Patent Landscape Report on

Solar Cooling Technologies

2012

PATENT LANDSCAPE REPORTS PROJECT

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The purpose of each report is three-fold:
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Patent Landscape Report
on
Solar Cooling Technologies

A patent landscape report prepared

for the
World Intellectual Property Organization (WIPO)

by the
Swiss Federal Institute of Intellectual Property
- Daniel Kunz, Heinz Müller and Christian Soltmann -

2012

Executive Summary

The main goal of this patent landscape report is to provide a general overview of existing solar cooling technologies and potential fields of application. For the purpose of this report, the definition of solar cooling was not limited to technologies using solar radiation for air-conditioning of buildings. Other applications such as cooling of water, refrigeration of sensitive goods, e.g. medicaments or desalination of seawater, were also included.

A second goal of the report is to exemplify how specific technical subject matter can be searched in patent databases. As the subject matter for this report covers a wide range of technologies, the search for relevant patent families was based on a broad search strategy. The search was performed without any explicit restrictions to countries, regions or time. In a first step, a selection of potentially relevant patent families was created by combining different search concepts. Secondly, the patent families selected were analysed individually with regard to their relevance to solar cooling. Thirdly, patent families identified as relating to solar cooling were categorised in order to structure the technical information and to facilitate access to the information. Finally, the set of patent families relating to solar cooling was analysed regarding patent family size, country distribution of priority and published documents, as well as with regard to main patent applicants and inventors from industry and the academic/public sectors.

The first search step yielded around 1230 potentially relevant patent families from the previous four decades, of which approximately 550 were judged to relate to solar cooling.

Interesting results were found in particular with regard to the use of solar cooling technologies in developing countries. Numerous inventions in the field of solar cooling were filed for patent protection in industrialised countries only. Moreover, various patent applications for solar cooling technologies were filed more than 20 years ago. Accordingly, the underlying technical inventions may be used freely in developing countries.

While most patent families were found to disclose neither particularly simple nor very complex technologies, more than 70 patent families were judged to concern simple technologies. These technologies may be easily used, require low maintenance and can be serviced with little effort and technological know-how. Only around 10 patent families were identified as clearly describing particularly complex systems.

Various patent families were found to address applications which may be relevant to developing countries. Several hundred patent families concern the cooling of buildings and more than 30 patent families describe technologies for the cooling of sensitive goods such as food or medicaments. In addition, more than 20 patent families address the desalination of seawater.

The average patent family size is below two, i.e. only one patent application was filed for numerous inventions in the solar cooling field. The most active countries developing and applying for patent protection of such technologies are the United States, Germany, China, Japan and France. In the United States, the most active period regarding patent applications for solar cooling technologies was in the 1970s, whereas most Chinese patent applications have been filed during the last five years. In Germany and Japan, solar cooling technologies have been steadily filed for patent protection over the last 40 years. In France, almost all patent applications were filed up to the early 1980s.

The geographical distribution of published patent family members shows that most of the patent family members were published for Europe, with North America being second and Asia third. Only a small number of patent family members were published for Africa and South America.

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1. Introduction

1.1 Objectives

The World Intellectual Property Organization (WIPO) established a development agenda in 2007 aiming to ensure that development considerations form an integral part of WIPO's activities. More than forty recommendations were adopted to strengthen the development dimension of WIPO's work. Within this context, WIPO has started the project 'Developing Tools for Access to Patent Information', which aims to improve the transfer of technology to developing countries and to facilitate access to publicly-available patent information.[1]

The patent landscape report on solar cooling forms part of this project. The goal of the patent landscape report is to identify and present technologies for cooling devices driven by solar power. In particular, those technologies that can be used in rural areas of developing countries will be highlighted, with a focus on improving the environment, life and health of humans, animals and plants and food security. The report shall show specific examples of patent documents[2] describing solar cooling devices or processes which are easy to use, require low maintenance, can be serviced with little effort and technological know-how, and do not consist of complex technologies.

For the purpose of this report, processes and devices which use solar energy only for generating electric energy to run electrical cooling elements, such as so-called Peltier elements, will be disregarded. Likewise, systems which are based on electric energy from solar power stations and distributed over long-distance systems will also be disregarded. Furthermore, devices which include an external power supply (such as electrical power from power outlets or generators run with fuel), and where solar energy is only marginally used, will also not be considered.

1.2 Structure of the report

The report is divided into four main sections. This section gives a short overview of established technical concepts which are used to realise solar cooling. In the second section, the search methodology to identify patent documents relating to solar cooling is briefly presented. Subsequently, selected inventions are presented which are considered representative of common technical categories, according to which the technical content of the identified patent documents may be characterised. The fourth section summarises the results of a patent statistical analysis. An appendix includes a glossary of patent-related terms, detailed information about the databases used and the search strategy. The report is complemented by a separate electronic Excel sheet containing bibliographic information about all identified patent documents and about the categories the documents were assigned to.

[1] *See www.wipo.int/edocs/mdocs/mdocs/en/cdip_4/cdip_4_6.pdf for a detailed description of the project.*

[2] *The term patent document will be used for both patents and utility models. Furthermore, the term will include patent applications as well as granted patents without taking into account the legal status of the patent document, e.g. whether a patent is in force, expired or invalidated by a court decision.*

1.3 Solar cooling technologies

The term ‘solar cooling’ refers to devices and processes that use solar energy for cooling. Solar cooling systems have the advantage of using predominantly non-toxic and environmentally sound working fluids such as water or salt solution, and can be used as stand-alone systems. Solar cooling systems are in many cases able to simultaneously generate refrigeration and save conventional energy. Cooling can be provided by both active and passive systems.[3] The capacity of solar cooling devices is generally at its peak when insolation, i.e. solar irradiation, is highest. Accordingly, solar cooling devices can ideally meet the needs of countries in sunny regions where the demand for cooling is generally high around noon.

The report aims to provide a general overview of existing solar cooling technologies and potential fields of application. Accordingly, the search for solar cooling devices and processes will not be limited to technologies using solar radiation for air-conditioning of buildings. Other applications such as cooling of water, refrigeration of sensitive goods, e.g. medicaments, food or desalination of seawater will also be included.

At least four different established techniques are used to realize solar cooling: vapour compression, sorption-based cooling (including absorption and adsorption chilling), evaporative cooling and solar ejector cooling.

1.3.1 Vapour compression

A vapour-compression refrigeration system uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently dissipates that heat elsewhere. This type of cooling system is widely used for air-conditioning as well as for refrigeration. Vapour compression machines generally comprise a mechanical compressor, a condenser, an expansion valve and an evaporator arranged in a closed loop, which transform the refrigerant into different thermodynamic states.

First, vaporous refrigerant is compressed and heated in the compressor, transforming the refrigerant into a state at which it can subsequently be condensed to a liquid in the condenser. During the condensation process, the refrigerant yields thermal energy to the condenser, which is absorbed and removed by cooling water or cooling air.

The condensed refrigerant is then directed to an expansion valve where it experiences a steep decrease in pressure, abruptly vaporising part of the liquid refrigerant and cooling the mixture of liquid and vaporous refrigerant.

The cooled mixture is further directed to the evaporator where ambient air of the space to be cooled is routed through the evaporator in order to vaporise the liquid portion of the refrigerant. In doing so, thermal energy is extracted from the air which is chilled.

Finally, the vaporous refrigerant is returned to the compressor and the loop is closed.

The development of vapour compression technology essentially started in the 19th century. Hence, it does not come as a surprise that the technology is mature and, due to the various improvements, rather inexpensive. A substantial drawback is the fact that many technical concepts in the field are based on refrigerants that assist the depletion of the atmospheric

[3] *Active solar energy systems use a mechanical or electrical mechanism to transfer solar energy absorbed in a solar collector to another component in the system. Passive systems rely upon the design or architecture of the building itself to ensure climate control by way of natural thermal conduction, convection and radiation. These passive systems function by either shielding buildings from direct heat gain or by transferring excess heat outside.*

ozone layer. For this reason, research has specialised in developing alternatives to these conventional refrigerants, which are less critical yet easy to use.

While vapour compression devices are mostly run by electrical or mechanical energy, solar cooling may make a major contribution to providing sufficient energy for the process. Figure 1 presents an example of a vapour compression machine where a solar collector supplies heated water to an absorption cooler (see the following section 1.3.2). The absorption cooler partly undertakes the task of the condenser in the vapour compression loop, thus saving conventional energy.

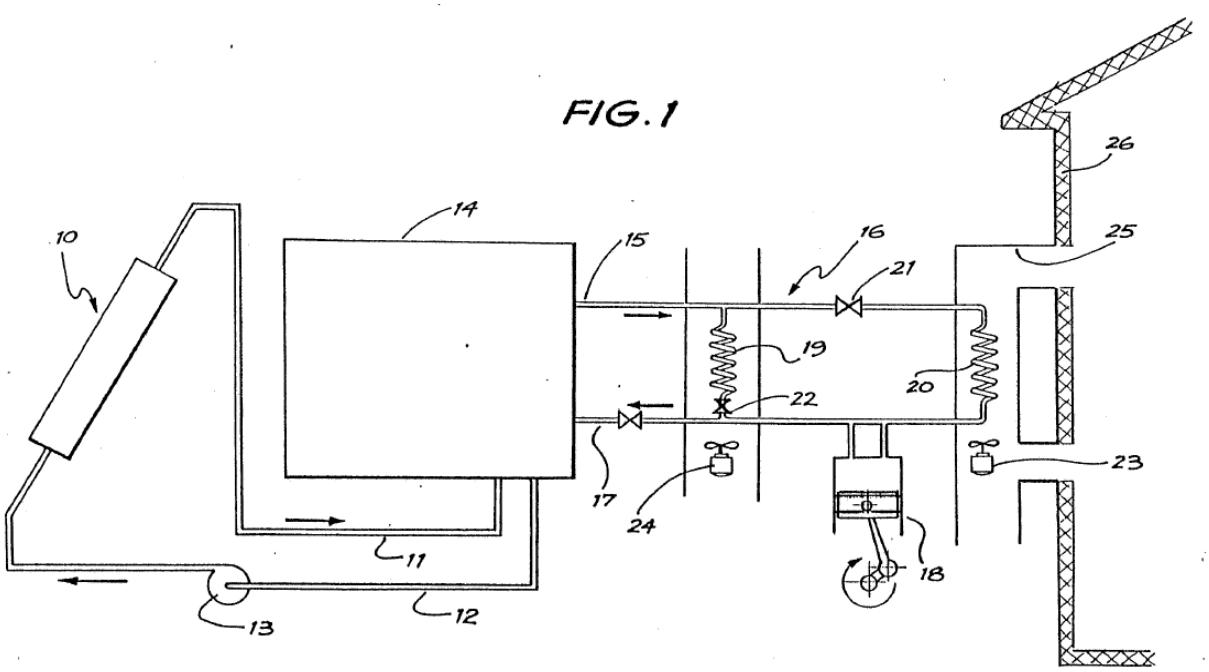

Figure 1: A cooling plant connected to a solar collector (10)[4], according to patent document WO8300917A1. The plant comprises a vapour compression machine (16) which is essentially composed of a mechanical compressor (18), a condenser (19) and an evaporator (20). In this particular example, the refrigerant, which leaves the condenser (19) in a liquid state, is completely vaporised in the evaporator, skipping partial vaporisation by an expansion valve. The solar collector (10) supplies heated water to an absorption cooler (14) to which part of the heated and compressed vaporous refrigerant from the compressor (18) can be bypassed in order to reduce the work load of the condenser (19), thus saving conventional energy.

[4] *In the following, numbers in brackets are used in the figure captions and in the running text to refer to technical elements in the related figures which are labelled by these numbers.*

1.3.2 Solar sorption cooling

Whereas vapour compression is a very mature and common technology, it involves vibration and noise owing to the functional principle of the components. Sorption-based cooling devices, which are based on different processes, are alternatives to vapour compression machines if the drawbacks of these machines need to be overcome. In addition, sorption-based cooling devices are particularly attractive if the power supply is insufficient or costly, or if thermal energy is easily available, e.g. from solar plants or solar heat collectors.

Sorption-based cooling devices rely on so-called sorbents, which are capable of ”holding” liquids or gases.[5] Two technologies are distinguished: absorption cooling where the liquids or gases are dissolved in the bulk of the sorbent in one stage of the process, and released in another stage; and adsorption cooling where the liquids or gases are bound to the surface of the sorbent in one stage of the process, and released in another stage.[6] Such phase changes are accompanied by release or consumption of thermal energy.

a) Absorption cooling

Absorption cooling machines[7] generally use a closed loop comprising four steps: evaporation, absorption, regeneration and condensation, as exemplified in Figure 2. In a first step, a liquid refrigerant, mostly water, is vaporised at low pressure in the evaporator (17). It may be sprayed on cooling pipes through which a chilled liquid such as water flows. Since the liquid refrigerant extracts thermal energy from the surrounding during the vaporisation, the chilled liquid in the cooling pipes is further refrigerated. The refrigerated liquid is generally directed to a heat exchanger where the air of a space to be cooled may be refrigerated.[8]

In a second step, the vaporised refrigerant is directed to the absorber section (19) where it is absorbed at low pressure by an absorber solution, consisting of an absorbent dissolved in liquid refrigerant. The absorption heat released during the absorption step is discharged by cooling water. By absorbing vaporous refrigerant, the absorber solution is diluted.

The diluted absorber solution is subsequently directed to a regenerator (15) where the solution is heated and concentrated by vaporising part of the refrigerant. The thermal energy that is required to heat the diluted absorber solution may be provided by solar heat collectors. The concentrated solution is returned to the absorber section (19) while the vaporised refrigerant is transported to the condenser (16).

In the condenser (16), the vaporised refrigerant is condensed to liquid and reinserted into the evaporator (17), which closes the loop.

Common absorbent/refrigerant combinations in absorption chilling machines include ammonia/water and lithium bromide/water mixtures.

[5] For a general overview, see for example G.A. Florides et al., Review of solar and low energy cooling technologies for buildings, Renew. Sustain. Energ. Rev. 6 557-572, 2002

[6] In the technical and patent literature, a third technology is sometimes mentioned: dessicant cooling. This technology is basically covered by sorption-based cooling und will not be addressed as a separate technology in this report.

