
Heiz- und Kühllast
Wärme/Kältebedarf / kW
250
200
150
100
50
0
0 2000 4000 6000 8000
Stunden im Jahr
Q_kühl [kW]
Q_heiz [kW]
Folie 27
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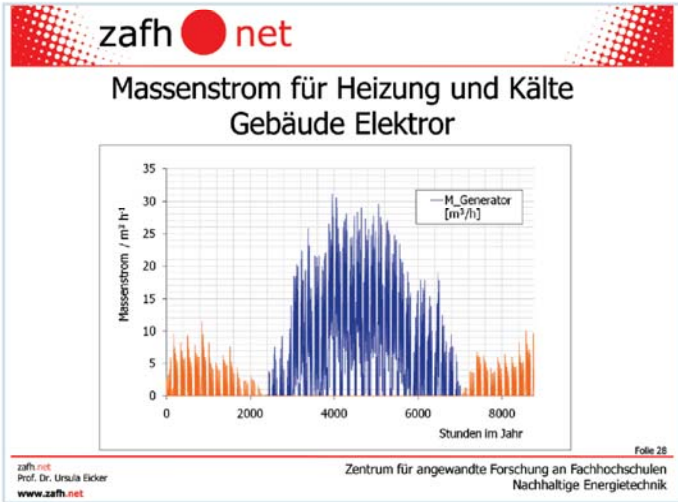
zafh net
Massenstrom für Heizung und Kälte
Gebäude Elektror
Massenstrom / m³ h⁻¹
35
30
25
20
15
10
5
0
0 2000 4000 6000 8000
Stunden im Jahr
M_Generator
[m³/h]
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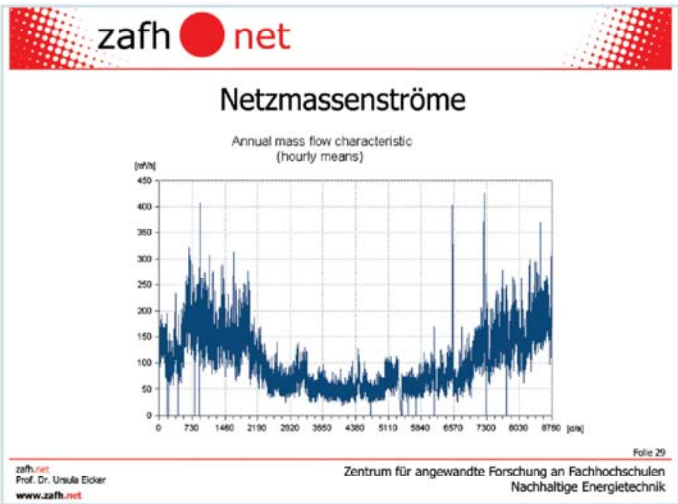
zafh net
Netzmassenströme
Annual mass flow characteristic
(hourly means)
[m³/h]
450
400
350
300
250
200
150
100
50
0
0 730 1460 2190 2920 3650 4380 5110 5840 6570 7300 8030 8760 [h/a]
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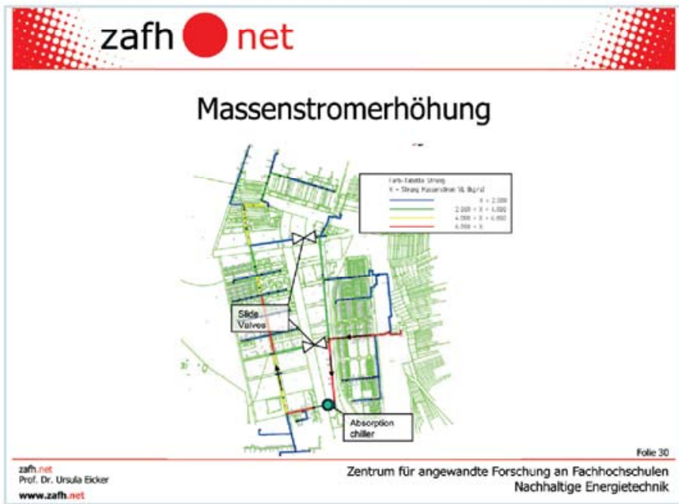
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Massenstromerhöhung
Slide
Valves
Absorption
chiller
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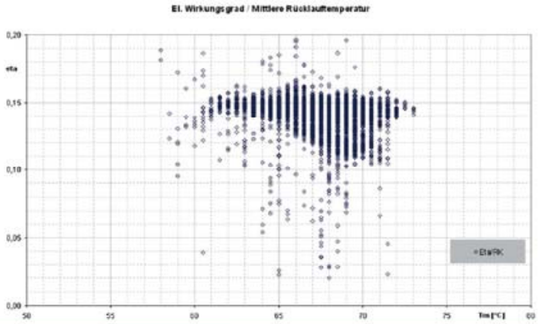
ORC Wirkungsgrad



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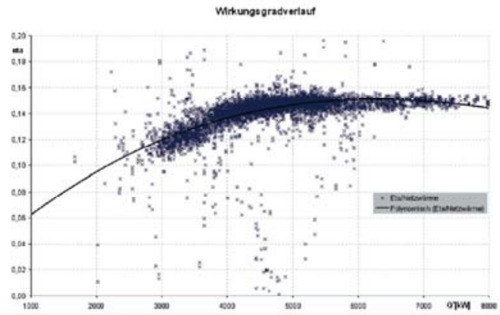

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Zusammenfassung

- Thermische Kühlung mit kostengünstiger Abwärme nahe der Wirtschaftlichkeit
- CO_2 neutral bei Biomasse Kraft-Wärme-Kopplung
- Erhöhung der Last im Netz verbessert Wirkungsgrad und kompensiert teilweise Verluste durch höhere Netztemperaturen
- Einbindung in Wärmenetze erfordert hohe Massenströme – Hydraulik beachten

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Nahwärmenetze in Österreich

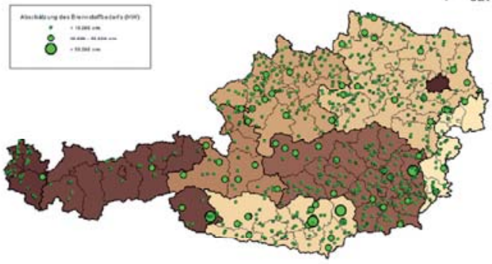
Potenziale, Chance und Risiken aus Sicht der Fernwärmebetreiber

ENERGIEAG Wärme

Biomasse – Fernwärmeprojekte in Österreich

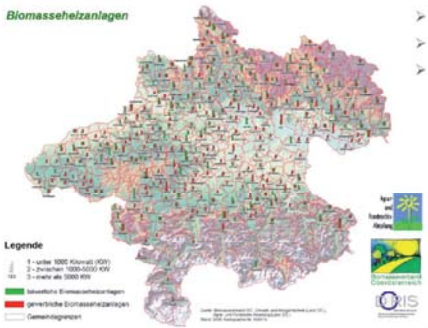
- ca. 1100 Anlagen
- ca. 1150 MW Leistung

Stand Ende 2006



ENERGIEAG Wärme

Biomasse - Fernwärmeprojekte in Oberösterreich



- 230 Anlagen
- 200 MW Leistung
- 360 km Leitungslänge

Stand Ende 2007

ENERGIEAG Wärme

Fernwärme „Muster"

- Investitionskosten:

Baugrund und Aufschließung	194.845,--
Baulichkeiten	460.000,--
Kessel und Heiztechnik	506.700,--
FW-Netz	954.885,--
Übergabestationen und Zähler	232.810,--
Planung/Beratung	136.256,--
sonstige Kosten (Eigenleistung, Stempelgebühr, Genehmigung, usw.)	74.001,--
Gesamtinvestition (netto)	2.559.500,--

ENERGIEAG Wärme

Fernwärme „Muster"

- Finanzierung:

Eigenmittel	256.000,--	(10,0%)
Anschlusskosten	705.305,--	(27,5%)
Förderung	756.540,--	(29,6%)
Fremdmittelt	841.655,--	(32,9%)

ENERGIEAG Wärme

Fernwärme „Muster"

- Betriebskosten / Jahr:

		Srm	MWh	€/Srm	Kosten/a
Waldhackgut	41%	2.197	1.791	19,90	43.724,-
Sägenebenprodukte	19%	1.383	830	14,00	19.363,-
Biogaseinspeisung	40%		1.747		41.928,-
Brennstoffkosten gesamt					105.015,-
Personalkosten					10.988,-
Instandhaltung, Service, Versicherung					14.147,-
Stromkosten (1,8 €/MWh BWL)					7.862,-

ENERGIEAG Wärme

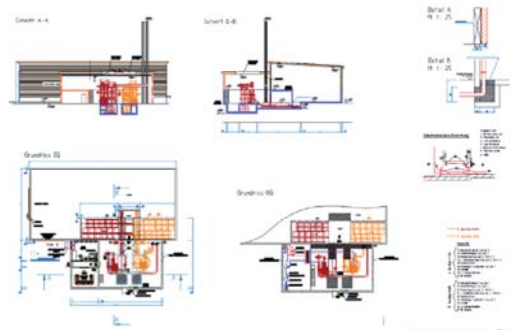
Fernwärme „Muster"

- Technische Daten:

Kessel 1	1.100 kW
Kessel 2	550 kW
Biogaseinspeisung	250 kW
Anschlussleistung	2.561 kW
Abnehmeranzahl	110
Verkaufte Energie	2.797 MWh/a
Netzverluste	1.056 MWh/a
Erforderliche Brennstoffwärme	4.368 MWh/a
Netzlänge	4.975 m

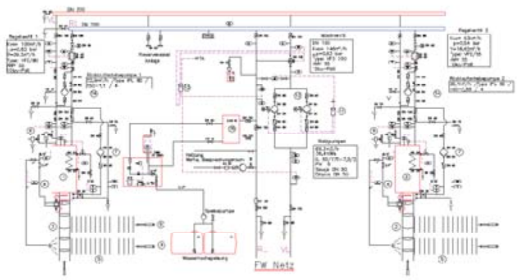
ENERGIE AG Wärme

Fernwärme „Muster" Anlagenplan



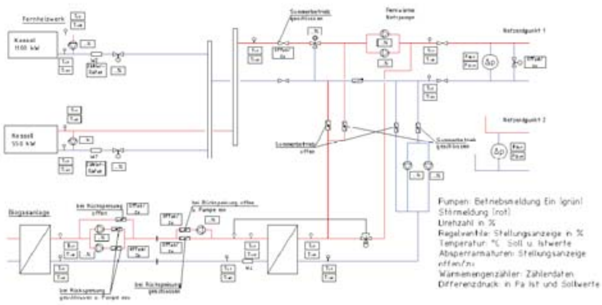
ENERGIE AG Wärme

Fernwärme „Muster" Anlagenschema



ENERGIE AG Wärme

Fernwärme „Muster" Anlagenschema mit Biogaseinspeisung



ENERGIE AG Wärme

Fernwärme „Muster" Netzplan

ENERGIE AG Wärme

Fernwärme Gutau

ENERGIE AG Wärme

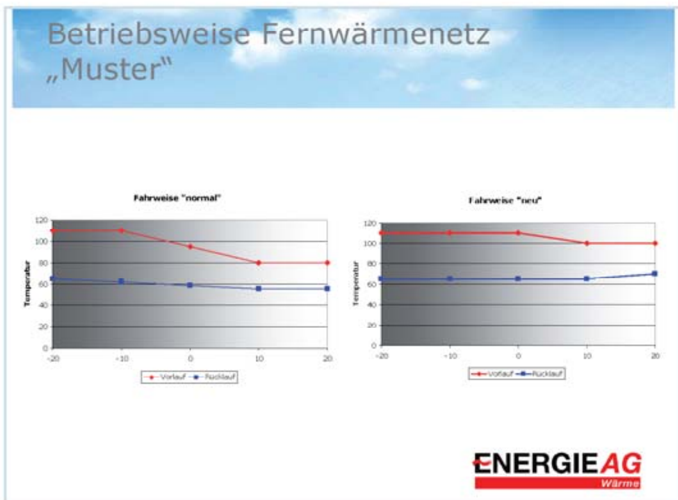

Fernwärme Gutau
ENERGIE AG
Wärme


Fernwärme Gutau
ENERGIE AG
Wärme


Fernwärme Gutau
ENERGIE AG
Wärme


Fernwärme Gutau
ENERGIE AG
Wärme


Fernwärme Gutau
FERNWÄRME GUTAU
ENERGIE AG
Wärme

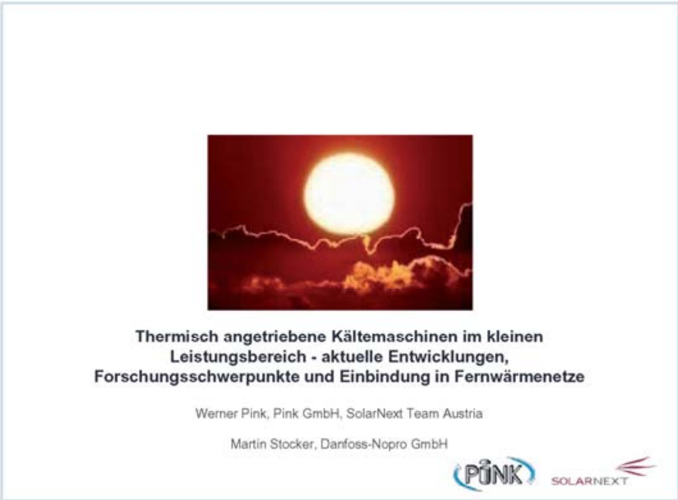

Betriebsweise Fernwärmenetz „Muster"
Fahrweise "normal"
Fahrweise "neu"
Temperatur
120
100
80
60
40
20
0
-20
-10
0
10
20
Vorlauf
Rücklauf
ENERGIE AG
Wärme


Betriebsweise Fernwärmenetz
„Muster“
Brennstoff
60 % Sägenebenprodukte: 14,00 €/Srm
40 % Waldhackgut: 19,90 €/Srm
Heizwert: 0,65 MWh/Srm
Wirkungsgrad: η = 80 %
⇒ Erzeugungskosten Normalbetrieb 31,46 €/MWh
⇒ Absorptionskälte Erzeugungskosten 31,46 €/MWh
Höhere Fahrweise -,-- €/MWh
gesamt -,-- €/MWh
ENERGIE AG
Wärme


Vergleich
Kompressionskälte ⇔ Absorptionskälte
Kompressionskälte
Stromkosten: 120,00 €/MWh
ε ≈ 3
⇒ Kälte: 40,00 €/MWh
⇒ Wärme: 40,90 €/MWh
Investitionskosten: Faktor 2 -3 höher
Vorteil: CO2-Reduktion
ENERGIE AG
Wärme


... so erreichen Sie uns:
Energie AG Oberösterreich
Wärme GmbH
Böhmerwaldstraße 3
A-4020 Linz
Tel.: +43 (0)732/90510-0
Fax: +43 (0)732/90510-3463
www.energieagwaerme.at
ENERGIE AG
Wärme


Herzlichen Dank für Ihre
Aufmerksamkeit!
ENERGIE AG
Wärme


Thermisch angetriebene Kältemaschinen im kleinen Leistungsbereich - aktuelle Entwicklungen, Forschungsschwerpunkte und Einbindung in Fernwärmenetze
Werner Pink, Pink GmbH, SolarNext Team Austria
Martin Stocker, Danfoss-Nopro GmbH
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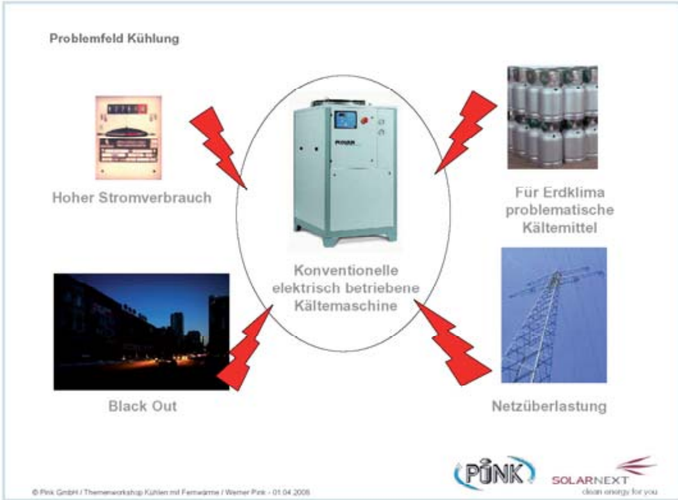
Problemfeld Kühlung
Hoher Stromverbrauch
Für Erdklima problematische Kältemittel
Konventionelle elektrisch betriebene Kältemaschine
Black Out
Netzüberlastung
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Absorptionskältetechnik als eine Alternative
Antrieb durch Wärme
Umweltfreundliche Kältemittel
Absorptions-kältemaschine
Geringe Netzbelastung
Geringer Strombedarf → Geringe CO_2-Emissionen aus Kraftwerksprozessen
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Mögliche Wärmequellen für thermisch angetriebene Kältemaschinen
Solar
Fernwärme
Blockheizkraftwerk
Quelle: EC-Power
Quelle: ecopower
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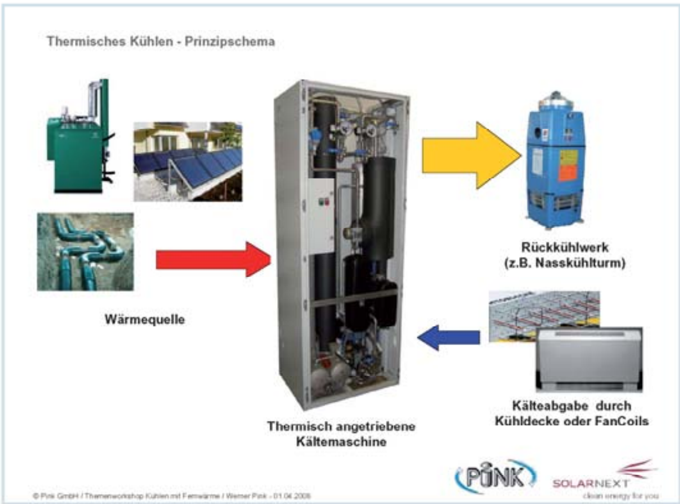
Thermisches Kühlen - Prinzipschema
Rückkühlwerk (z.B. Nasskühlturm)
Wärmequelle
Kälteabgabe durch Kühldecke oder FanCoils
Thermisch angetriebene Kältemaschine
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Marktgängige Absorptionskältemaschinen mittlerer und großer Leistungen
Broad
Carrier
Trane
Dunham
McQuay
York
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Marktgängige Adsorptionskältemaschinen mittlerer und großer Leistungen
Mayekawa (70 - 700 kW)
Nishiyodo (70 - 525 kW)
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Aktuelle Entwicklungen von Absorptionskältemaschinen kleiner Leistungen (1)
Wasser / Lithiumbromid (H2O / LiBr)
Yazaki (17.5 - 105 kW)
EAW (15 - 200 kW)
Schüco (15 - 30 kW, EAW)
Sonnenklima (10 kW)
Abakus (4.5 kW)
Rotartica (4.5 kW, air-cooled)
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Aktuelle Entwicklungen von Absorptionskältemaschinen kleiner Leistungen (2)
Wasser / Lithiumclorid (H2O / LiCl)
Climatewell (10 kW)
Ammoniak / Wasser (NH3 / H2O)
ABB (15 kW)
Helioplus (5 kW)
Robur (17 kW, air-cooled)
AoSol (6 kW, air-cooled)
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Aktuelle Entwicklungen von Absorptionskältemaschinen kleiner Leistungen (3)
Ammoniak / Wasser (NH3 / H2O)
Gewinner
Energy Globe Styria Award
chillii® PSC 10 kW
Eigenentwicklung
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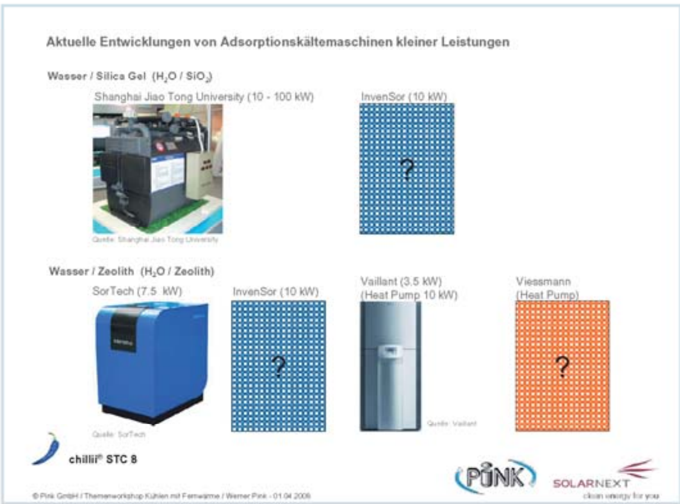
Aktuelle Entwicklungen von Adsorptionskältemaschinen kleiner Leistungen
Wasser / Silica Gel (H2O / SiO2)
Shanghai Jiao Tong University (10 - 100 kW)
InvenSor (10 kW)
?
Wasser / Zeolith (H2O / Zeolith)
SorTech (7.5 kW)
InvenSor (10 kW)
?
Vaillant (3.5 kW)
(Heat Pump 10 kW)
Viessmann
(Heat Pump)
?
chillii® STC 8
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Prüfstand für thermische Kältemaschinen kleiner Leistungen bei Pink
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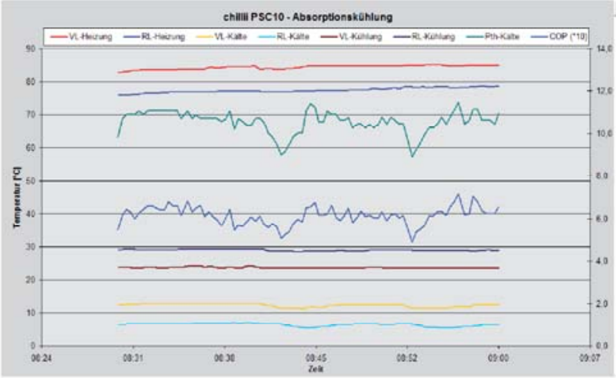
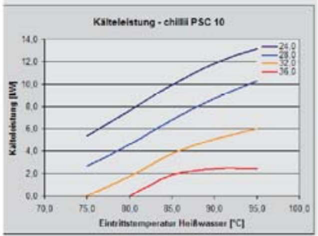
Leistungsmessung (Beispiel Nominalbedingungen chillii PSC10)