[7] See also http://en.wikipedia.org/wiki/Absorption_refrigerator

[8] See K. Kimura, Solar absorption cooling, in: A.A.M. Sayigh and J.C. McVeigh (eds.), Solar air conditioning and refrigeration, Pergamon Press, p. 66-80, 1992

Absorption chilling devices may use solar thermal energy to change the refrigerant from liquid to vapour. The devices can be used for refrigeration as well as for air conditioning. However, absorption chilling does not generally achieve very low temperatures and is rather complicated.

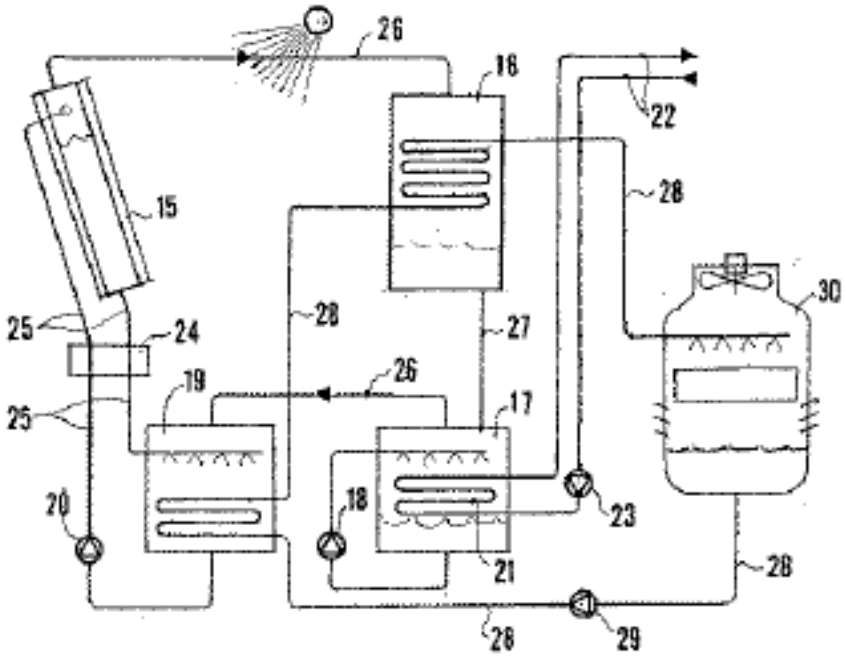

Figure 2: Absorption-type cooling device for household use, according to patent document JP2010032193A. A diluted absorber solution is transported from an absorber section (19) by an absorber pump (20) to a solar heat collector/regenerator (15) where the absorber solution is heated and refrigerant is partly vaporised. The vaporous refrigerant is directed to a condenser (16). After condensation, the refrigerant is transported to the evaporator (17) where evaporation of the refrigerant cools a medium circulating in pipeline (21) which is then used for the proper cooling purpose.

b) Adsorption cooling

Adsorption cooling is a thermally driven refrigeration process, which can be powered by solar energy. Adsorption cooling is based on the evaporation and condensation of a refrigerant combined with adsorption. Adsorption refrigeration is mainly used for air-conditioning[9].

Adsorption cooling machines are based on solid or liquid solvents, the so-called adsorbents, which can bind gases or liquids to their surface. Adsorbed particles can be removed from the surface by heating the adsorbent. Unlike the closed loop in absorption cooling machines, the process in adsorption cooling machines is discontinuous. A supplementary step to regenerate or exchange exhausted adsorbent is required.

Many adsorption cooling machines have been proposed. In the following, a solar-based adsorption cooling machine is presented by way of example (see Figure 3) which uses solar energy to chill food. A solar collector (8) containing an adsorbent (10) is connected to a sealed circuit including a cooling chamber (1), an evaporator (2) and a condenser (6). Water vapour is transported within the circuit.

During the day, sunlight heats the solar energy collector (8) and the adsorbent (10). The adsorbent (10) thereby releases adsorbed water, producing water vapour which is directed to the condenser (6). Water vapour is precipitated in the condenser (6) because pressure is much lower in this component than in the solar energy collector (8). The condensed water is subsequently directed towards the evaporator (2) where it is collected.

At night, as the solar energy collector (8) cools down, the adsorbent (10) becomes ready to adsorb water vapour again. A three-way valve (7) is turned over so that the absorbent (10) can adsorb water vapour evaporating in the evaporator (2). Since evaporation consumes thermal energy, the temperature in the cooling chamber (1) drops. That way, the adsorption process allows to cool the chilling chamber (1) at night. During the day, the adsorbent is regenerated by using solar radiation.

The selection of the absorbent depends on the field of application of the adsorbent chilling machine and on the load of water vapour that is needed to safeguard the cooling capacity of the machine. Common adsorbents range from solid materials such as silica gels and zeolites to liquids, e.g. triethylene glycol.

[9] *See also http://en.wikipedia.org/wiki/Solar_air_conditioning*

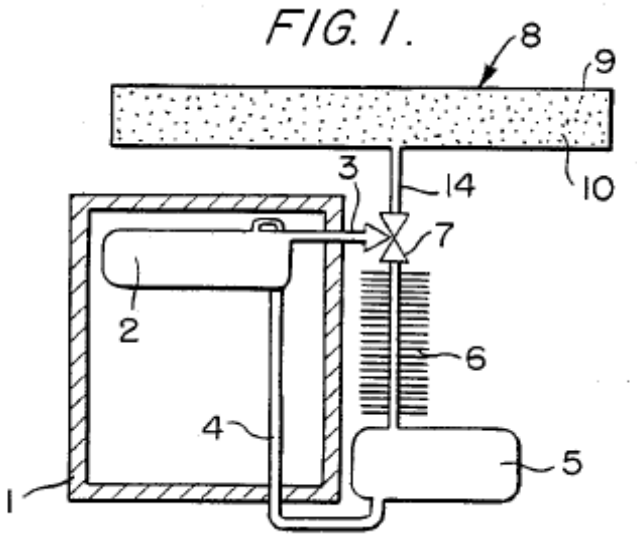

Figure 3: Refrigerator operated by solar energy, according to patent document US4531384A. The refrigerator comprises a solar energy collector (8), a three-way valve (7), a cooling chamber (1), a condenser (6), an external tank (5) and an evaporator (2) inside the cooling chamber (1). The energy collector (8) contains an adsorbent (10) with high adsorption and desorption capacity, such as zeolite.

1.3.3 Evaporative cooling

In evaporative cooling devices, refrigeration is generally achieved by evaporating a liquid. Evaporation consumes thermal energy which lowers the temperature of the substrate on which evaporation takes place, and thereby also of the neighbouring material. Most common are evaporative systems where water is evaporated into air. Evaporative cooling devices are mainly used for air-conditioning.

Evaporative cooling may be achieved by direct air-cooling, indirect air-cooling, a combination of both or combined with other refrigeration techniques.[10] In direct evaporative cooling devices, water evaporates directly from an evaporative pad or from a water spray component into air. The evaporation extracts thermal energy from the environment, corresponding to a decrease in temperature. In addition, the evaporated water may humidify the environment.

In indirect evaporative cooling devices, water evaporates into a so-called secondary air stream through the channels of a heat exchanger, which cools air flowing in a primary air stream. This two-stage process ensures that the evaporated water is never in direct contact with the space to be refrigerated.

Evaporative cooling devices as such do not require solar energy; however, they may use solar energy for heating the surface of a substrate containing water in order to increase the evaporation rate. The evaporation rate increases because the air into which the water vaporizes is heated which increases the capacity of the air to absorb water vapour. Figure 4 presents a

[10] For further information, see for example G.A. Florides et al., Review of solar and low energy cooling technologies for buildings, Renew. Sustain. Energ. Rev. 6 557-572, 2002

solar type air-condition system with a cooling panel (20) having a porous component (23). The porous component (23) is impregnated with water which may be heated in the sun and evaporates, thus refrigerating the cooling panel (20). Air passing through the cooling panel (20) is chilled and directed to the interior of a building.

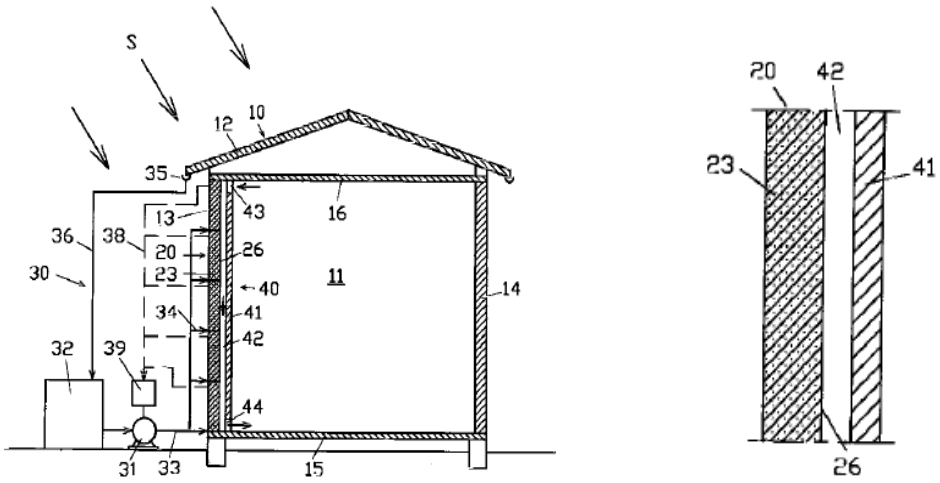

Figure 4: Solar-type air-conditioning system for a building, according to patent document JP2003083656A. Water is supplied to the porous component (23) of a cooling panel (20) that constitutes the outer wall or roof of a building. The porous component (23) is impregnated with water. Water on the surface of the component heats up and evaporates in the sun, which extracts thermal energy from the surroundings and thereby cools the panel. Air brought into contact with the cooling surface (26) of the cooled panel (20) is chilled and directed to the space (11) to be refrigerated (left: global image of a building comprising the solar type air-conditioning system; right: enlarged view of the cooling panel (20), comprising the porous component (23) and the cooling surface (26)).

1.3.4 Solar ejector cooling

Solar ejector cooling devices rely on so-called ejectors that use the Venturi effect and perform the task of a thermally-driven compressor in a heat pump refrigeration cycle.

A fluid is directed through a nozzle-type ejector, which narrows in a first section and widens in a second section (see Figure 5). Accordingly, the velocity of the fluid increases in the first section while the pressure decreases, creating a low-pressure zone in the suction chamber (52) where a second fluid can be drawn in. Both fluids mix and approach the exit (55) of the nozzle in the second section where the mixture is slowed down and pressure increases again.

In solar ejector cooling devices, the second fluid, mostly water vapour, is generally drawn in from an evaporator. As a consequence, additional water is vaporised in the evaporator and thermal energy is extracted from that component, chilling the component and its surroundings.

Solar ejector cooling devices range from small and simple-to-use machines to complex devices for industrial applications. Figure 6 shows, by way of example, a relatively simple refrigerator based on solar ejector cooling.

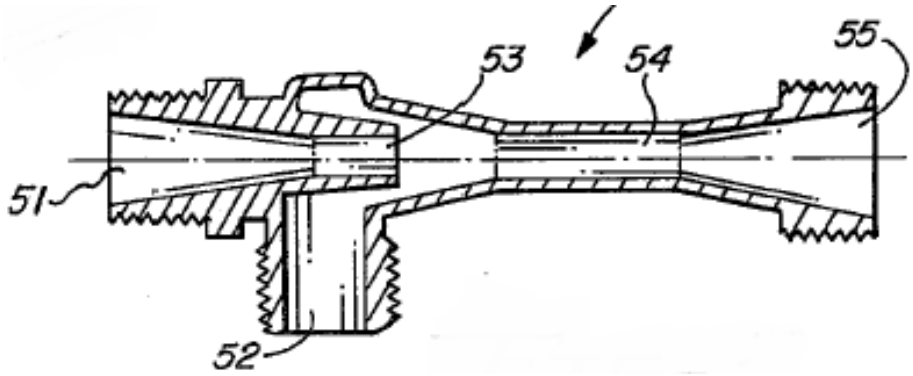

Figure 5: An ejector, according to patent document US4448039A. Liquid heat exchange medium is directed to the first inlet (51) of the ejector where it is compressed and accelerated, creating a low-pressure zone in the suction chamber (52) where a heated vaporous medium is drawn in. Both fluids mix and are directed through the ejector to the exit (55).

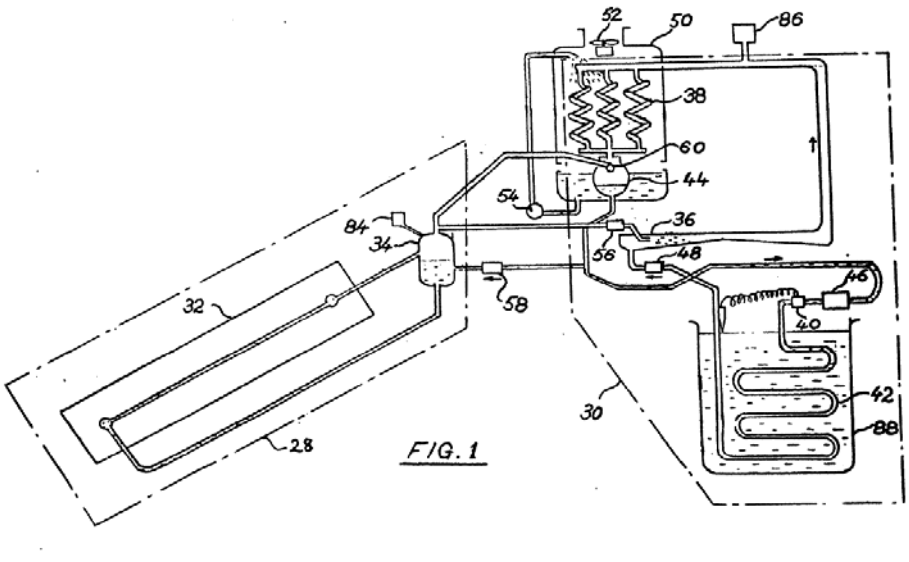

Figure 6: Solar ejector cooling device, according to patent document GB2158220A. The device operates in a closed loop comprising three main steps: pressure build-up, ejection/refrigeration and draining. At the beginning, the vaporising chamber (34) is almost filled with liquid refrigerant while the condenser chamber (44) is almost empty of liquid refrigerant. When the absorber (32) absorbs solar energy, the refrigerant in the pressurisation section (28) is heated and the refrigerant is partly vaporised. The vaporous refrigerant is subsequently condensed in the condenser (50). Condensed refrigerant may be directed from the condenser chamber (44) to the evaporator (42).

When the valves (46) and (56) are opened, vapour from the vaporising chamber (34) is directed to the ejector (36), drawing in vaporous refrigerant from the evaporator (42). Additional refrigerant evaporates in the evaporator (42), extracting thermal energy from that component. Correspondingly, water in the tank (88) surrounding the evaporator is cooled.

2 Methodology

The report aims to provide a comprehensive overview of technologies relating to solar cooling and to analyse trends in the solar cooling field. The search for and the analysis of patent documents relating to solar cooling were carried out and quality-controlled by search specialists in the fields of engineering, materials science and physics. The analysis was based on high quality patent data from the Derwent World Patent Index database,[11] which provided the reference database for the search and statistical analysis in this report.

Search

Patent documents were searched without any restrictions to countries or regions. No time limits were explicitly set, i.e. patents dating back as far as the databases used cover their publication were considered for the search and patent analysis.[12]

In a first step, different search concepts such as patent classification codes[13], keyword concepts in the description or abstract of the patent documents, as well as combinations thereof, were used to create a basic set of patent documents.

Second, the patent documents of the defined basic set were analysed individually by the search team with regard to their relevance to solar cooling. Patent documents were deselected if solar cooling was only mentioned as a potential field of application, or if solar energy was only mentioned as an alternative to other sources of energy without detailed information on how to realise that alternative.

Third, patent documents identified as relating to solar cooling were categorised in order to structure the technical information and to facilitate access to the information (please see section 0 for the results and Appendix C for detailed information about the search strategy and categorisation).

Statistical analysis

The statistical analysis characterises patenting and innovation activity in the solar cooling field as driven by individual technical inventions. For this reason, the statistical analysis was not based on individual patent documents but on patent families. Patent families comprise all patent applications filed in different countries for the same invention. In particular, it was decided to use the so-called DWPI family definition which is widely considered to have certain advantages over

[11] Derwent World Patents Index (DWPI) is one of the most comprehensive database of enhanced bibliographic patent information. The database includes enhanced patent data from over 44 worldwide patenting authorities, covering more than 43 million patents and 20 million inventions. Patent data is covered from 1963 to present, implying an implicit lower time limit for the considered patent documents in this report. An upper time limit is implied by the fact that patent applications are generally published 18 months after filing. From then on, the database provider can process the data and amend the database, which usually takes several weeks. Further information about the data coverage of DWPI is accessible at science.thomsonreuters.com/support/patents/coverage/dwpicovkinds.

[12] See previous footnote for the data coverage of the reference database.

[13] In the patent domain, technical features of inventions described in patent documents are categorised by patent classification codes, which are defined in so-called patent classification systems. Patent classification codes are assigned by experts in the technical field and help to identify patent documents relating to a specific technology.

other patent family definitions.[14] Details of the statistical analysis and the results are presented in section 0.

3 Categorisation

During the patent search and analysis, numerous patent documents were identified as relating to solar cooling. In order to facilitate access to and handling of the technical concepts disclosed in these patent documents, the documents were categorised according to the following features:

a. whether a complete solution for solar cooling is provided, or whether components or details of a solar cooling system are concerned;
b. simplicity of use;
c. the potential field of application:
   i. for use in buildings/structures,
   ii. refrigeration of sensitive goods,
   iii. desalination,
   iv. other applications,
   v. no specific field of application indicated.

In the following, patent documents are presented which are considered to exemplarily show these features. A separate electronic Excel sheet to this report is available which lists the identified patent documents and indicates which of the categories the individual patent documents were assigned to.

3.1 Components of systems or complete systems

3.1.1 Component

Publication number	Publication date	Title	Patent applicant
DE102008018092	16.10.2008	Facade element for buildings has collector chamber that can be heated by solar radiation arranged behind outer facade wall in air path of diagonal channel	Schabert Jan

The facade element described in the patent document has an outer side with at least one vertical channel forming a heat exchange channel, and at least one diagonal channel in the facade element from an opening on the outer side and an opening into the vertical channel. The facade element has a collector chamber that can be heated by solar radiation. The facade element can be part of an air-conditioning system.

[14] The DWPI family definition is used for the DWPI database and combines patent documents that were intellectually assigned to the same invention. The DWPI family is created in two steps: First, patent documents are automatically pre-selected according to the priority date. Second, the selection is revised by an expert. If the patent documents are judged to belong to different inventions, the selection is divided into two or more new DWPI families.

3.1.2 Complete system

Publication number	Pub. date	Title	Patent applicant
WO2010141392	09.12.2010	Cooling infrastructure leveraging a combination of free and solar cooling	Hamann Hendrik F; Iyengar Madhusudan K; Van Kessel Theodore G

The invention relates to energy-efficient data centre cooling techniques that utilise free cooling and/or solar cooling. In one embodiment of the invention, a cooling system is provided, which includes a cooling tower, one or more modular refrigeration chiller units, and a water loop that can be selectively directed through the cooling tower, through one or more of the modular refrigeration chiller units or through a combination thereof. In a second embodiment of the invention, the cooling system comprises a solar cooling unit, one or more modular refrigeration chiller units and a water loop that can be selectively directed through the solar cooling unit, through one or more of the modular refrigeration chiller units or through a combination thereof.

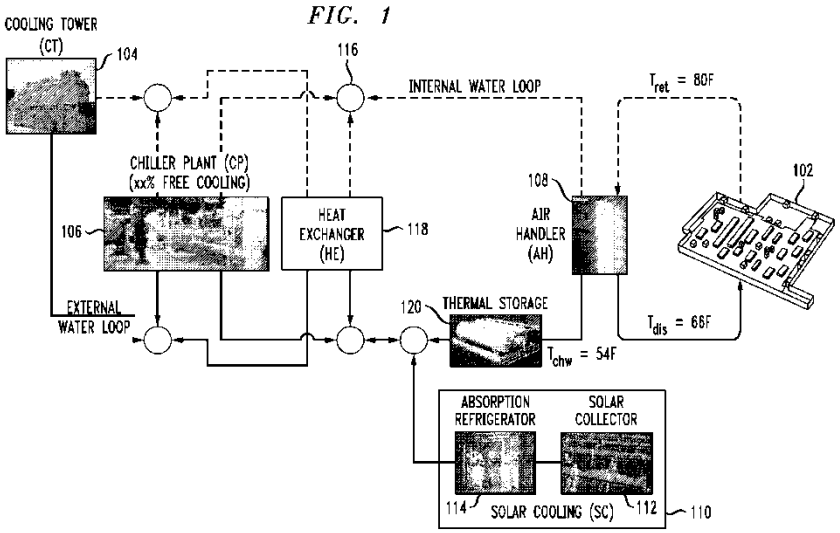

Figure 8: Diagram illustrating an exemplary data centre cooling infrastructure according to an embodiment of the invention

3.2 Simple or complex technology

3.2.1 Simple technology

a) First example

Publication number	Pub. date	Title	Patent applicant
US2010071869	25.02.2010	Cooling system	Code Valley Corp Pty Ltd

In the patent document, a cooling apparatus is described which includes a solar tower (100) with a solar collector (120) that radially outwardly extends from a base (161) of a chimney (110). The solar collector (120) heats air using solar radiation to induce air flow (170) radially inwards from the solar collector perimeter and up the chimney (110). A cooling air pipe partially extends along the chimney length to draw cool air, partially using the air flow (170). The cool air is used to cool equipment, e.g. a computer system.

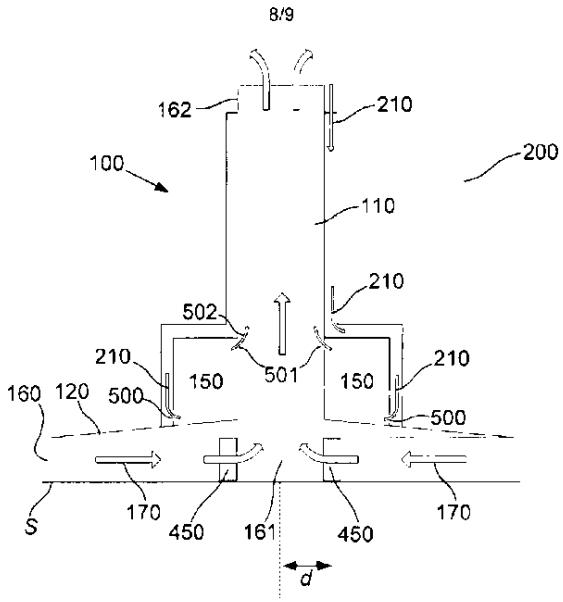

Figure 9: Schematic side view of a solar tower for providing cooling, according to an embodiment of the invention

b) Second example

Publication number	Pub. date	Title	Patent applicant
GB2213244	09.08.1989	Refrigerating appliances	Brissonneau & Lotz Marine Soci

The invention relates to a refrigerator which comprises a solar panel (6) covering an enclosure (5) whose rear surface (7) forms a condenser with extended surface (10). A dividing grille or perforated plate (13) is fitted across the enclosure which contains an absorber (14).

The evaporator (2) is connected to the lower enclosure space (9) by a circuit containing a reservoir with a ball valve (20). The evaporator is in an enclosure with water walls (3). The valve is operated as a function of the relative differential pressures in the evaporator and condenser.

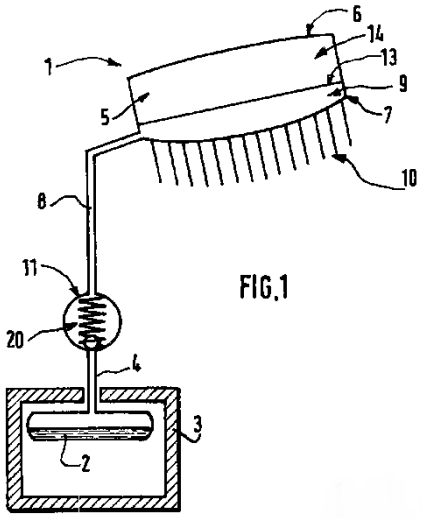

Figure 10: Refrigerating appliance according to the invention

3.2.2 Complex technology

Publication number	Pub. date	Title	Patent applicant
US4223535	23.09.1980	Absorption solar powered air conditioning system with storage capacity	Kumm Emerson I

The invention relates to a water vapour absorption system for heating and cooling the air of an enclosure. The system may utilise solar energy for both purposes. The system employs a strong salt solution, e.g. sodium hydroxide, and a weak salt solution, e.g. calcium chloride or lithium chloride, which are stored separately from each other, and two vapour exchangers containing several vertical perforated columns with towers packing material positioned in insulated proximity to each other. The strong and weak solutions are introduced into alternate columns to wet the tower packing in concurrent gravity operated flow to obtain vapour transfer between the two solutions at a partial vacuum. The system includes heat exchangers for selectively obtaining heat exchange between the solutions and the enclosure air and the solutions and atmospheric air.

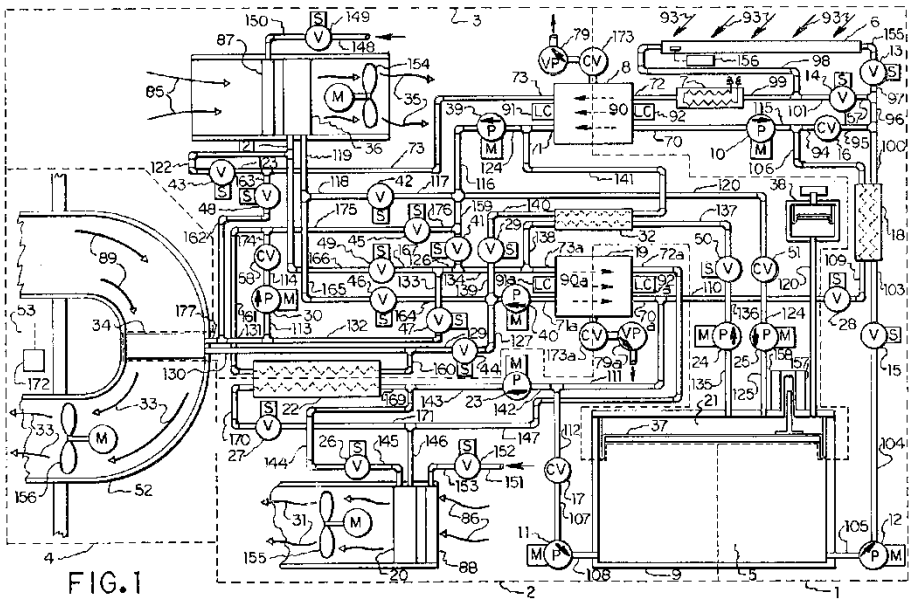

Figure 11: Schematic view of some of the equipment and a flow diagram of a system according to the invention

3.3 Field of application

3.3.1 For use in buildings / structures

a) First example

Publication number	Pub. date	Title	Patent applicant
WO8102923	15.10.1981	Refrigeration method and apparatus using heat	Samek S

A vapour compression refrigeration cycle is described in the patent document which incorporates a heat exchanger for heating the refrigerant vapour in indirect heat exchange with a flow of hot gas. The heat exchanger includes a stove with an insulated firebox in communication with adjustable flue sections. The vapour is in indirect heat exchanging relationship with the hot flue gases exiting from the firebox. The exchanger preheats the vapour from the evaporator to a temperature between that of the evaporator and the condenser.