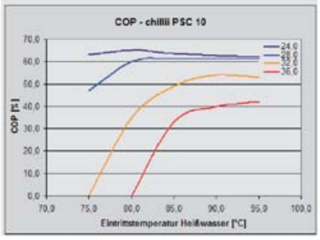


Kennfelderstellung (Beispiel Nominalbedingungen chillii PSC10, Kaltwasser 12/6°C)

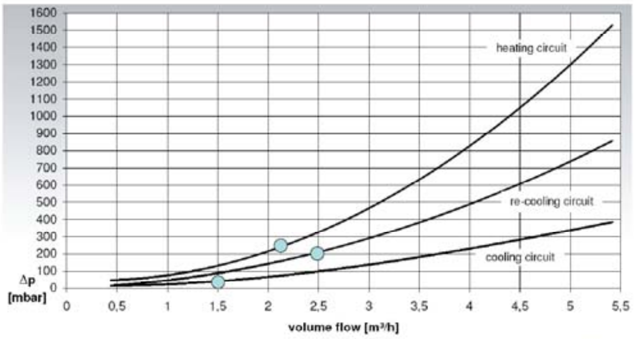
Kühlkreislauf Ein	Kühlkreislauf Aus	Heizungskreislauf Ein 75,0 / Aus 68,0	Ein 80,0 / Aus 73,0	Ein 85,0 / Aus 78,0	Ein 90,0 / Aus 83,0	Ein 95,0 / Aus 88,0
24,0	29,0	5,4	7,6	9,9	11,8	13,1
28,0	33,0	2,7	4,6	6,8	8,7	10,3
32,0	37,0	-	1,8	3,8	5,1	6,0
36,0	41,0	-	-	1,9	2,5	2,4
40,0	45,0	-	-	-	-	-

Kühlkreislauf Ein	Kühlkreislauf Aus	Heizungskreislauf Ein 75,0 / Aus 68,0	Ein 80,0 / Aus 73,0	Ein 85,0 / Aus 78,0	Ein 90,0 / Aus 83,0	Ein 95,0 / Aus 88,0
24,0	29,0	63,0	65,0	63,4	62,5	62,0
28,0	33,0	47,0	60,0	61,0	61,0	61,0
32,0	37,0	-	35,0	49,0	54,0	53,0
36,0	41,0	-	0,0	33,0	40,0	42,0
40,0	45,0	-	-	-	-	-

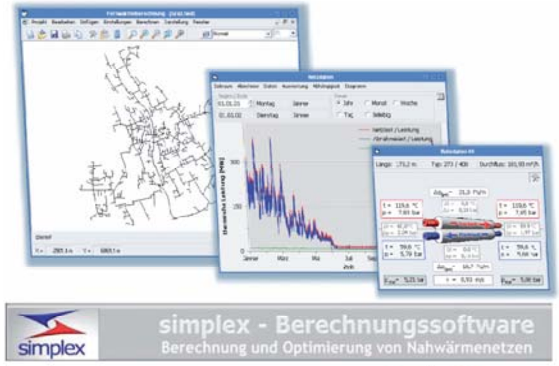




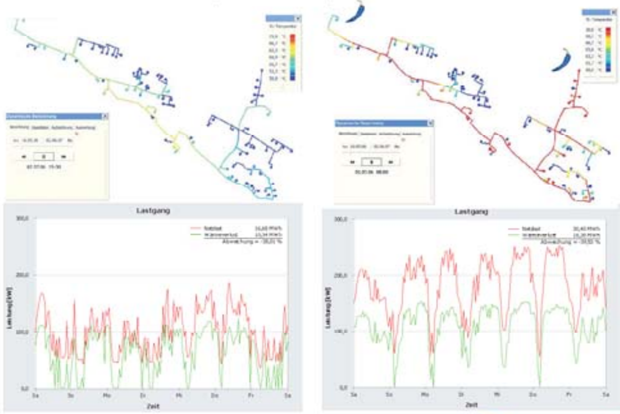
Druckverlustermittlung (Beispiel Nominalbedingungen chillii PSC10)



Abschätzen der Vor- und Nachteile durch Netzsimulation

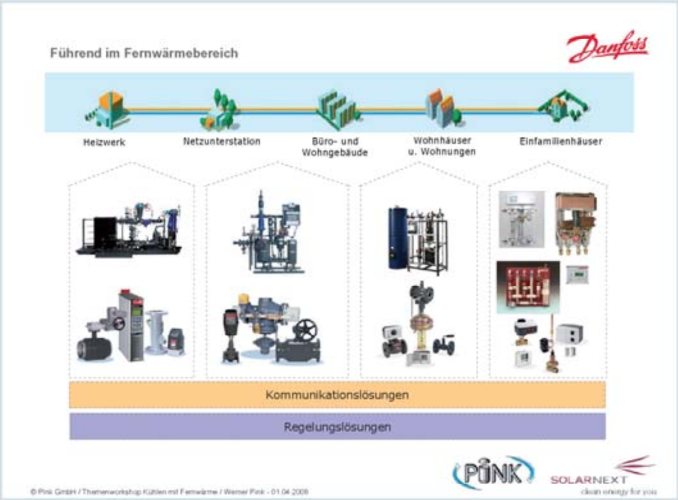


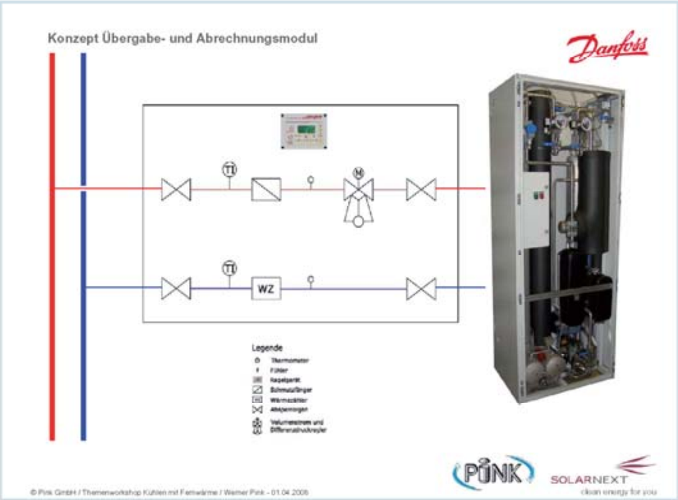
Netzsimulation Sommerbetrieb (ohne und mit AKM)

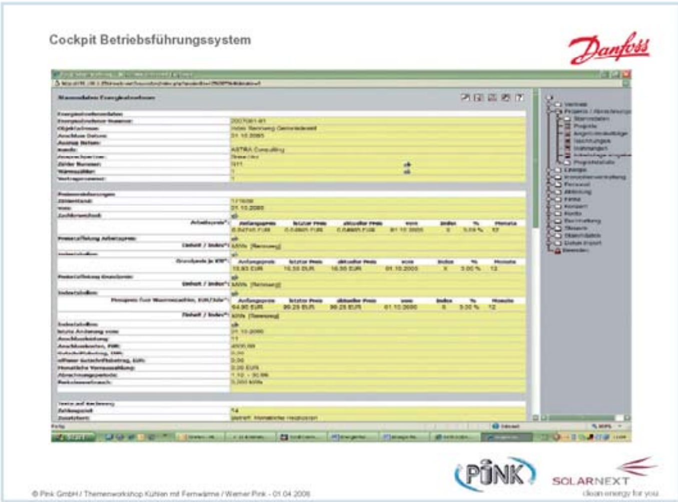


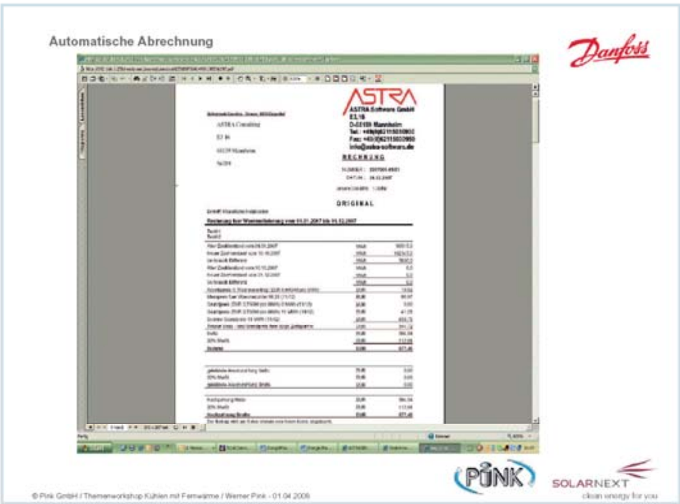
Zusammenfassung

- Viel versprechende aktuelle Entwicklungen im kleinen Leistungsbereich
- Erste Maschinen bereits verfügbar
- Österreichische Kompetenzen in der Maschinen- und Systementwicklung
- Analyse der verfügbaren Technologien am eigenen Prüfstand möglich
- Weiterführende Maschinenentwicklungen erforderlich, um den speziellen Anforderungen der Netzeinbindung gerecht zu werden
- Umfassende Analyse jeder geplanten Netzeinbindung unbedingt erforderlich
  - Probleme im laufenden Netzbetrieb (Bypass)?
  - Attraktivität des Sommerbetriebes
  - Positionierung der AKM
  - Möglichkeit der Abwärmenutzung?