The work required for the compression of the refrigerant is derived from the same source as the energy used to heat the vapour. A turbine wheel is driven by nozzles in the flue section, which direct the gases towards the wheel. The wheel is mechanically coupled to the compressor. In an alternative arrangement the vapour can be heated by a solar powered thermal collector.

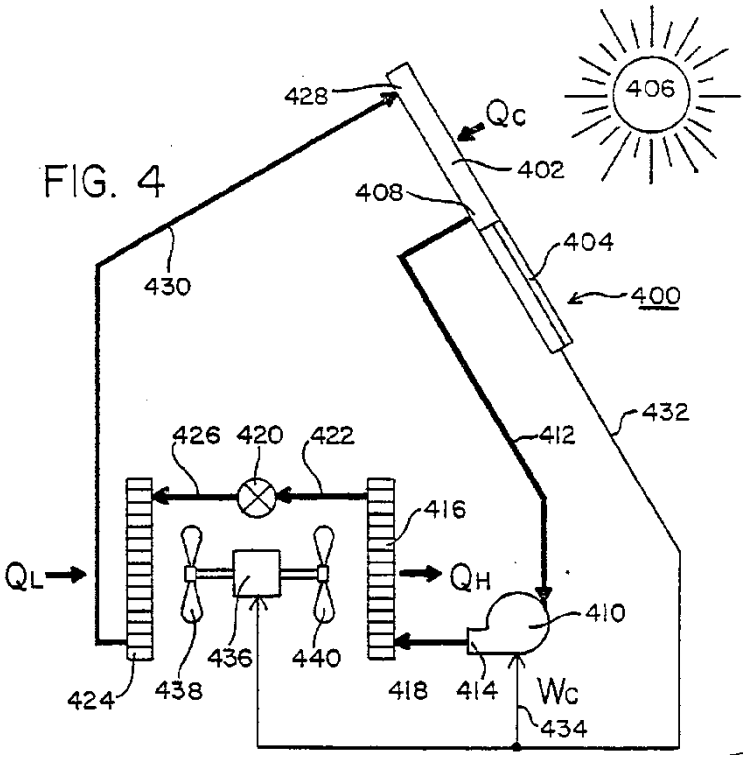

Figure 12: Vapour compression refrigeration cycle utilising a hybrid solar thermal/solar electric array to provide thermal and electrical energy according to the invention

b) Second example

Publication number	Pub. date	Title	Patent applicant
US6250091	26.06.2001	Efficient structure cooling system	Jerome G A

The invention relates to a control unit (16) which detects the status of a solar-irradiated area of a roof. The control unit (16) controls the operation of specific control valves (18) for supply of fluid on the roof through nozzles, so as to effect maximum evaporation when the status exceeds a predetermined value. The valves (18) are connected to a water pipe (15) that supplies water to several spray nozzles (19). Several moisture retention sensors (23) are connected to the control unit (18).

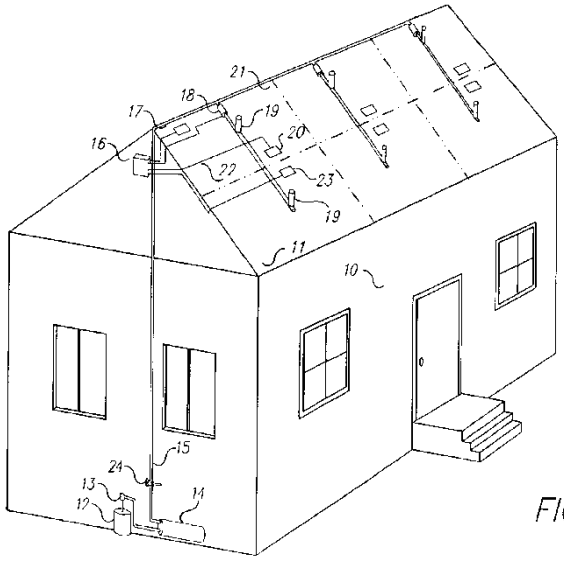

Figure 13: System and roof components of an evaporative cooling system according to the invention

3.3.2 Refrigeration of sensitive goods

a) First example

Publication number	Pub. date	Title	Patent applicant
DE3620847	19.02.1987	Cooling container	Poehlmann Erich

In the patent document, a cold storage container (1) is disclosed which has a cooling chamber (2) with a thermally insulated roof (3), floor and sides. An absorption refrigerator is arranged outside the cooling chamber with an ejector (9), a condenser (10) and an evaporator (8) mounted inside the cooling chamber. Also arranged outside is a heating tube solar collector (5) with multiple parallel heating tubes (6), with the ejector arranged directly at the low temperature side of the heating tube solar collector.

Arranged directly on one side of the roof (3) of the cooling chamber, and inclined to the horizontal, are the heating tubes of the solar collector (5), and on the other side the ejector and condenser of the absorption refrigerator (4).

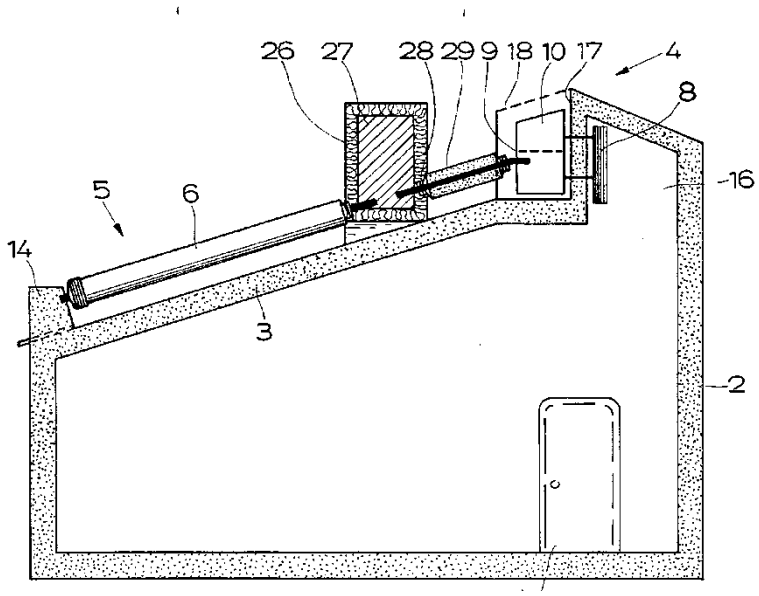

Figure 14: Cold storage container according to an embodiment of the invention

b) Second example

Publication number	Pub. date	Title	Patent applicant
US4744224	17.025.1988	Intermittent solar ammonia absorption cycle refrigerator	Erickson D C

The invention relates to refrigeration produced by an intermittent absorption cycle. The cycle is driven by solar radiation and utilises ammonia as refrigerant, and a liquid, preferably water, as absorbent. Solar radiation is collected by a compound parabolic collector (2) which reflects the light onto a cylindrical target vessel (1) containing the refrigerant and absorbent. Ammonia is boiled out of the target vessel (1), the ammonia vapour travels to a condenser (5) where it is cooled to liquid, and the liquid is stored in a receiver vessel (6).

During the night, liquid is released from the receiver vessel (6) into an evaporator coil (8) located in a cold box (9) where it vaporises, thus removing heat from the contents of the cold box (9). The vaporised ammonia is then absorbed back into the absorbent in the target vessel (1). The target vessel (1) contains a U-tube (13) of continuous uphill slope, which acts as a thermosyphon in conjunction with the condenser (5).

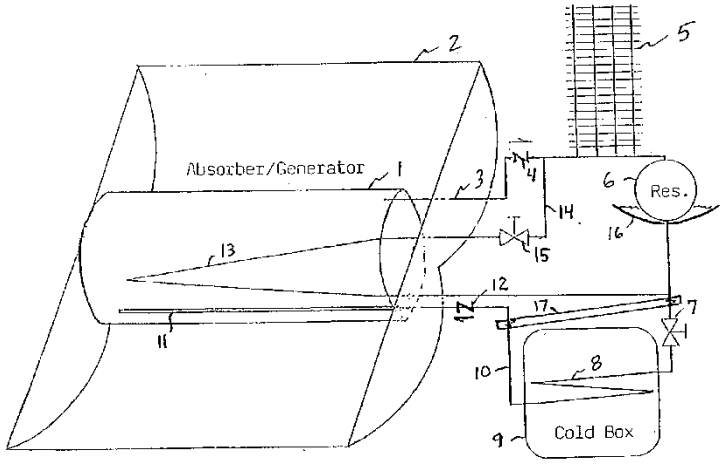

Figure 15: Schematic representation of a solar ammonia absorption cycle refrigerator according to the invention

3.3.3 Desalination

Publication number	Pub. date	Title	Patent applicant
DE10161211	26.06.2003	Seawater desalination process comprises using an adsorption exchanger in which water is adsorbed in a first phase and is then extracted in a second phase at higher pressure in a direct evaporator	Inst Luft & Kaeltetechnik

The invention relates to a seawater treatment process using thermal adsorption. The process uses an adsorption exchanger in which water is adsorbed by an adsorber under vacuum in a first phase, and is then extracted in a second phase at higher pressure in a direct evaporator, followed by condensation in a condenser to give drinking water. In a preferred embodiment, solar energy is utilised to run the seawater treatment process.

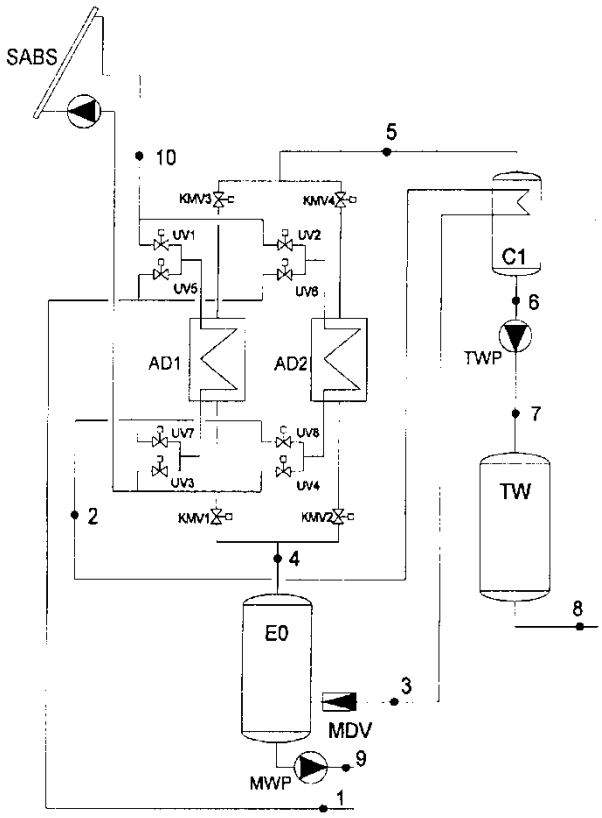

Figure 16: Seawater desalination process according to an embodiment of the invention

3.3.4 Other applications

The category “others” includes specific applications not covered by the previously presented categories.

a) First example[15]

Publication number	Pub. date	Title	Patent applicant
US2010071869	25.03.2010	Cooling system	Code Valley Corp Pty Ltd

In the patent document, a cooling apparatus is described which includes a solar tower (100) with a solar collector (120) that radially outwardly extends from a base (161) of a chimney (110). The solar collector (120) heats air using solar radiation to induce air flow (170) radially inwards from the solar collector perimeter and up the chimney (110). A cooling air pipe partially extends along the chimney length to draw cool air, partially using the air flow (170). The cool air is used to cool equipment, e.g. a computer system.

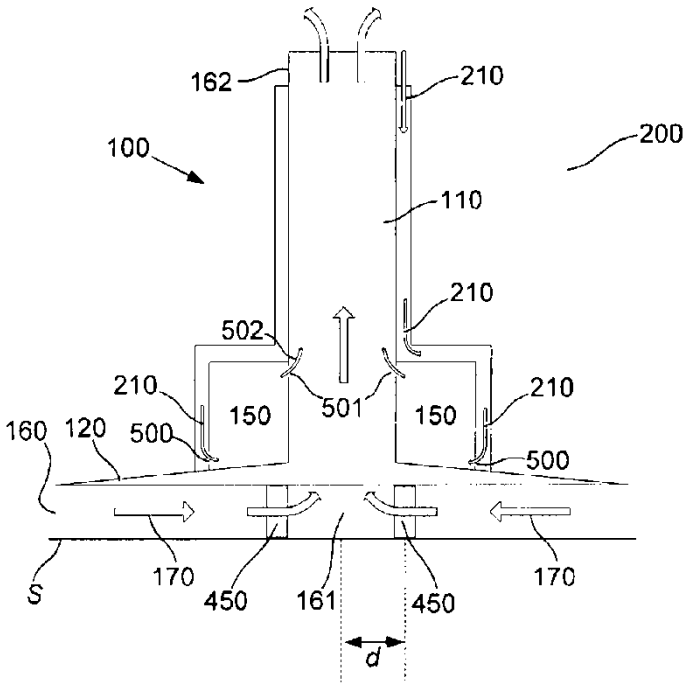

Figure 17: Schematic side view of a solar tower for providing cooling according to an embodiment of the invention

[15] *This invention was also assigned to the category ‘Simple technologies’ (see section 0).*

b) Second example

Publication number	Pub. date	Title	Patent applicant
EP1936300	25.06.2008	Water generation from air utilizing solar energy and adsorption refrigeration unit	Al-Maaitah A A

The invention relates to a drinking water generator device from air utilising solar thermal energy. The system is based on an adsorption refrigeration unit with ether as a refrigerant and activated carbon as adsorbent. The required heat is generated from an evacuated tube solar system, and the heat sink is the atmosphere. The adsorption unit is an air-cooled refrigeration unit that can operate at relatively low hot water temperature (60-70 °C) and relatively high atmospheric temperature (30-40 °C). The water condensed from air is driven through a simple water purification unit to assure its quality as drinking water. The small amount of electricity needed to operate the hot water and cold water pumps along with the filtration unit and the controller of the adsorption unit is generated from a small photo-voltaic unit for stand-alone systems.

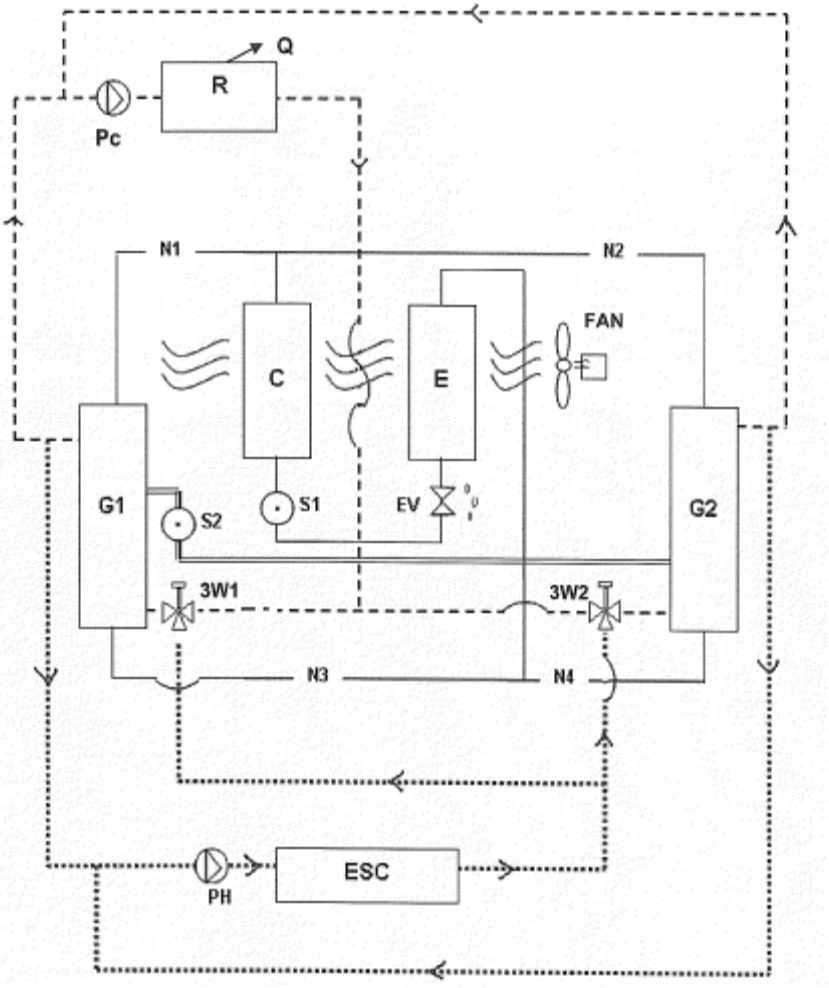

Figure 18: Refrigeration cycle according to the invention

c) Third example

Publication number	Pub. date	Title	Patent applicant
CN2896092Y	02.05.2007	Cooling and water ejecting structure for sunshade umbrella, has water ejecting system provided with nozzle that is connected to assembling unit, where nozzle is connected to water inlet pipe	Jisheng Ind Shanghai Co Ltd

In the patent document, a water ejecting structure is described which has a nozzle connected to an assembling unit and linked to a water inlet pipe. The water ejecting system comprises a water controlling valve that controls the water outlet quantity of the nozzle and includes a timer. The water ejecting system may be used for a sunshade umbrella.

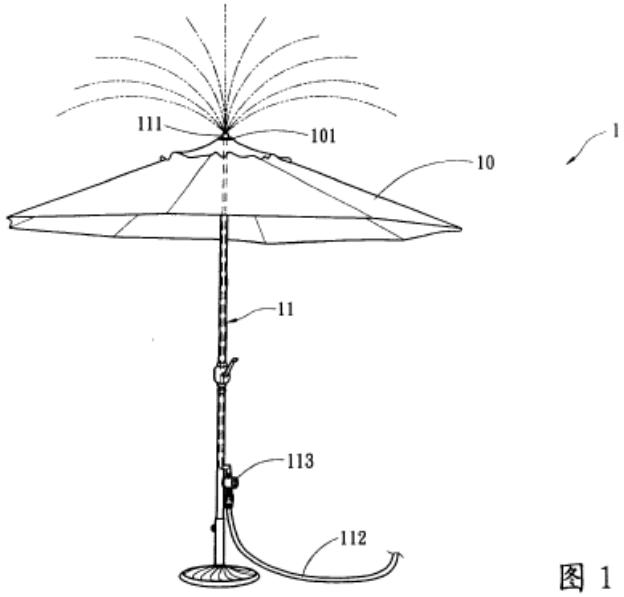

Figure 19: Sunshade umbrella with cooling and water ejecting structure according to the invention

d) Fourth example

Publication number	Pub. date	Title	Patent applicant
DE19740066	18.03.1999	Absorption refrigeration machine for automobile, boat or caravan	Schlenker W

An absorption refrigeration machine described in the patent document uses excess heat provided by an internal combustion engine, incident solar radiation or another heat source for cooling, by using the heat for driving the driver of the absorption refrigeration machine.

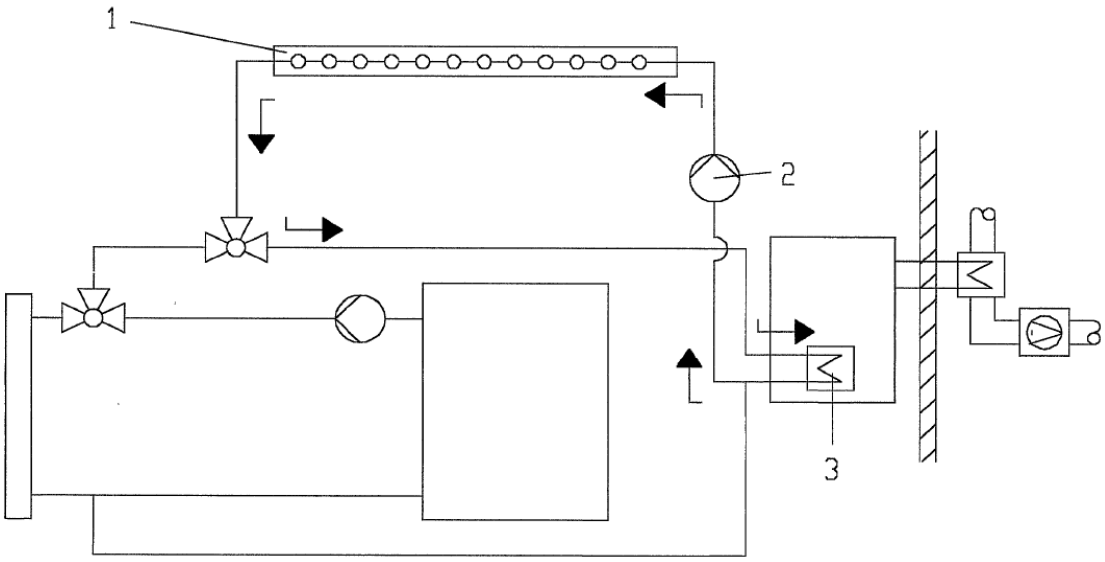

Figure 20: Absorption refrigeration machine, taking heat energy from a collector/absorber, according to an embodiment of the invention

3.3.4 Non-specified

Patent documents were assigned to the category ‘non-specified’ if they do not disclose information about a specific field of applications or if the applicants consider the invention to be applicable to various fields of application.

Publication number	Pub. date	Title	Patent applicant
WO03071197	28.08.2003	Energy efficient adsorption system	Indian Inst Technology

A refrigeration-heating system is disclosed in the patent document that can be heated by a heat source such as solar energy, direct fuel fire and waste heat. The system comprises adsorption modules, which are easy to fabricate and overcome the problems of low thermal conductivity of adsorbents without increasing the thermal mass of the system. The system further comprises switchable heat pipes with a mechanism to actuate or isolate the hot end from the cold end in order to transfer heat intermittently.

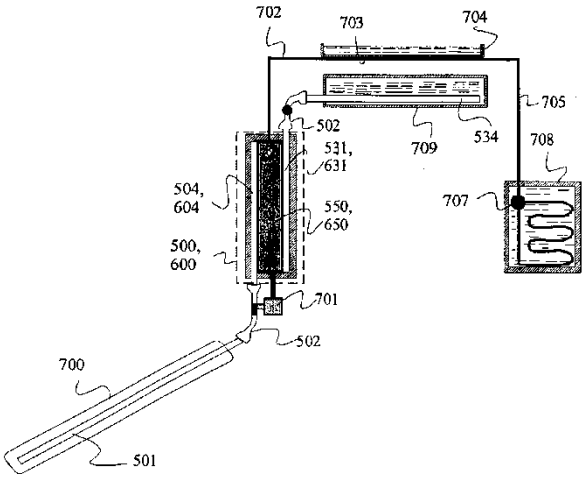

Figure 21: Refrigeration-heating system according to the invention

4 Statistical analysis[16]

4.1 Family size per priority year

A total of about 550 DWPI patent families relating to solar cooling were identified according to the chosen search strategy (see section 0 and Appendix C). The average family size is 1.7. The evolution of the average patent family size per priority year[17] is shown in Figure 22.[18]

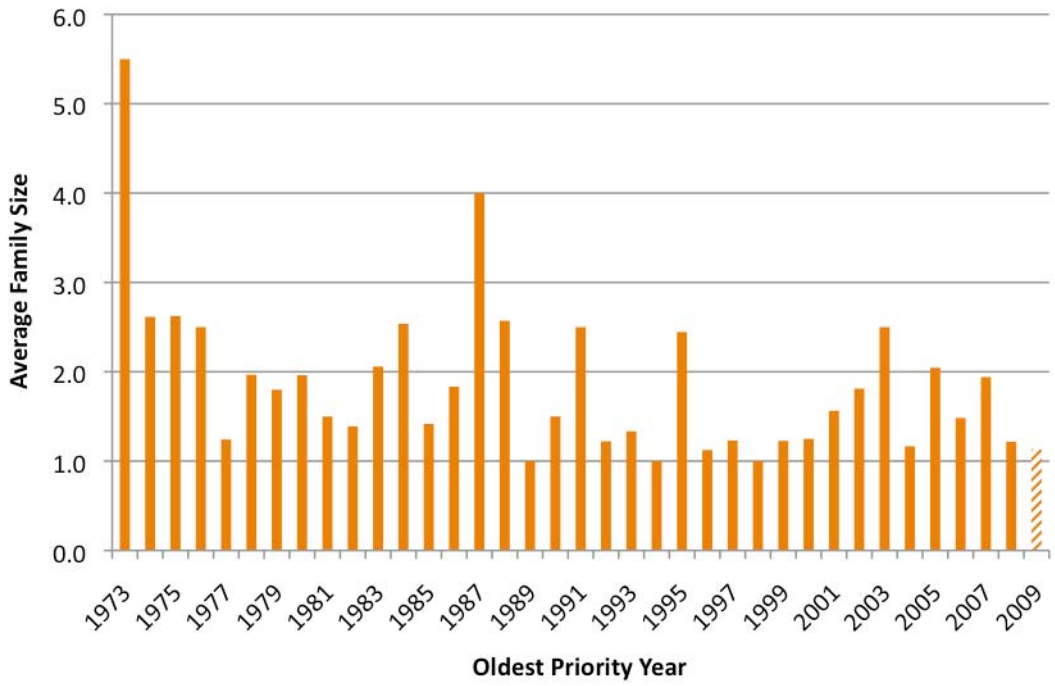

Figure 22: The average patent family size per priority year

The average family size in the solar cooling field is considerably lower than in other fields of technology. Several factors may contribute to this situation. A large portion of the identified

[16] *In this section, countries and supranational institutions in the patent field are abbreviated according to WIPO Standard ST.3 (see www.wipo.int/standards/en/pdf/03-03-01.pdf).*

[17] *The priority year is the year in which the priority document relating to the invention was filed.*

According to the priority concept of the Paris Convention for the Protection of Industrial Property (see www.wipo.int/treaties/en/ip/paris/trtdocs_wo020.html), the filing date of an initial patent application may be used by subsequent patent applications if the invention of the initial and subsequent patent applications match and a time limit is observed. In this particular case, the initial patent application is called the priority document of the subsequent patent applications.

[18] *Due to the fact that not all patent applications of 2009 have been published at the time this report was generated, the values for 2009 are marked as preliminary in the figures of this section.*

patent documents were filed by individuals who are expected to lack the financial capacity to commercialise their invention on the international level.

Moreover, many of the identified patent documents seem to disclose subject matter which is relatively known and may therefore lack the potential for a globally successful product. For this reason, applicants may refrain from investing substantial financial resources into patent protection in multiple countries.

In addition, some of the identified patent documents seem to be rather visionary, and without obvious competence or interest of the applicants in commercialising the invention.

4.2 Number of patent filings per priority year

The number of patent filings per priority year is often taken as an indicator for the dynamics and commercial relevance of a technical field. However, it's the technical inventions that provide the basis of the patent filings and actually trigger the dynamics and commercial relevance of a technical field. In addition, the number of patent filings per priority year is influenced by peculiarities of the patent prosecution procedure and tradition in the various countries and supranational patent systems.

For this reason, DWPI patent family data of the patent documents relating to solar cooling was analysed and plotted in place of the number of patent filings in order to map the evolution of the number of inventions in the field and to mitigate potential artefacts due to the above-mentioned peculiarities (see Figure 23).