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Kraft-Wärme-Kälte-Kopplung in Fussach
Biomasse-Heizkraftwerk Fussach - „Projekt Biostrom“

Dipl.-Ing. Alfred Hammerschmid

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TEL.: +43 (316) 481300; FAX: +43 (316) 4813004
E-MAIL: hammerschmid@bios-bioenergy.at
HOMEPAGE: http://www.bios-bioenergy.at

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Gliederung

- Überblick Gesamtkonzeption
- Technische Daten
- Betriebsdaten
- Erfahrungen
- Zukünftige Entwicklungen
- Fallbeispiel
- Zusammenfassung und Empfehlungen

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Biomasse-Kraft-Wärme-Kälte-Kopplung BIOSTROM, Fussach

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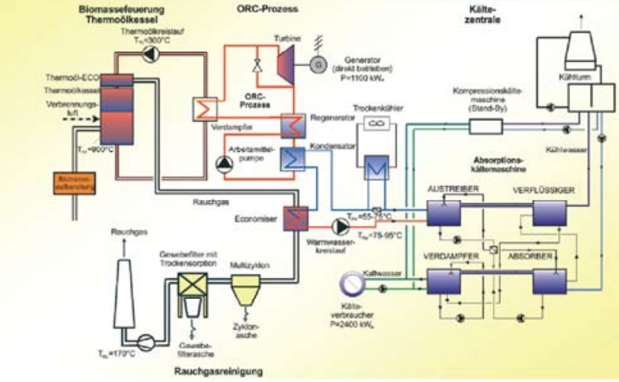
Gesamtanlagenschema



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Technische Daten Gesamtanlage

Biomasse-Kraft-Wärme-Kälte-Kopplung

Brennstoffwärmeleistung Feuerung (Auslegung mit 20% Leistungsreserve)	9.750 kW
Brennstoffwärmeleistung Feuerung (Nennleistung)	7.800 kW
Nennleistung Thermoölkessel und Thermoöl-ECO	6.200 kW
Nennleistung Warmwasser-Economiser	1.000 kW
Verfügbare thermische Nutzleistung (Fern- und Prozesswärme)	5.800 kW
Elektrische Nettoleistung ORC	1.100 kW
Thermische Antriebsleistung Absorptionskältemaschine	3.200 kW
Kälteleistung Absorptionskältemaschine	2.400 kW
Zukünftiges Ausbaupotential Fern- und Prozesswärme	2.600 kW
Erzeugte Wärme aus Biomasse	43.500 MWh/a
Erzeugter Strom aus Biomasse	8.250 MWh/a
Erzeugte Kälte aus Biomasse	18.000 MWh/a
Eingesparter Strom (durch Substitution von Kompressions-kältemaschinen durch eine Absorptionskältemaschine)	3.400 MWh/a

Primärenergie

Altholz (Q1 bis Q4)	78.000 Srm/a
Eingesetzte Brennstoffenergie	58.500 MWh/a

Gesamtinvestitionen

Heizkraftwerk	6,14 Mio €
Kältezentrale Alpla	1,35 Mio €
Fernwärmetrasse zur Kältezentrale	0,50 Mio €

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Innovationen

Technologieinnovationen

- Erste Biomasse-Kraft-Wärme-Kälte-Kopplung auf ORC-Basis in Österreich
- Altholzaufbereitung mit Eisen- und Nicht-Eisen-Metall-Abscheidung
- Low-NO_x-Altholzfeuerung mit lokal thermoölgekühlten Flächen und CFD-optimierter Geometrie
- Thermoölkessel mit getrennten Strahlungs- und Konvektionsheizflächen und automatischer Kugelregen-Abreinigungsanlage
- Hocheffizienter Gewebefilter mit integrierter Trockensorption
- Verstromung des Altholzes mittels ORC-Prozess
- Verschaltung ORC-Prozess mit Niedertemperatur-Absorptionskältemaschine

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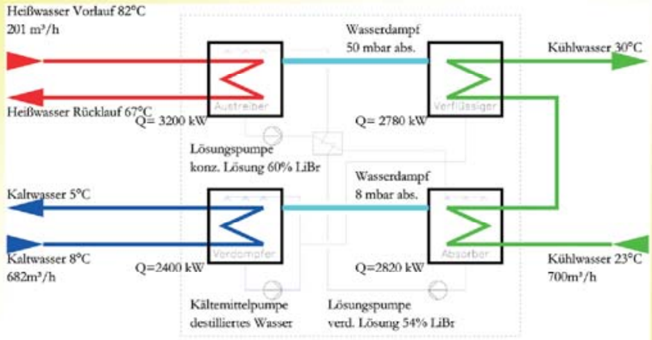
Absorptionskältemaschine Funktionsweise



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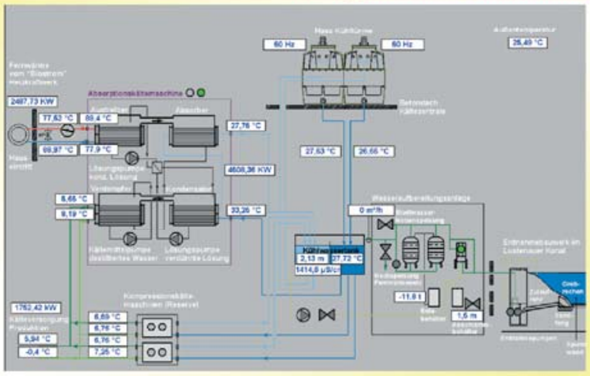
Anlagenschema Kältezentrale



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Absorptionskältemaschine Technische Daten (I)

Kühlwasser:	
Eintrittstemperatur:	23 °C
Austrittstemperatur:	30 °C
Abzuführende Wärme (Auslegung):	5600 kW
Kaltwasser:	
Eintrittstemperatur:	8 °C
Austrittstemperatur:	5 °C
Kälteleistung:	2.400 kW
Leistungsbereich (Kälte):	von 500 bis 2400 kW
Min. Jahresvollaststunden:	7.500 h/a
Heißwasser:	
Eintrittstemperatur:	82 °C
Austrittstemperatur:	67 °C
Max. Wärmeverbrauch (Auslegung):	3.200 kW
Elektrotechnische Einrichtungen:	
Elektrischer Leistungsverbrauch:	18 kW

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Absorptionskältemaschine Technische Daten (II)

Abmessungen der Maschine:	
Länge (über Rohrplatten / Flansche):	9.000/9.600 mm
Breite:	3.300 mm
Höhe:	4.000 mm
Gewichte:	
Leergewicht:	45.000 kg
Betriebsgewicht:	55.000 kg
Störfallgewicht:	90.000 kg

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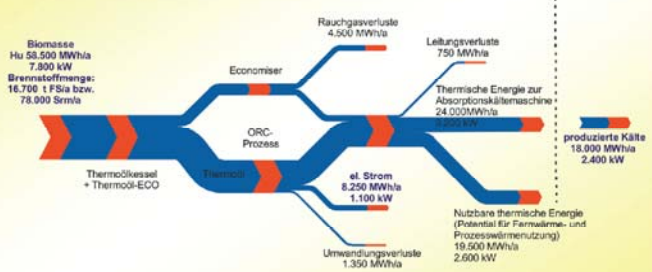
Energieflußbild



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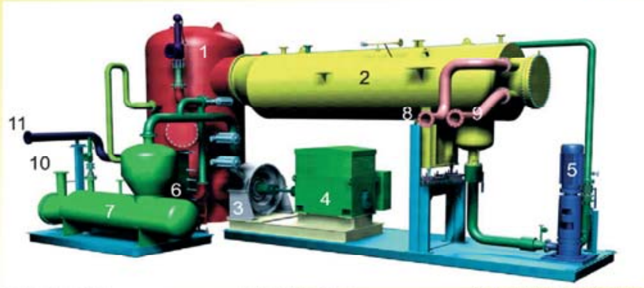
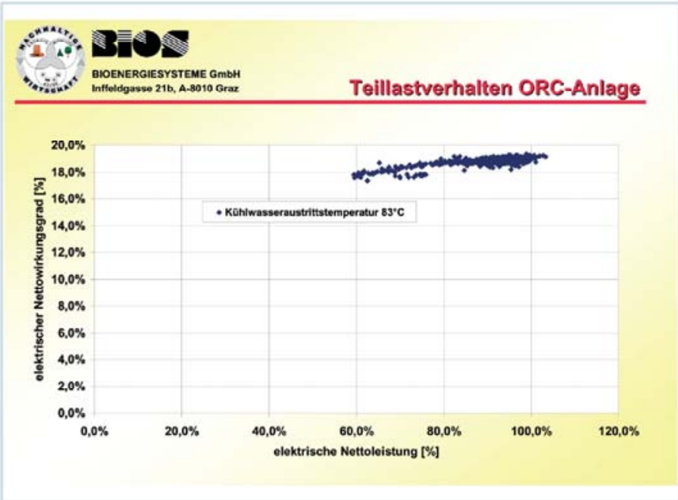
ORC-Anlage



1 Regenerator
2 Kondensator
3 Turbine
4 Elektrischer Generator
5 Umwälzpumpe
6 Vorwärmer
7 Verdampfer
8 Fernwärme-Vorlauf
9 Fernwärme-Rücklauf
10 Thermoöl-Vorlauf
11 Thermoöl-Rücklauf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Teillastverhalten ORC-Anlage
elektrischer Nettowirkungsgrad [%]
elektrische Nettoleistung [%]
Kühlwasseraustrittstemperatur 83°C
20,0%
18,0%
16,0%
14,0%
12,0%
10,0%
8,0%
6,0%
4,0%
2,0%
0,0%
0,0%
20,0%
40,0%
60,0%
80,0%
100,0%
120,0%