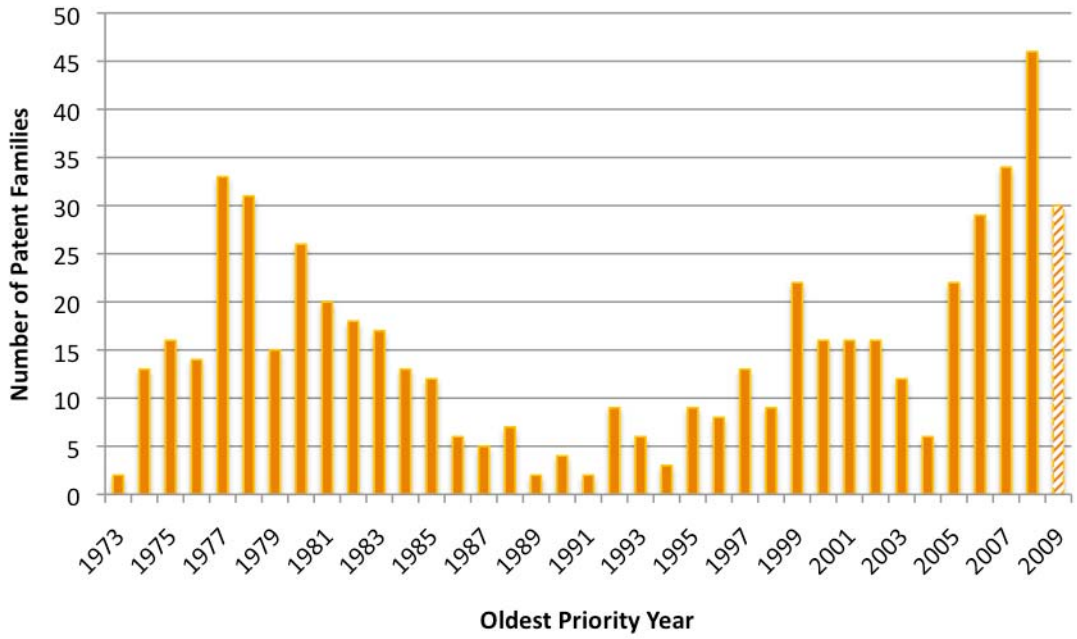

Figure 23: The number of patent families per priority year

The number of patent families has fluctuated considerably over the last 40 years. While at the beginning of the 1990s patent activity was low, a lot of inventions were filed for patent protection in the 1970s, in the mid-nineties and in the last five years.

Patenting activity seems to reflect to what extent ecological and economic issues attract (public) attention. The observed high patent activity in the 1970s may be attributed to the 1973 oil crisis,

while the significant increase in the mid-nineties may be attributable to the intensified discussion about ecological issues and climate change, which was stimulated by related international conferences such as the United Nations Conference on Environment and Development in 1992. The steep increase in the last five years may be attributable to Chinese patent applicants rushing to the Chinese patent office.

4.3 Total of patent families per relevant IPC code

The International Patent Classification[19] (IPC) code characterises the technical content of a patent document and may be used to identify the fields of technology where solar cooling plays an important role.

DWPI patent family data of the patent documents relating to solar cooling was analysed in terms of the assigned IPC codes. Table 1 presents a ranking list of relevant IPC codes in the solar cooling field. The two predominant IPC domains are F24 ('Heating; ranges; ventilating') and F25 ('Refrigeration or cooling; combined heating and refrigeration systems; heat pump systems; manufacture and storage of ice; liquefaction or solidification of gases').

Table 1: Ranking list of the IPC codes assigned to patent documents that relate to solar cooling[20]

Number of patent families	IPC main group	Description
259	F25B27	Machines, plant, or systems, using particular sources of energy (F25B 30/06 takes precedence)
211	F24J2	Use of solar heat, e.g. solar heat collectors (distillation or evaporation of water using solar energy C02F 1/14; roof covering aspects of energy collecting devices E04D 13/18; devices for producing mechanical power from solar energy F03G 6/00; semi-conductor devices specially adapted for converting solar energy into electrical energy H01L 25/00, H01L 31/00; semiconductor devices including arrays of solar cells using heat energy H01L 31/058; generators in which light radiation is directly converted into electrical energy H02N 6/00)
181	F24F5	Air-conditioning systems or apparatus not covered by group F24F 1/00 or F24F 3/00
136	F25B15	Sorption machines, plant, or systems, operating continuously, e.g. absorption type
66	F25B1	Sorption machines, plant, or systems, operating intermittently, e.g. absorption or adsorption type
63	F24D1	Central heating systems using heat accumulated in storage masses (self-contained storage heating units F24D 15/02; storage masses, see the relevant subclasses)
47	F25B29	Combined heating and refrigeration systems, e.g. operating alternately or simultaneously
39	F25B30	Heat pumps
34	F24F3	Air-conditioning systems in which conditioned primary air is supplied from one or more central stations to distributing units in the rooms or spaces where it may receive secondary treatment; Apparatus specially designed for such systems (room units F24F 1/00; construction of heat-exchangers

[19] *See www.wipo.int/classifications/ipc/en/index.html*

[20] *Since the patent search according to the search strategy (see Appendix C) comprised a search step based on key words in full text databases, some of the retrieved patent documents have IPC codes other than those drawn on for the searches in bibliographic patent databases. The sum of all patent families exceeds the number indicated in section 0 because patent documents are often assigned more than one IPC code in order to sufficiently characterise the technical subject matter of the patent document, which gives rise to multiple counting.*

		F28)
25	F25B1	Compression machines, plant or systems with non-reversible cycle (F25B 3/00, F25B 5/00, F25B 6/00, F25B 7/00, F25B 9/00 take precedence)
23	F28D20	Heat storage plants or apparatus in general (specially adapted for particular applications, see the relevant places, e.g. F24D 15/02) ; Regenerative heat-exchange apparatus not covered by groups F28D 17/00 or F28D 19/00
20	F25B25	Machines, plant, or systems, using a combination of modes of operation covered by two or more of the groups F25B 1/00 to F25B 23/00 (combinations of two or more modes of operation covered by a single main group, see the relevant group)
18	F25B13	Compression machines, plant, or systems, with reversible cycle (defrosting cycles F25B 47/02)
17	E04B1	Constructions in general; Structures which are not restricted either to walls, e.g. partitions, or floors or ceilings or roofs (scaffolds, shutterings E04G; structures specially adapted for buildings for special purposes, general layout of buildings, e.g. modular co-ordination, E04H; the particular parts of buildings, see the relevant groups for those parts)
16	B01D53	Separation of gases or vapours; Recovering vapours of volatile solvents from gases; Chemical or biological purification of waste gases, e.g. engine exhaust gases, smoke, fumes, flue gases or aerosols (recovery of volatile solvents by condensation B01D 5/00; sublimation B01D 7/00; cold traps, cold baffles B01D 8/00; separation of difficult-to-condense gases or air by liquefaction F25J 3/00)
16	C02F1	Treatment of water, waste water, or sewage (C02F 3/00 to C02F 9/00 take precedence)
15	F03G6	Devices for producing mechanical power from solar energy (solar boilers F24)
12	E04D13	Special arrangements or devices in connection with roof coverings; Roof drainage (ventilation tiles E04D 1/30; ventilation slabs E04D 3/40; internal channels E04F 17/00; roofing elements therefor, see the relevant groups)
12	F24D3	Hot-water central heating systems (F24D 10/00, F24D 11/00 take precedence)
10	F24D19	Details (of water or air heaters F24H 9/00; of heat-exchange or heat-transfer apparatus, of general application F28F)

4.4 Share of patent families with a PCT[21] member

With the help of an International Patent Application or PCT application, patent protection can be applied for in more than 140 countries. Expenses related to a PCT application are generally higher than for a patent application in only one country. A PCT application may accordingly indicate that the applicant presumes that the invention has good economic prospects and is worth commercialising at international level.

Figure 24 shows how the share of DWPI patent families with a PCT application has evolved in the solar cooling field. Table 3 presents the data set providing the basis of Figure 24.

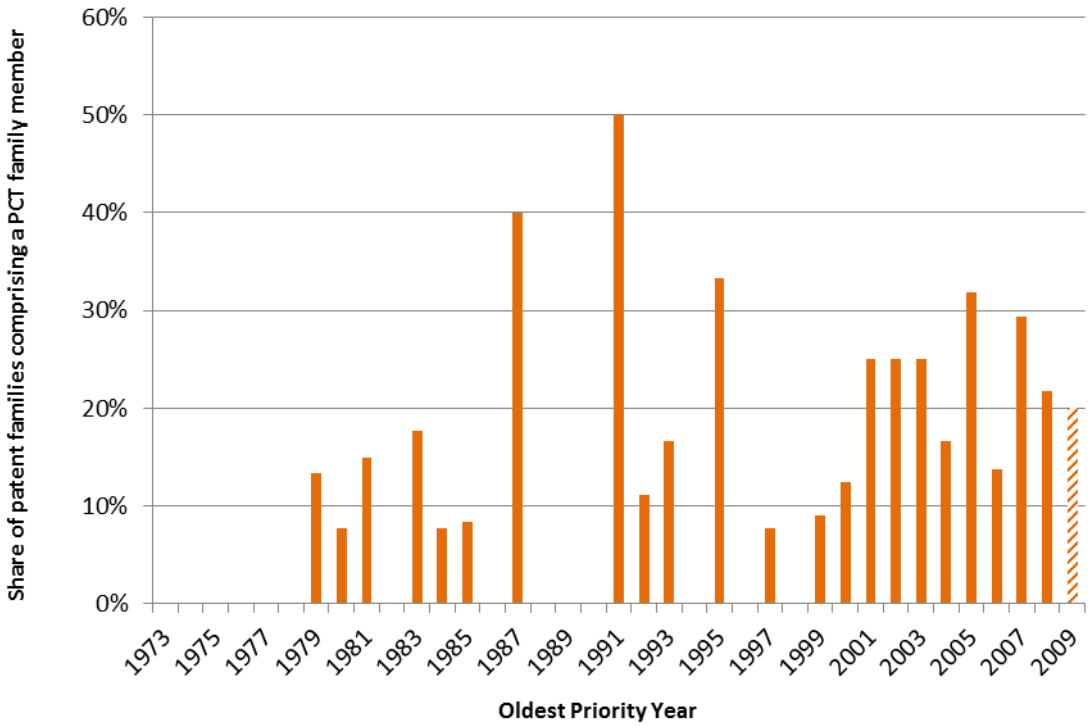

Figure 24: The share of patent families comprising a PCT application

While the share fluctuated significantly in earlier times, which may be partly attributed to statistical noise due to small absolute numbers of patent families in the late 1980s and 1990s,[22] data suggests a trend towards international patent protection in the last ten years.

[21] *Patent Cooperation Treaty*

[22] *E.g., there are only two DWPI patent families in the priority year 1991, of which one has a PCT family member, amounting to a share of 50 per cent.*

4.5 Distribution over priority countries

The country where the first patent application relating to an invention was filed may be considered indicative of the place where the invention happened. The share of priority documents relating to a specific country may accordingly be considered indicative of a country's innovation activity in a technical field and may help to identify which countries are most active in developing new solutions for the solar cooling field.

DWPI patent family data was analysed. For each year in the period 1973 to 2009, DWPI patent families in the solar cooling field were screened and the priority documents of the DWPI patent family members determined.[23] Finally, the patent authorities of these priority documents were ranked. Figure 25 presents the top-ranked countries.

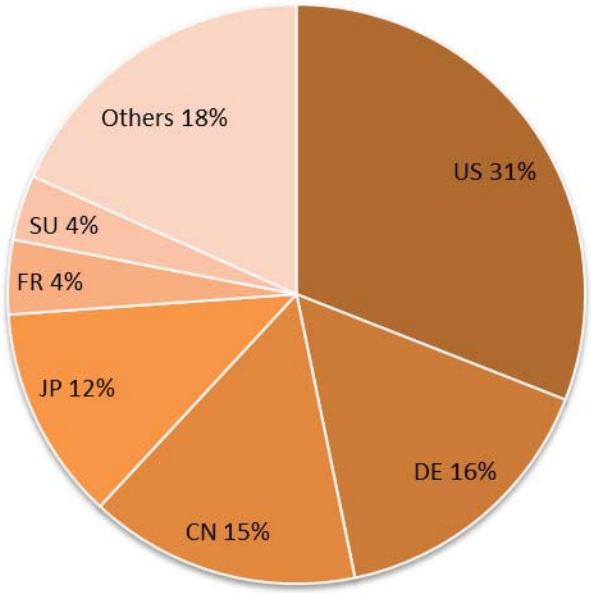

Figure 25: The share of priority countries in the period 1973 to 2009 (see Table 2 for details of the ranking)

It does not come as a surprise that industrialized countries take top positions in the ranking.[24] Remarkable is the fact that China takes the third position, reflecting the country's steep increase in patent activity in the solar cooling field in the last years. In the last five years, applicants from China even took the leading position (see Table 2).

[23] This approach tends to undervalue a patent document which serves as a priority document for multiple subsequent patent applications because it is only counted once as a priority document within a DWPI patent family

[24] As no time-limit was set for the patent landscape analysis, countries were included in the ranking which no longer exist. For example, the Soviet Union (SU) takes a leading position in the ranking, reflecting their significant patent activity in the eighties.

Table 2: Distribution over priority filing countries, over time

Oldest priority date		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Number of patent families		**2**	**13**	**16**	**14**	**33**	**31**	**15**	**26**	**20**	**18**	**17**	**13**	**12**	**6**	**5**	**7**	**2**	**4**	**2**	**9**	**6**	**3**	**9**	**8**	**13**	**9**	**22**	**16**	**16**	**16**	**12**	**6**	**22**	**29**	**34**	**46**	**30**	**562**
Patent authority	**Number of priority documents**																																						
US		1	8	13	14	27	21	11	11	11	4	7	3	4	1	1		2		1	4	1		2		6	1	9	4		3	2		2	2	2	5	3	186
CN																	1		2		1	1	1					1	2	1	3	4	2	9	17	16	16	14	91
DE			1		1	1	2	1	1	1	1		1	5	1	1	2		2	1	2	2	1	5	4	6	1	6	5	9	3	1	2	5	3	7	7	4	95
JP			2			2	5		5	5	3						1			1			1	1	2	1	6	2	5	5	3	3	1	1	1	2	9	5	72
FR			1	1		3	6		2		2	1	5			1						1	1										1							25
SU									2		5	8	1	3	2		1																							22
GB			2					3	2				4			1	1			1		1													1		2			18
AU				1	1	1				2														1							1			3	1		2	1	14
CA			1			1	1		2	2										1																			8
IT			1			1	2				1																									2			7
WO								1	1	1		1												1							1						1		7
EP									2	1		1																							2				6
BE															2									1													2		5
AT																	1																		1			2	4
BR			1									1	1																					1					4
IL			1				1																													2			4
KR																	1											1			1			1					4
SE		1	1								1																									1			4

Oldest priority date	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
CH			1				1			1																												3
DK		1													1																					1			3
ES												1															2											3
HU																								2														2
IN																														2								2
NL																											1				1							2
RU																				1						1												2
SI																																		1			1	2
GR																															1							1
MX																																				1		1
RO								1																														1
SG																																				1		1
TW																																			1			1
ZA																													1									1

4.6 Country distribution of published patent documents

The countries where a patent document was filed and published may be indicative of the places where the applicant intends to commercialize the invention or where he suspects potential competitors. Accordingly, an analysis of the distribution of published patent documents can help to estimate which countries represent important markets and where key players in the solar cooling field aggregate.

DWPI patent family data was analysed.[25] For each year in the period 1973 to 2009, DWPI patent families in the solar cooling field were screened and the published patent documents of the DWPI patent families determined. Finally, the patent authorities of these patent documents were ranked. Figure 26 presents the top-ranked countries.

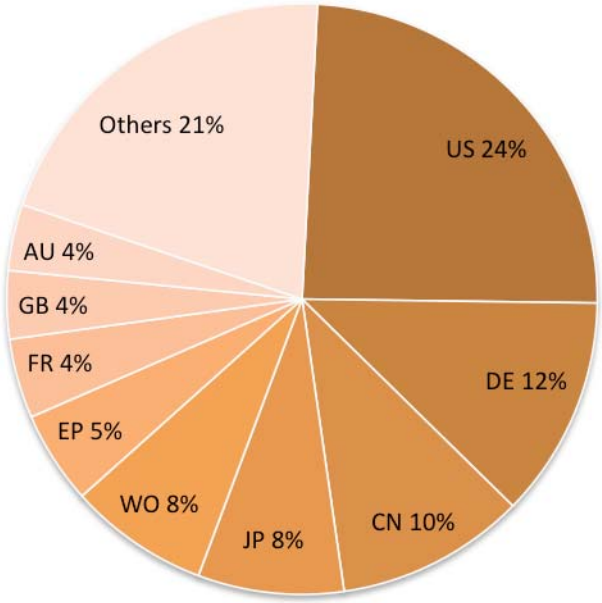

Figure 26: The share of published patent documents of a patent authority (see table 3 for details of the ranking)

Similar to the distribution over priority countries (see section 0), industrialized countries take top positions in the ranking (see figure 26).[26] Again, China takes an important position owing to the country's high patent activity in the solar cooling field in the last years (see table 3).

[25] *See section 0 for an explanation why DWPI patent family data was analysed in place of the initial quantify to be measured.*

[26] *Patent applications filed with the European Patent Office (EP code) and with the World Intellectual Property Organization (WO code) form a special case. They do not represent individual countries but appear in the ranking because first patent applications may be filed with these two supranational institutions.*

Table 3: Distribution over publication countries, over time

Oldest priority date	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Number of patent families	**2**	**13**	**16**	**14**	**33**	**31**	**15**	**26**	**20**	**18**	**17**	**13**	**12**	**6**	**5**	**7**	**2**	**4**	**2**	**9**	**6**	**3**	**9**	**8**	**13**	**9**	**22**	**16**	**16**	**16**	**12**	**6**	**22**	**29**	**34**	**46**	**30**	**562**
Patent authority	**Number of published patent documents**																																					
US	2	11	14	14	30	25	11	15	15	7	6	5	5	2	2	3	2		1	4	1		4		6	1	10	4	1	5	4		5	4	7	6	3	235
DE	1	4	4	3	1	4	3	2	2	2	1	4	5	1	2	3		2	1	2	2	1	5	4	6	1	6	5	9	3	1	2	4	3	7	7	4	117
CN														1		1		2		1	1	1					1	2	1	3	5	2	12	18	19	16	14	100
JP		1	2			1	2	8	3	1	1				2	2				1		1	1	2	1	6	3	5	5	3	4	1	2	1	4	9	5	77
WO							2	2	3		3	1	1		2				1	1	1		3		1		2	2	4	4	3	1	7	4	10	10	6	74
EP								6	2	1	5	2	2	2	3	2		1					2	1	1					3	2		5	4	5			49
FR	1	4	5	4	3	8	1	2		2	1	5			1					1	1											1				2		42
GB	1	2	4	4	1	2	4	4	1			4			2	1			1		1										1			1		2		36
AU					1				2	1	2	2	1	1	2						1		2		1		1	2	4	4	1		2	2	2	1		35
CA	1	4	6	2	2	3	2	3	2	1	1								1				1										1	2				32
SU								2		5	8	1	3	2		1																						22
BR		1		3		3		1		1	1	2			1	1															1		1				16
IT		1	3	1	1	4	1			1	1	1																							2		16
IN																														2	1		3	2	3			11
ZA		1		1		2		2		1	1																		1		1		1					11
ES											1	2			1	1		1					1				2			1								10
CH	1	1	1	1	1	2	1			1																												9

Oldest priority date	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
DK	1	1						1			1	3			1																							8
BE			1			2								2									1													1			7
KR																1											1			1	1		1		2			7
NL	1	1	1			2																					1				1							7
AT	1				1											1																		1			2	6
IL		1	1	1		1						1				1																						6
SE	1	1		1				1		1																									1			6
MX																															1				2	1		4
NO											1				1																			1				3
TW																															2				1			3
HU																								2														2
PT						2																																2
RU																				1						1												2
SG																																	1			1		2
CZ																							1															1
DD								1																														1
FI											1																											1
NZ																															1							1
RO								1																														1
SK																							1															1
VN																																			1			1
Number of publications	11	34	42	35	41	61	27	51	30	25	35	33	17	11	20	18	2	6	5	11	8	3	22	9	16	9	27	20	25	29	30	7	45	43	66	56	34	964
Average family size	5.5	2.6	2.6	2.5	1.2	2.0	1.8	2.0	1.5	1.4	2.1	2.5	1.4	1.8	4.0	2.6	1.0	1.5	2.5	1.2	1.3	1.0	2.4	1.1	1.2	1.0	1.2	1.3	1.6	1.8	2.5	1.2	2.0	1.5	1.9	1.2	1.1	1.7
Share of patent families with a PCT family member (in per cent)	0.0	0.0	0.0	0.0	0.0	0.0	13.3	7.7	15.0	0.0	17.6	7.7	8.3	0.0	40.0	0.0	0.0	0.0	50.0	11.1	16.7	0.0	33.3	0.0	7.7	0.0	9.1	12.5	25.0	25.0	25.0	16.7	31.8	13.8	29.4	21.7	20.0	13.2

Oldest priority date	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Number of patent families comprising at least one publication of a patent grant	2	11	15	14	31	26	12	21	16	9	7	7	5	2	2	3	2		1	4	2		4		3	1	2	2	1	2	5	1	4	2	7	1		
Share of patent families comprising at least one publication of a patent grant (in per cent)	100.0	84.6	93.8	100.0	93.9	83.9	80.0	80.8	80.0	50.0	41.2	53.8	41.7	33.3	40.0	42.9	100.0	0.0	50.0	44.4	33.3	0.0	44.4	0.0	23.1	11.1	9.1	12.5	6.3	12.5	41.7	16.7	18.2	6.9	20.6	2.2	0.0	0.0

4.7 Geographical distribution

In addition to the ranking of countries for which the patent documents in the solar cooling field were published (see sections 0), the geographical distribution of the countries was analysed to shed further light on important markets and the aggregation of important players in the technical field.

DWPI patent family data was analysed.[27] The data from the country distribution of published patent documents (see Table 3) was clustered to give information about the regional distribution (see figure 27).

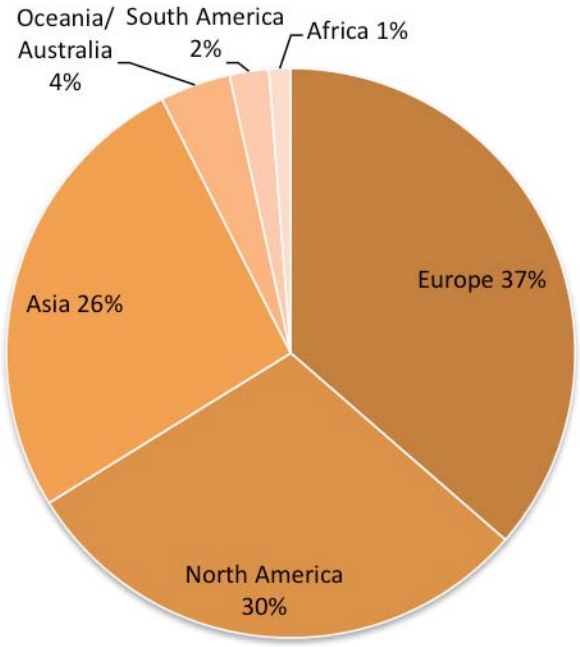

Figure 27: The share of geographic regions in patent publications relating to solar cooling

The vast majority of patent documents relates to Europe, North America and Asia, reflecting the economic importance or dynamics of these geographical regions and the country of residence of potential competitors. Only a small number of patent documents were published for Africa and South America. However, in interpreting such data it should also be taken into account that publication policies of patent authorities, e.g. publication of full specification or only notifications in Gazettes, and the respective coverage of such publications in patent databases has changed and is still changing.

[27] *See section 0 for an explanation on why DWPI patent family data was analysed in place of the initial quantity to be measured.*

4.8 Top applicants/inventors

DWPI patent family data was further analysed to identify the main players in the solar cooling field. The most active applicants from industry and the academic/public sectors are shown in Tables 4 and 5.

Results suggest that the solar cooling field is dominated by inventors and applicants with a rather small number of inventions. Due to the low number of inventions per applicant, a detailed analysis such as the patenting activity of the applicants over time or per technology area does not seem to be appropriate from a statistical point of view.

Table 4: List of the most active applicants and inventors from industry

Company name	Number of patent families	Supplementary comment
DAIKIN KOGYO KK	9	Japanese patent families only
BORG WARNER CORP	5	
HITACHI LTD	5	
NIPPONDENSO CO LTD	5	Japanese parent families only
SANYO ELECTRIC CO LTD	5	4 Japanese patent families
TOKYO GAS CO LTD	5	Japanese patent families only
JEUMONT SCHNEIDER SA	4	
OSAKA GAS CO LTD	4	2 Japanese patent families
OWENS-ILLINOIS INC	4	

Table 5: List of the most active applicants and inventors from the academic/public sectors

Name of institution	Number of patent families	Supplementary comment
UNIV SHANGHAI	13	Chinese patent families only
DEUT ZENT LUFT & RAUMFAHRT EV	4	
FRAUNHOFER GES FOERDERUNG ANGEWANDTEN	4	
INST LUFT & KAELTETECHNIK GEMEINNUETZIGE	4	
NASA US NAT AERO & SPACE ADMIN	4	
US DEPT ENERGY	4	
ZAE BAYERN BAY ZENT ANGEWANDTE ENERGIEFO	4	
ANVAR AGENCE NAT VALORISATION	3	

4.9 Summary

The statistical analysis showed that the average DWPI patent family size in the solar cooling field is 1.7, i.e. for numerous inventions, only one patent application was filed. The average family size is considerably lower than in other fields of technology. A large portion of the patent documents were filed by individuals.

The most active countries developing and applying for patent protection of solar cooling technologies are the United States, Germany, China, Japan and France. In the United States, the most active period regarding patent applications for solar cooling technologies was in the 1970s. In Germany and Japan, solar cooling technologies have been steadily filed for patent protection over the last 40 years while in France, almost all patent applications were filed up to the early 1980s. Patent activity of Chinese applicants has steeply increased in the last five years, clearly exceeding the patent activity of other countries in this period.

The geographical distribution of published patent documents shows that most of the patent documents were published for Europe, with North America being second and Asia third. Only a small number of patent documents were published for Africa and South America.

Appendix

A. Glossary

European patent
The European patent is a patent which is granted by the European Patent Office after the completion of a centralised application and examination procedure. It consists of a number of national patents, which are valid in the respective countries and have been selected by the applicant during the patent examination procedure.

Invention
A new solution to a technical problem. If the invention also represents a certain creative act and is industrially applicable, legal protection can be applied for through a patent or a utility model. Inventions can relate to objects as well as manufacturing processes and operating procedures.

International patent application (PCT application)
With the help of an international patent application or PCT application, patent protection can be applied for in more than 140 countries. After submission of the international patent application, a search to establish the prior art for the claimed invention is one of the procedures carried out in a first international phase. In a subsequent national phase, the national or regional patent offices of selected by the applicant will independently examine the patent application and grant a patent upon fulfilment of the requirements.

More detailed information about the PCT application procedure is available at: www.wipo.int/pct/en/ .

National Patent Office
The National Patent Office is the organisation of a country that processes national patent applications and grants patents for the respective country.

Patent
An intellectual property right that gives the applicant the right to prevent others from commercially exploiting the invention for a specific length of time. In return, the applicant must disclose how the invention works. Patents usually cover products or processes containing new functional or technological aspects. Patents therefore deal with how something functions, what it does, how it does something or how and from what it is produced.

Patent application
The documentation necessary to apply for the granting of a patent. A patent application can be filed at a national patent office, at a regional patent office such as the European Patent Office, or at the World Intellectual Property Organization.

Patent classification
Patent documents are classified according to technical classifications systems in order to make the information contained therein more easily retrievable. Almost all patent publications are classified at least according the International Patent Classification (IPC).

Patent document
General term for published documents relating to an invention that was filed for legal protection. A patent document may be the published patent application, documents relating to changes during the prosecution procedure or the granted patent. Within the context of this report, documents relating to utility models are covered, too.

Patent family
A patent family combines all patent documents that relate to the same invention. There are a number of different approaches to assess whether two patent documents belong to the same invention. For this report, the DWPI family approach, the EPO/DOCDB simple family approach and the EPO/INPADOC extended family approach were used:[28]

- A DWPI family combines patent documents that were intellectually assigned to the same invention. The DWPI family is created in two steps: First, patent documents are automatically pre-selected according to the priority date. Second, the selection is revised by an expert. If the patent documents are judged to belong to different inventions, the selection is re-divided into two or more new DWPI families.
- Patent documents are combined into an EPO/DOCDB simple family if they have exactly the same priority documents. The assignment is done automatically.
- An EPO/INPADOC extended family comprises patent documents which have at least one priority document in common. The assignment is done automatically.