BIOS
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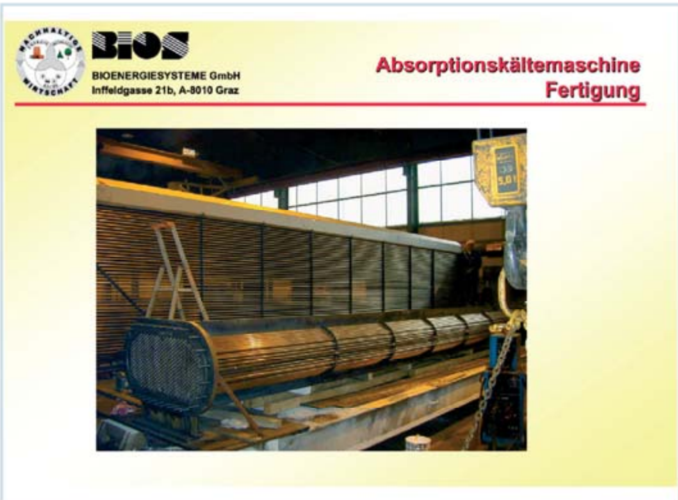
ORC-Prozess –
Einsatzbereich und Anwendungen
Einsatzbereich:
Dezentrale KWK im Leistungsbereich zwischen 200 und 2.000 kWel
Vorteile:
Ausgezeichnete Teillastfähigkeit und Lastwechselfähigkeit (sehr wichtig für wärmegeführten Betrieb)
Guter elektrischer Wirkungsgrad für Kleinanlagen
Hohe Automatisierbarkeit (sehr niedriger Personalaufwand)
Geschlossene Kreisläufe (niedrige Betriebskosten)
Anwendungen:
Rund 70 Anlagen in Ö, I, D, CH, CZ, PL und NL bereits in Betrieb bzw. gerade in Errichtung


BIOS
BIOENERGIESYSTEME GmbH
Inffeldgasse 21b, A-8010 Graz
Absorptionskältemaschine
Fertigung


BIOS
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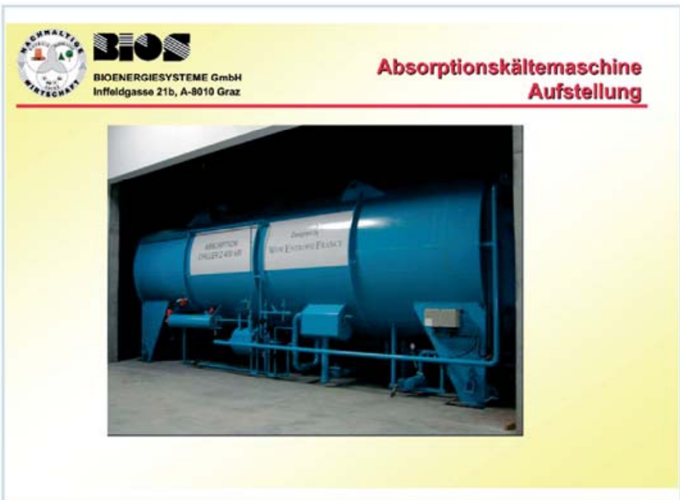
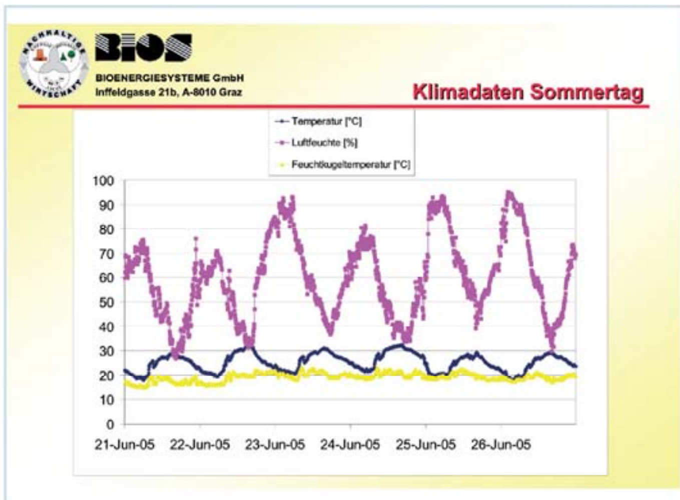
Inffeldgasse 21b, A-8010 Graz
Absorptionskältemaschine
Transport


BIOS
BIOENERGIESYSTEME GmbH
Inffeldgasse 21b, A-8010 Graz
Absorptionskältemaschine
Aufstellung


BIOS
BIOENERGIESYSTEME GmbH
Inffeldgasse 21b, A-8010 Graz
Klimadaten Sommertag
Temperatur [°C]
Luftfeuchte [%]
Feuchtkugeltemperatur [°C]
100
90
80
70
60
50
40
30
20
10
0
21-Jun-05
22-Jun-05
23-Jun-05
24-Jun-05
25-Jun-05
26-Jun-05

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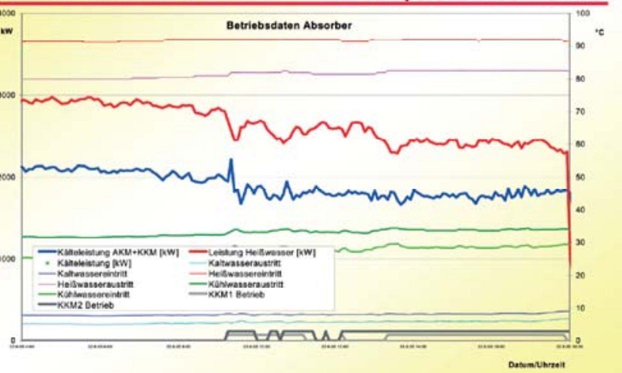
Betriebsdaten Absorptionskältemaschine



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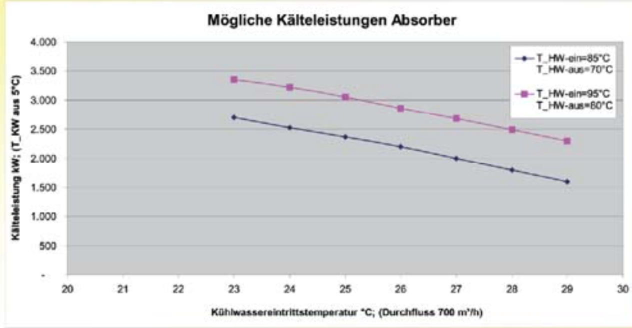
Kälteleistung versus Kühlwasser- und Heißwassertemperatur



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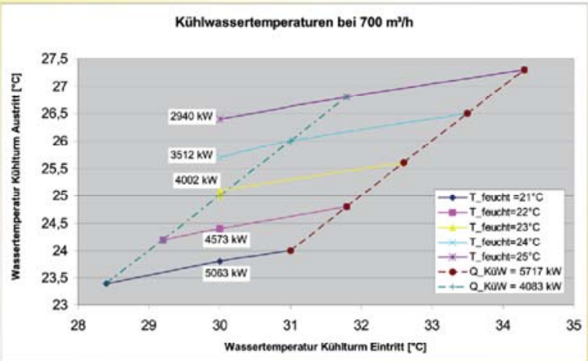
Nasskühlturm Kennfeld



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Betriebserfahrungen (I)

- Gleichmäßige Heißwasser-Vorlauftemperatur der Biomasse-KWK ist wichtig für genaue Regelung der Kälteerzeugung
- Absorptionskältemaschine hat eine Trägheit von ca. 15 min (d.h. Veränderung der Kälteleistung nach Betätigung des Heißwasserventils)
- 1°C höhere / niedrigere Warmwasser-Vorlauftemperatur bei der ORC-Anlage → 0,5% niedrigere / höhere elektrische Leistung
- Regelung der Kaltwassertemperatur auf +/- 0,5°C möglich
- Sehr rasche Lastschwankungen sind durch Kaltwasser-zwischenbecken auszugleichen

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Betriebserfahrungen (II)

- Sehr hohe Verfügbarkeit der Absorptionskältemaschine und der Biomasse-KWK-Anlage
- Wartung & Instandhaltung
  Absorber:
  etwa 5 h / Woche für Kontrolltätigkeiten; 1 x /Jahr Analyse Arbeitsmittel
  Offener Kühlkreislauf:
  täglich etwa 1 h für Kontrollen und Wasseranalysen; ca. alle 2-3 Jahre Reinigung des gesamten Kühlkreislaufes
- Regelung der Gesamtanlage nach wirtschaftlichem Optimierungskriterium als große Herausforderung (bei unterschiedlichem Außenklima, Optimierung von – Kühlwassertemperatur, Heißwassertemperatur, Eigenstrombedarf, Ökostromerzeugung, Brennstoffbedarf)

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Zukünftige Entwicklungen (I)

- Anwendungsgebiete

  Fernwärmenetze:

  a) Kälteproduktion dezentral bei ausgewählten Fernwärme/kältekunden

  b) Kälteproduktion zentral im Heizkraftwerk und Verteilung über eigenes Kältenetz

  Gewerbe/Industriebetriebe:

  a) Prozesskälteproduktion

  b) Verbrennungsluftkühlung für Gasturbinenanlagen

  c) Wärmerückgewinnung aus Abgaskondensationsanlagen (Absorptionswärmepumpen)

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Zukünftige Entwicklungen (II)

- Auslegungskriterien

Kaltwasser:

- Genaue Analyse der Ganglinien und Temperaturanforderungen
- Möglichkeit von Speichersystemen prüfen
- Mengenkonstante oder mengenvariable Regelung prüfen
- Pumpstrombedarf beachten

Heißwasser:

- Festlegung der max. Vorlauftemperatur (> 110°C → überwachungspflichtige Druckgeräte)
- Mengenvariable Regelung versus hohes COP bei Teillast

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Zukünftige Entwicklungen (III)

Kühlwasser:

- Lokale Klimadaten und Entwicklungen berücksichtigen
- Genaue Prüfung des am besten geeigneten Kühlverfahren
- Evaluierung offenes / geschlossenes System und hydraulische Weichen
- Exakte Voranalysen des Kühlwassers und Mengenverfügbarkeit
- Geeignete Wasseraufbereitung vorsehen
- Ausreichende Berücksichtigung der Foulingfaktoren für die Flächenreserven der Wärmetauscher (Absorber und Kondensator)
- Werkstoffwahl aller Kühlwasserberührten Teile von großer Bedeutung
- Evtl. automatische Wärmetauscherreinigung im Betrieb vorsehen
- Mengenkonstante oder mengenvariable Regelung prüfen

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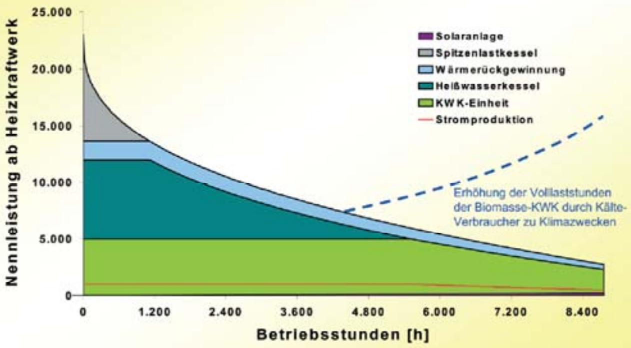
Jahresdauerlinie Fernwärmeversorgung – Potential Kälteerzeugung



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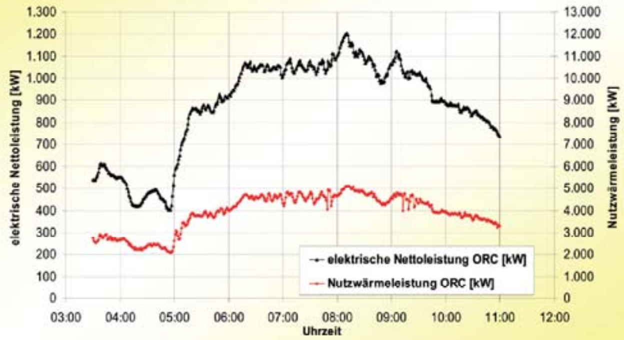
ORC-Prozess – Lastwechselverhalten im wärmegeführten Betrieb



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Fallbeispiel für Absorptionskältemaschine

- Grundlast-Kälteversorgung für Motorenwerk eines Automobilherstellers:
- Kälteleistung 4.000 kW

Kälteleistung	4.000 kW
Erzeugte Kälteenergie	32.000 MWh/a
Kühlwassertemperatur	32/27°C
Kaltwasser	6/12°C
Heißwasser	85/70°C
Wärmepreis	25,- €/MWh
Kältepreis	65,- €/MWh
Strompreis	100,- €/MWh

Nasskühlturm unter Verwendung von Frischwasser als Zusatzwasser

Verzinsung 7% p.a.
Investition Kälteerzeugung (ohne Wärmeerzeugungsanlage) 1,6 Mio €

- → Amortisationszeit ca. 6 Jahre

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Zusammenfassung und Empfehlungen (I)

- Absorptionskältemaschinen für Niedertemperaturanwendungen sind gut entwickelt
- ORC-Anlagen lassen sich mit Absorptionskältemaschinen aufgrund der Heißwassertemperaturen sehr günstig kombinieren
- Investitions- und Betriebskosten (insbesondere Pumpstrom) für die hydraulische Anlage sind ganz wesentlich von den gewählten Spreizungen auf Kaltwasser- und Kühlwasserseite abhängig
- Beträchtliche Stromeinsparungen und CO_2-Reduktionen durch Biomasse-Kraft-Wärme-Kälte-Kopplung möglich
- Die Kälteerzeugung benötigt relativ hohe Vollaststunden

BIOS
BIOENERGIESYSTEME GmbH
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Zusammenfassung und Empfehlungen (II)

- Die Hauptkriterien für die Wirtschaftlichkeit von Niedertemperatur-Absorptionskältemaschinen sind der erzielbare Wärmepreis der Biomasse-KWK-Anlage, die verfügbare Kühlwasserbereitung und der Strompreis für eine vergleichbare Kälteerzeugung mit Kompressionskältemaschine
- Bei in Zukunft zu erwartenden steigenden Strompreisen werden Absorptionskältemaschinen in Biomasse-KWK-Anlagen verstärkt Anwendung finden können.

Danke für Ihre Aufmerksamkeit

BIOS BIOENERGIESYSTEME GmbH
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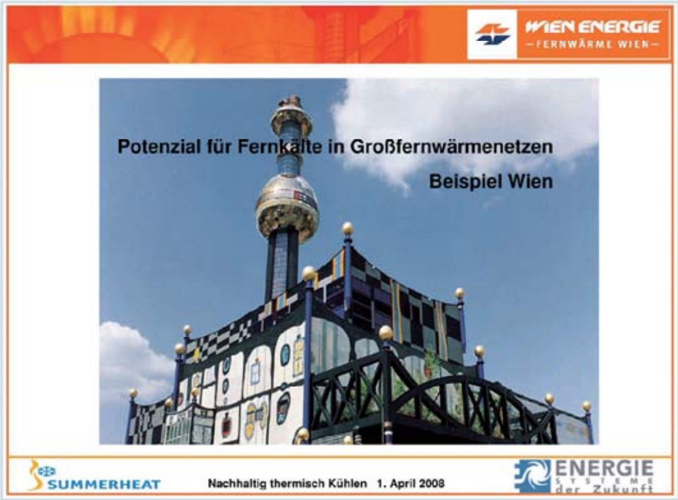
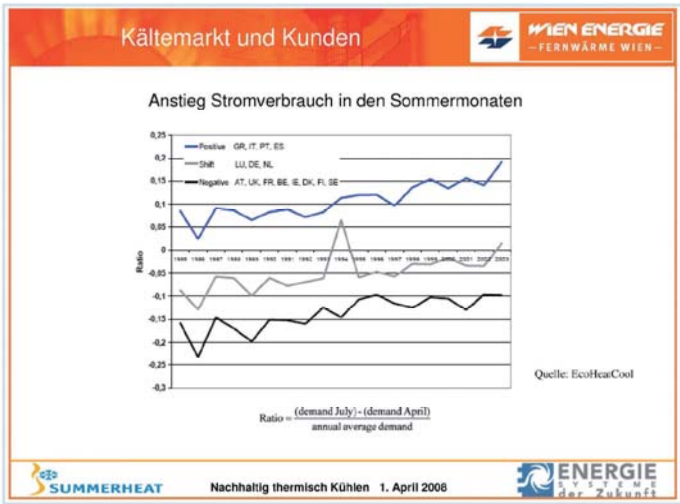
TEL.: +43 (316) 481300; FAX: +43 (316) 4813004
E-MAIL: hammerschmid@bios-bioenergy.at
HOMEPAGE: http://www.bios-bioenergy.at


WIEN ENERGIE
FERNWÄRME WIEN
Potenzial für Fernkälte in Großfernwärmenetzen
Beispiel Wien
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Treiber & Herausforderungen
WIEN ENERGIE
FERNWÄRME WIEN
• Kältemarkt und Kunden
• Preise und Kosten
• Energieversorgung
• Umweltrelevanz
• Rahmenbedingungen
• Komfort
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Kältemarkt und Kunden
WIEN ENERGIE
FERNWÄRME WIEN
Internationale Energieagentur:
„Kühlung und Klimatisierung ist eines der am schnellsten wachsenden Felder neuen Energiebedarfs.“
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Kältemarkt und Kunden
WIEN ENERGIE
FERNWÄRME WIEN
Anstieg Stromverbrauch in den Sommermonaten
Positive GR, IT, PT, ES
Shift LU, DE, NL
Negative AT, UK, FR, BE, IE, DK, FI, SE
Ratio
Quelle: EcoHeatCool
Ratio = (demand July) - (demand April) / annual average demand
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ENERGIE SYSTEME der Zukunft


Kältemarkt und Kunden
WIEN ENERGIE
FERNWÄRME WIEN
>50 MW
10 MW
60 MW
20 MW
25 MW
Vienna
Markterhebung zu Fernkälte hat in Wien einige kurzfristig erschließbare Gebiete ergeben
In Summe
>200 MW Kälteleistung
SUMMERHEAT
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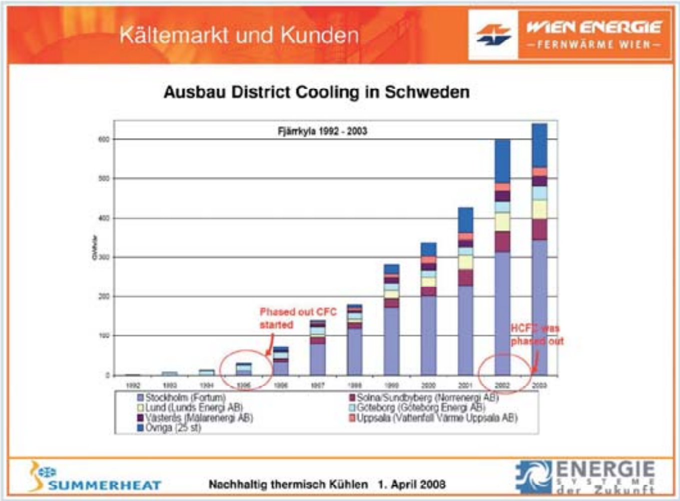
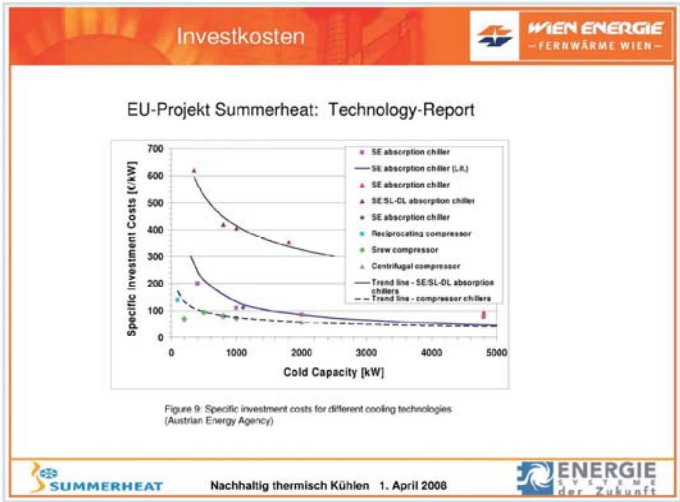
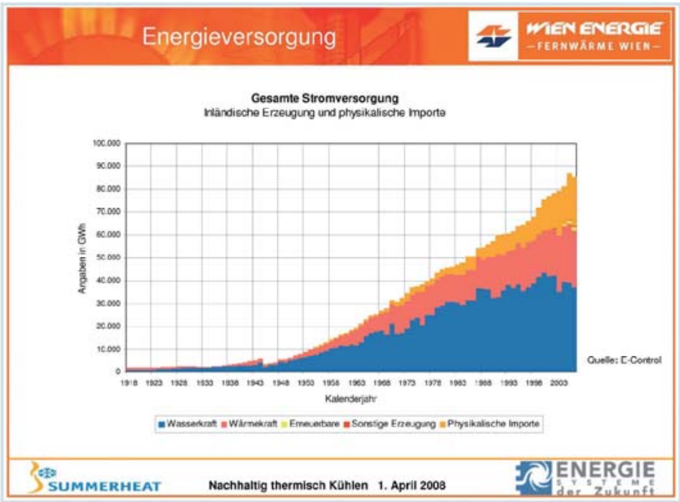
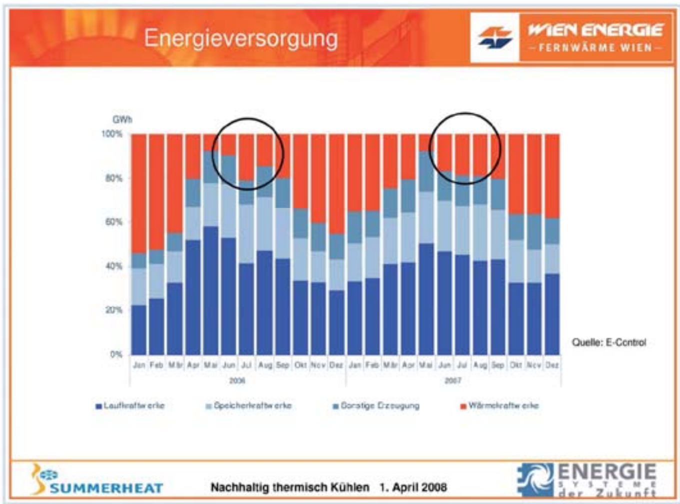
ENERGIE SYSTEME der Zukunft