Priority, priority right
In order to obtain patent protection in several countries for a specific invention, one can or may have to stagger the filing of the respective individual applications time wise with the responsible authorities. The date of the first filing is called the priority date and defines the start of the twelve-month priority period. By claiming the priority right of the first filing during this period, further applications in other countries can be made without the fear that someone will pre-empt you with an identical application because the prior art relevant for examining inventiveness are only the disclosures, e.g. publications, available to the public before the priority date and not before the actual application date. The priority right can be claimed in all countries being member to the respective Paris Convention for Protection of Industrial Property (see www.wipo.int/treaties/en/ip/paris/) or to the TRIPS agreement.

Priority document
According to the priority concept, the filing date of an earlier patent application may be recognized for subsequent patent applications if the subsequent patent applications relate to the same invention and if they are filed within the twelve-month priority period. The earlier or initial patent application is called the priority document of the subsequent patent applications.

Priority year
The year in which the priority document relating to the invention was filed.

Utility model
In many countries, utility models can be used as an alternative and faster way to protect industrially applicable inventions. The protection requirements for a utility model are often

[28] *For further information, please see C. Martinez, Insight into different types of patent families, STI Working paper 2010/2, Organisation for Economic Co-operation and Development, 2010 .*

similar to those for a patent. Protection is usually already in force after registration of the utility model, which is usually effected after successful examination of formal requirements only, i.e. without substantive examination. Third parties can attempt to revoke protection by filing a request for substantive examination of the utility model. Utility models have a shorter term than patents.

B. Patent databases used

The patent searches for this report were conducted by using the European Patent Office search system EPOQUE which comprises both bibliographic and full text databases[29]:

Bibliographic databases

EPODOC
EPODOC is the systematically classified collection of documents of the European Patent Office. The database contains patent documents from industrial countries. In addition to patent documents from the national patent offices, applications with regional and international organisations as well are included (PCT (Patent Cooperation Treaty; administered by the WIPO), EPO (European Patent Organisation), ARIPO (African Regional Intellectual Property Organization) and OAPI (Organisation Africaine de la Propriété Intellectuelle) patent documents). Detailed information about patent data coverage can be found at www.epo.org/gpdc. Citations from EPODOC contain the documents cited (patent and non-patent literature such as scientific articles), bibliographical data, title and abstract.

Derwent World Patent Index (DWPI)
The Derwent World Patent Index contains information about patent documents from the 44 most important patent issuing authorities. The most current list of countries and the time periods they cover can be found at scientific.thomson.com/support/patents/coverage/. Currently, the database contains information on more than 20 million inventions relating to approximately 42.5 million patent documents. Unlike other databases, experts interpret the information in the patent documents themselves, and prepare their own detailed and insightful titles and abstracts for these patent documents, which allows for premium patent information. For this reason, DWPI is strongly used throughout the world for advanced patent analysis.

Full text databases of the European Patent Office
Databases containing full text can be searched for key words in every part of the patent or patent application. Unlike databases containing only bibliographic information and abstracts, full text databases make it possible to search the description and claims section of a patent publication as well.

[29] *For more information see www.ip-search.ch/en/patent-searches/search-methods.html*

C. Methodology: search, categorisation, statistical analysis

In order to prepare the search, patent classification codes were identified, which relate to devices and processes capable of using solar energy to achieve cooling (see Table 6). It became apparent that no single patent classification code completely covers the solar cooling field.

For the purpose of efficiency, a balance was struck between a search procedure which uses only a small number of highly relevant patent classification codes (high precision and limited recall), and a broad search procedure which aims to be as comprehensive as possible by including numerous patent classification codes but which is, conversely, less efficient since it returns many irrelevant documents (high recall but limited precision) that need to be sorted out by intellectual screening.

Search

The search was carried out in databases provided by the European Patent Office (see Appendix B for general information about the databases used).

First, a basic set of patent documents was created which were suspected to relate to solar cooling. The basic set of patent documents was built from the following individual search steps (see Table 7):

a. full text search in English, German and French for the search concept ‘solar cooling’ (search step 1);
b. search for patent documents having the US classification codes 165/48.2 (for US patent documents only) or the F-Term 3L0993/BB25 (for Japanese patent documents only) (search step 2);
c. search in English, German and French for patent documents which have ECLA classification codes F24F5 and F25B27, and which disclose the search concepts ‘solar cooling’ or ‘solar adsorption/absorption’ in the abstract or title (search step 3);
d. search for patent documents of which the DWPI abstract or DWPI title discloses the search concept ‘solar cooling’ (search step 4).

The created basic set of patent documents corresponds to approximately 1230 DWPI patent families, which were subsequently screened by the search team for relevancy. The original abstract, the DWPI abstract, the description, the claims and the figures were analysed in order to determine to what extent the underlying invention relates to solar cooling.

In this context, patent documents were deselected if solar cooling was only mentioned as a potential field of application or if solar energy was only mentioned as an alternative to other sources of energy without detailed information on how to realise that alternative. In addition, patent documents were disregarded which exclusively use electric energy generated from solar energy for running electrical cooling elements such as Peltier elements. Likewise, patent documents were disregarded which are based on electric energy from solar power stations distributed over long-distance systems. Finally, patent documents were also not considered if an external power supply, such as electrical power from power outlets or generators run with fuel, is included to drive a cooling device while solar energy is only marginally used.

Around 550 DWPI patent families were identified as addressing solar cooling.

Categorisation
In order to facilitate access to the technical information in the patent documents, the identified patent documents were categorised with respect to the following features:[30]

a. whether a complete solution for solar cooling is provided (such as a complete air conditioning system) or whether components or details of a solar cooling system are concerned (such as heat exchangers or the operation of a solar cooling system); if a component is concerned, it is explicitly indicated[31]
b. simplicity of use, i.e. whether certain technical conditions need to be met and whether trained staff are required to run the system ('complex technology'), or whether the system can be used by non-professionals or in an environment without advanced technical infrastructure ('simple technology');[32] [33]
c. the potential field of application, as disclosed in the patent documents; the following commonly addressed fields of applications were used to categorise the patent documents:[34]
    - for use in buildings/structures,
    - refrigeration of sensitive goods,
    - desalination,
    - other applications,
    - non-specified.[35]

Statistical analysis
Bibliographic information about the identified patent documents was subsequently analysed with respect to the geographic distribution of the family members, the evolution of patent filings and IPC classification codes, as well as with regard to main patent applicants and inventors from industry and the academic/public sectors.

[30] See separate electronic datasheet which is provided with the report indicating which categories the patent documents were assigned to.

[31] To assess the feature 'complete solution/component', the patent claims of the individual patent documents were analysed.

[32] For the assessment of the feature 'simplicity of use', the patent claims of the individual patent documents were analysed.

[33] Most patent documents were assigned to neither the category 'simple' nor 'complex', reflecting the fact that the disclosed technologies were considered neither particularly complex nor very simple.

[34] To assess the potential field of application, the full text of the individual patent documents was analysed.

[35] Patent documents were assigned to the category 'non-specified' if they do not disclose information about a specific field of applications or if the applicants consider the invention applicable to various fields of application.

Table 6: Patent classification codes used to identify relevant patent documents for this report

International Patent Classification (IPC), FI classification of the Japanese Patent Office

Classification symbol	Description
F	Section F – Mechanical engineering; lighting; heating; weapons; blasting
F24	Heating; ranges; ventilating
F24F (2006.01)	Air-conditioning; air-humidification; ventilation; use of air currents for screening
F24F5/00 (2006.01)	Air-conditioning systems or apparatus not covered by group F24F 1/00 or F24F 3/00

Classification symbol	Description
F	Section F – Mechanical engineering; lighting; heating; weapons; blasting
F25	Refrigeration or cooling; combined heating and refrigeration systems; heat pump systems; manufacture or storage of ice; liquefaction or solidification of gases
F25B (2006.01)	Refrigeration machines, plants or systems; combined heating and refirgeration systems; heat pump systems
F25B27/00 (2006.01)	Machines, plant, or systems, using particular sources of energy

The complete classification schema is accessible at www.wipo.int/classifications/fulltext/new_ipc/ipcen.html , and www5.ipdl.inpit.go.jp/pmgs1/pmgs1/pmgs_E.

ECLA classification of the European Patent Office

Classification symbol	Description
F24F5/00F (883)	Air-conditioning systems or apparatus not covered by group F24F1/00 or F24F3/00 (e.g. using solar heat; combined with household units such as an oven or water heater) • using natural energy, e.g. solar energy, energy from the ground
F25B27/00B (185)	Machines, plant, or systems, using particular sources of energy • using solar energy

The complete classification schema is accessible at v3.espacenet.com/eclasrch.

F-Terms of the Japanese Patent Office

Classification symbol	Description
3L093/BB25	Structure • Heat source of generators • • solar heat

The complete classification schema is accessible at www5.ipdl.inpit.go.jp/pmgs1/pmgs1/pmgs_E.

US classification of the United States Patent and Trademark Office

Classification symbol	Description
165/48.2	Structural installation • Heating and cooling • • Solar

The complete classification schema is accessible at www.uspto.gov/go/classification/.

Table 7: Search history for the basic set of patent documents

Search step	Database	Queries[36][37]	Number of patent documents (approx.)	Comments
1	Full text databases	..fi cl txte; (SOLAR OR SUN) W (COOL+ OR CHILL+ OR REFRIGER+ OR FRESH OR RE_FRESH+) ;	260	search in English, German and French full text databases
		..mem m1 /pn rk 1; ..fi cl txtg;		publication numbers of result set are stored
		(SONN+ OR SOLAR+) w ([,AUS,AB,TIEF]KU?HL+ OR ENTWA?RM+ OR ERKALT+ OR KA?LTE+ OR EINFRIER+);	280	
		..mem m2 /pn rk 1; ..fi cl txtf; (SOLAIR+ OR SOLAR+ OR SOLEIL) w (RAFRAICH+ OR REFRIG+ OR FRAICH+ OR RECUI+ OR REFROID+ OR TIEDI+);	10	
		..mem m3 /pn rk 1; ..fi epodoc; *m1/pn OR *m2/pn OR *m3/pn;		publication numbers are transfered from full text databases to bibliographic database

[36] The following wildcards were used: '+' represents a string of any length including any character; '?' represents any character or no character.

[37] The following proximity operators were used: 'nW': in the correct order and separated by a maximum of n terms; 'nD': in any order and separated by a maximum of n terms.

2	EPODOC	165/48.2/UC OR 3L093/BB25/FT;	470	
3	EPODOC	F24F5/00F+/EC/ECC/ECI and (((SOLAR OR SUN) or (SONN+ OR SOLAR+)/DE or (SOLAIR+ OR SOLAR+ OR SOLEIL)/FR) 3d ((COOL+ OR CHILL+ OR REFRIGER+ OR FRESH OR RE_FRESH+) or ([,AUS,AB,TIEF]KU?HL+ OR ENTWA?RM+ OR ERKALT+ OR KA?LTE+ OR EINFRIER+)/DE or (RAFRAICH+ OR REFRIG+ OR FRAICH+ OR RECUI+ OR REFROID+ OR TIEDI+)/FR));	100	estimating number of patent documents
		F25B27/00B+/EC/ECC/ECI and (((COOL+ OR CHILL+ OR REFRIGER+ OR FRESH OR RE_FRESH+) or ([,AUS,AB,TIEF]KU?HL+ OR ENTWA?RM+ OR ERKALT+ OR KA?LTE+ OR EINFRIER+)/DE or (RAFRAICH+ OR REFRIG+ OR FRAICH+ OR RECUI+ OR REFROID+ OR TIEDI+)/FR) 3d ((SOLAR OR SUN) or (SONN+ OR SOLAR+)/DE or (SOLAIR+ OR SOLAR+ OR SOLEIL)/FR));	200	broader search possible owing to relatively small number of patent documents for the last two search steps
		(F25B27/LOW/FI/IC/ICCI/ICAI/ICAN/ICCN or F25B27+/EC/ECC/ECI or F24F5/LOW/FI/IC/ICCI/ICAI/ICAN/ICCN or F24F5+/EC/ECC/ECI);		
		(F25B27/LOW/FI/IC/ICCI/ICAI/ICAN/ICCN or F25B27+/EC/ECC/ECI or F24F5/LOW/FI/IC/ICCI/ICAI/ICAN/ICCN or F24F5+/EC/ECC/ECI);		
		(((SOLAR OR SUN) or (SONN+ OR SOLAR+)/DE or (SOLAIR+ OR SOLAR+ OR SOLEIL)/FR)) 3d ((COOL+ OR CHILL+ OR REFRIGER+ OR FRESH OR RE_FRESH+) or ([,AUS,AB,TIEF]KU?HL+ OR ENTWA?RM+ OR ERKALT+ OR KA?LTE+ OR EINFRIER+)/DE or (RAFRAICH+ OR REFRIG+ OR FRAICH+ OR RECUI+ OR REFROID+ OR TIEDI+)/FR);	1890	set union of previous two search steps intersection of set union with patent classification domains F24F5 and F25B27
		/FR/DE/BI AND (OR absor[b,p]+, adsor[b,p]+), ((SOLAR		

		OR SUN) or (SONN+ OR SOLAR+)/DE or (SOLAIR+ OR SOLAR+ OR SOLEIL)/FR); Or *,*1; * and *3;		
4	DWPI	..xt; ..fi wpi; *xt; ((SOLAR OR SUN)) w ((COOL+ OR CHILL+ OR REFRIGER+ OR FRESH OR RE_FRESH+)); * or *1;	116[38] 1232[21]	transfer of publication numbers from queries 1 – 3 to DWPI database; searching DWPI patent families which comprise these patent documents keyword search in DWPI abstract and title set union of previous two result sets, forming the basic set of patent documents

[38] *DWPI patent families*

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