Kältemarkt und Kunden
WIEN ENERGIE
FERNWÄRME WIEN
Legende
Fernwärme Wien
KÄLTEZENTRALEN
KÄLTEBEDARF
IN SUMME
ca. 245 MW
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Kältemarkt und Kunden
WIEN ENERGIE
FERNWÄRME WIEN
Ausbau District Cooling in Schweden
Fjärrkyla 1992 - 2003
Phased out CFC started
HCFC was phased out
Stockholm (Fortum)
Lund (Lunds Energi AB)
Västerås (Mälarenergi AB)
Övriga (25 st)
Solna/Sundbyberg (Norrenergi AB)
Göteborg (Göteborg Energi AB)
Uppsala (Vattenfall Värme Uppsala AB)
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Investkosten
WIEN ENERGIE
FERNWÄRME WIEN
EU-Projekt Summerheat: Technology-Report
Specific Investment Costs [€/kW]
Cold Capacity [kW]
SE absorption chiller
Reciprocating compressor
Srew compressor
Centrifugal compressor
Trend line - SE/SL-DL absorption chillers
Trend line - compressor chillers
Figure 9: Specific investment costs for different cooling technologies (Austrian Energy Agency)
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Energieversorgung
WIEN ENERGIE
FERNWÄRME WIEN
Gesamte Stromversorgung
Inländische Erzeugung und physikalische Importe
Angaben in GWh
Kalenderjahr
Quelle: E-Control
Wasserkraft
Wärmekraft
Erneuerbare
Sonstige Erzeugung
Physikalische Importe
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


Energieversorgung
WIEN ENERGIE
FERNWÄRME WIEN
GWh
2006
2007
Quelle: E-Control
Laufkraftwerke
Speicherkraftwerke
Sonstige Erzeugung
Wärmekraftwerke
SUMMERHEAT
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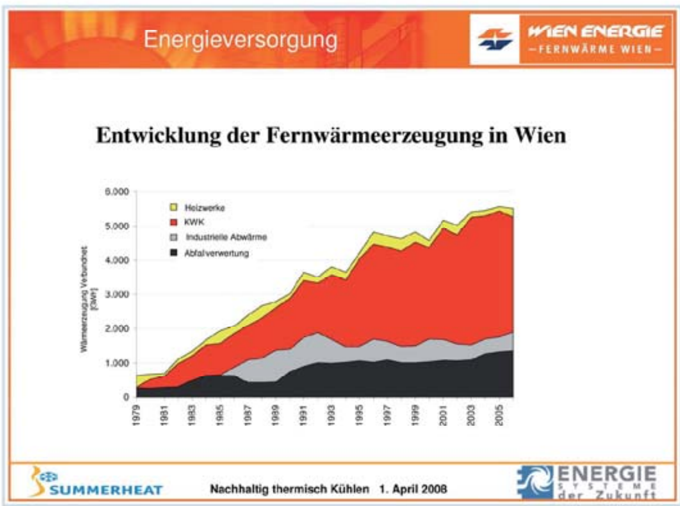
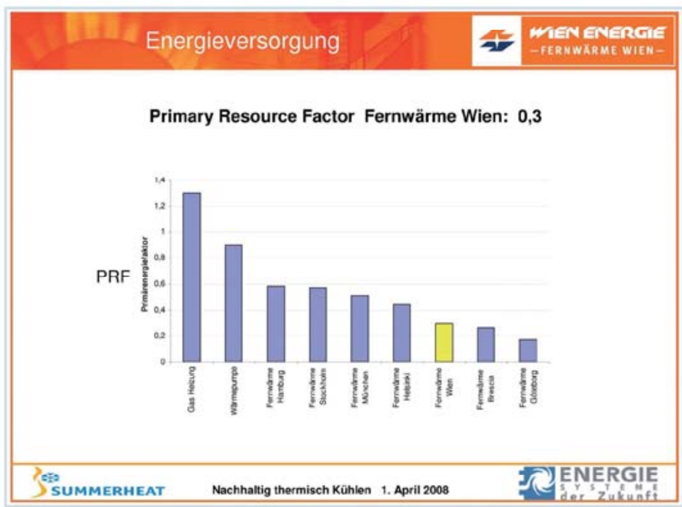
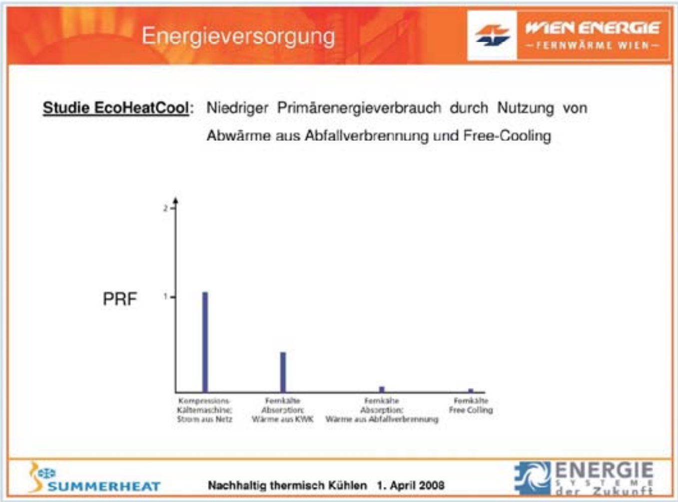
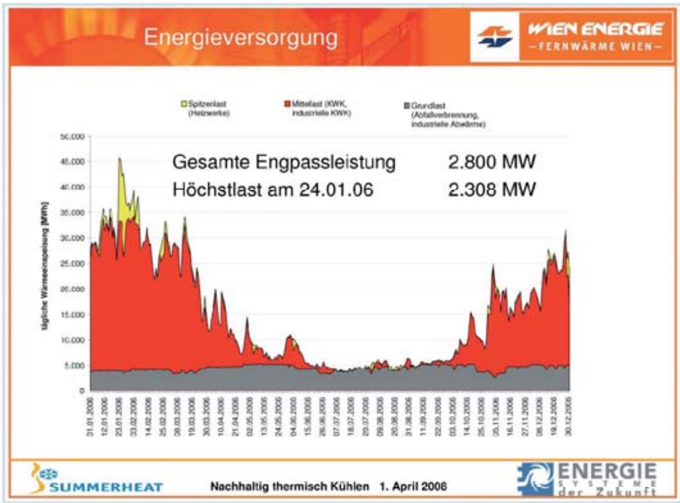
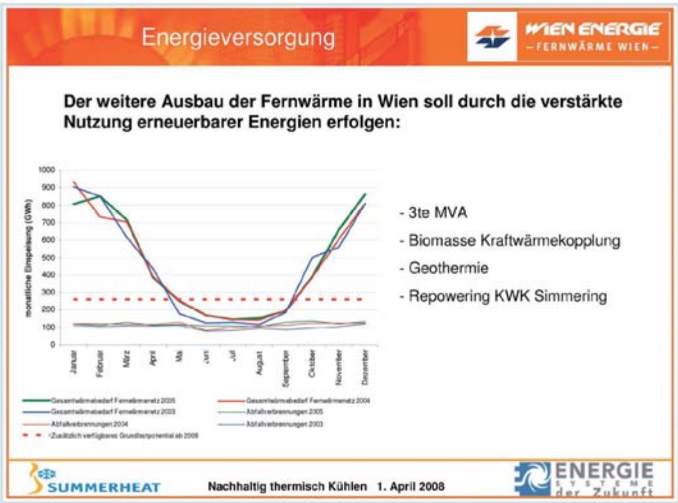
ENERGIE SYSTEME der Zukunft

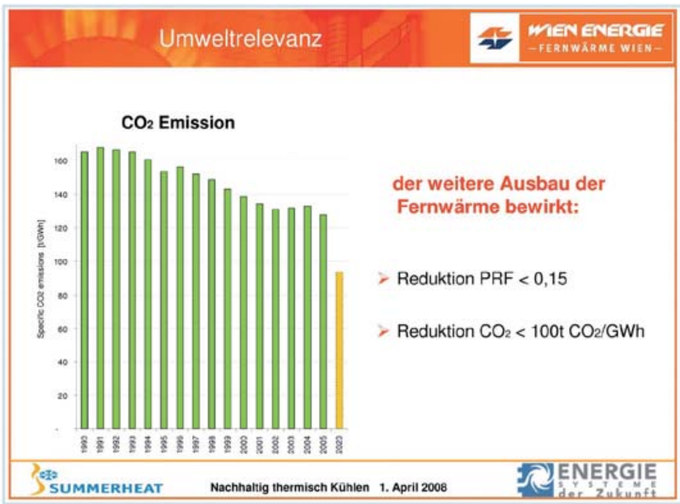

Energieversorgung
WIEN ENERGIE
FERNWÄRME WIEN
Entwicklung der Fernwärmeerzeugung in Wien
Heizwerke
KWK
Industrielle Abwärme
Abfallverwertung
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft

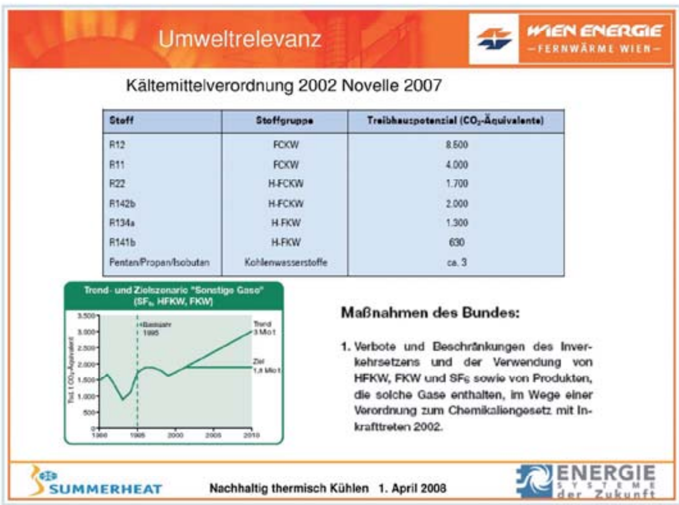

Energieversorgung
WIEN ENERGIE
FERNWÄRME WIEN
Primary Resource Factor Fernwärme Wien: 0,3
PRF
Primärenergiefaktor
Gas Heizung
Wärmepumpe
Fernwärme Hamburg
Fernwärme Stockholm
Fernwärme München
Fernwärme Helsinki
Fernwärme Wien
Fernwärme Brescia
Fernwärme Göteborg
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft



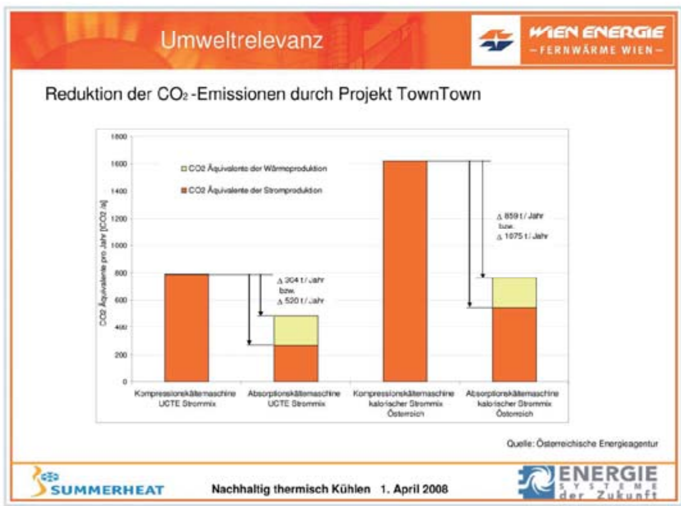








Stoff	Stoffgruppe	Treibhauspotenzial (CO_2-Äquivalente)
R12	FCKW	8.500
R11	FCKW	4.000
R22	H-FCKW	1.700
R142b	H-FCKW	2.000
R134a	H-FKW	1.300
R141b	H-FKW	630
Penten/Propan/Isobutan	Kohlenwasserstoffe	ca. 3




Rahmenbedingungen
WIEN ENERGIE
FERNWÄRME WIEN
• Klimaschutzprogramm der Stadt Wien:
Ausbau Fernwärme auf 50% Marktanteil
Einsatz Fernkälte, FreeCooling, Solare Kühlung 200MW
• EU-Richtlinien
Gebäuderichtlinie: Artikel 5
Alternativenprüfung für neue Gebäude >1000 m² in Bezug auf Anschluss Fernwärme bzw. Fernkälte
• Förderprogramme (Umwelt, Energieeffizienz, Kyoto)
National
EU
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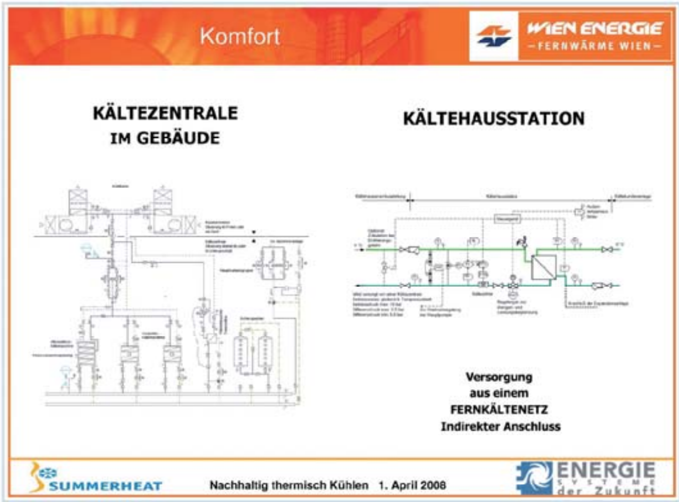
ENERGIE SYSTEME der Zukunft


Komfort
WIEN ENERGIE
FERNWÄRME WIEN
KÄLTEZENTRALE IM GEBÄUDE
KÄLTEHAUSSTATION
Versorgung aus einem FERNKÄLTENETZ Indirekter Anschluss
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ENERGIE SYSTEME der Zukunft


konkrete Projekte
WIEN ENERGIE
FERNWÄRME WIEN
TownTown ist das erste Fernkälteprojekt der Fernwärme Wien:
Schema des Fernkältenetzes in TownTown
21 Objekte
Nach Endausbau:
Spitzenlast 10 MW
AKM 6,5 MW
KKM 3,5 MW
SUMMERHEAT
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ENERGIE SYSTEME der Zukunft


konkrete Projekte
WIEN ENERGIE
FERNWÄRME WIEN
Kältezentrale Spittelau
am Gelände der MVA
geplante Spitzenlast 50 MW Kälte
Kältekunden in geringer Entfernung: AKH, Skyline-Bürokomplex, Technologiezentrum der Univ. für Bodenkultur, Bürogebäude Muthgasse,...........
SUMMERHEAT
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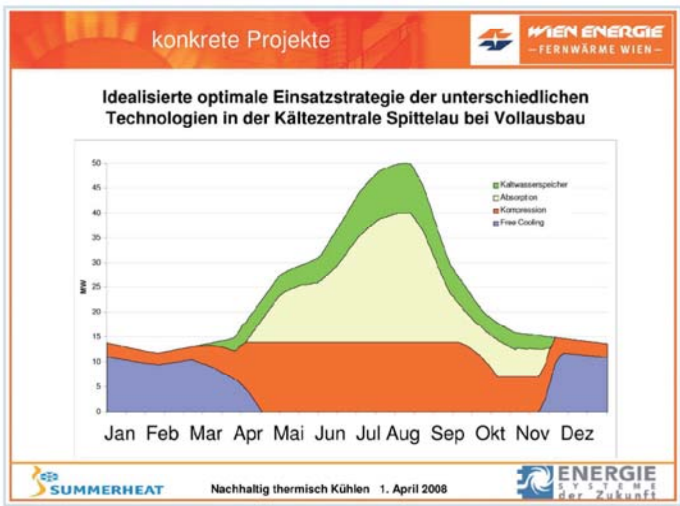
ENERGIE SYSTEME der Zukunft


konkrete Projekte
WIEN ENERGIE
FERNWÄRME WIEN
Von November bis April steht mit dem Donaukanal eine Free-Cooling Quelle zur Verfügung
Temperatur °C
SUMMERHEAT
Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE SYSTEME der Zukunft


konkrete Projekte
WIEN ENERGIE
FERNWÄRME WIEN
Idealisierte optimale Einsatzstrategie der unterschiedlichen Technologien in der Kältezentrale Spittelau bei Vollausbau
MW
Kaltwasserspeicher
Absorption
Kompression
Free Cooling
Jan Feb Mar Apr Mai Jun Jul Aug Sep Okt Nov Dez
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ENERGIE SYSTEME der Zukunft


Vorteile Fernkälte
WIEN ENERGIE
– FERNWÄRME WIEN –
Vorteile für Kältekunden
wirtschaftlich günstige Kälteversorgung
geringer Platzbedarf, Komfortgewinn
keine Kühltürme (Schall, Legionellen)
kein Kältemittelrisiko
Erhöhung der Versorgungssicherheit
umweltrelevante Aspekte:
Reduktion des Primärenergieeinsatzes durch Nutzung von Abwärme anstatt Strom
Reduktion der Treibhausgasemissionen
Geringere Leckrate bzw. unbedenkliche Kältemittel
volkswirtschaftliche – energiepolitische Aspekte:
Reduktion der sommerlichen Strom-Leistungsspitzen
Reduktion der Primärenergieimporte
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ENERGIE
SYSTEME
der Zukunft


Fernkälte Paris
CLIMESPACE
WIEN ENERGIE
– FERNWÄRME WIEN –
• Louvre Museum : 220 000m2 > Problem of space : 1500m2 saved
• Galeries Lafayette : 100 000m2 > Sanitary risk transfer and possibility to cool the Emergency Diesel
• National Opera : 22 000m2 > Problem of space and no electricity capacity for new chiller
• Caisse des Dépôts : 66 000m2 > Reduce operation cost
• MK2 (Cinema): 37 000m2 > Space saving : 300 seats more
• AXA : 37 000m2 > Risk transfer
• Hotel Meurice : 32 000m2 > Space saving on the top and underground to put cellar for wine
• Hotel Crillon : 15 000m2 > Cooling security in case of electrical power failure
• George V : 36 000m2 > Space saving on the top and underground to add a new room service
SUMMERHEAT
Intelligent Energy Europe


WIEN ENERGIE
– FERNWÄRME WIEN –
Danke für Ihre Aufmerksamkeit
DI Adolf Penthor
Leiter Engineering
Fernwärme Wien
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Nachhaltig thermisch Kühlen 1. April 2008
ENERGIE
SYSTEME
der Zukunft

e2050

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arsenal research
Ein Unternehmen der Austrian Research Centers

IEA FORSCHUNGS KOOPERATION

SIXTH FRAMEWORK PROGRAMME

FACHVERBAND GAS WÄRME FGW

ENERGIE SYSTEME der Zukunft

ENERGIE 2050 - Eine Initiative des BMVIT - An Initiative by the BMVIT

*Bundesministerium für Verkehr,
Innovation und Technologie
Abteilung für Energie- und
Umwelttechnologien
Leitung: DI Michael Paula
1010 Wien, Renngasse 5*

*Austrian Ministry for Transport,
Innovation and Technology BMVIT
Division of Energy- and
Environmental Technologies
Head of Division: DI Michael Paula
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