December 2005

Welcome to the second edition of the **MicroCHeaP** newsletter. The aim of the newsletter is to keep members of the **MicroCHeaP** consortium informed of the latest news and matters of interest relating to renewable energy industry, the micro-combined heat and power (micro-CHP) industry, and the renewable micro-CHP industry. The network website can be found online at http://www.microcheap.org/ and additional information can be obtained there.

Recent Developments in MicroCHeaP

A very successful Annual meeting was held on 28th and 29th September 2005, hosted by FORCE Technology at Kgs. Lyngby, Denmark. This included the second coordination seminar, the aim of which was to promote awareness of network members research interests within the consortium. Copies of the presentations can be found in the members area of the **MicroCHeaP** website along with agendas and meeting minutes.

Work is continuing on the construction of the Centres of Activity database. A significant amount of information has already been collected and questionnaires requesting more information have been completed. These are being distributed by partners and the results will be added to the current data before the completed database is added to the website.

Preparation for the Technology Transfer Workshop is beginning. This will take place along side the Month 18 meeting hosted by ECN in the Netherlands and will bring together leading experts in the fields of sustainable energy production and decentralisation from around Europe. The workshop will include presentations on:

- Instruments, Methods and Financing for CHP Technology Transfer.
- Best Available Technologies, Outstanding Projects, Most Promising Near Market Technical Research in the EU.
- Demand Driven Decentralised Energy Supply Using Micro-CHP and Micro-Polygeneration Powered by renewable Energy Carriers.

A brief introduction to the Micro-CHP unit based on a two-cycle-alpha Stirling engine

Andreas Gymsa, ENERLYT Potsdam GmbH, Germany

General

ENERLYT Potsdam GmbH is currently engaged in the development of a combined heat and power (CHP) unit on the basis of a new 2-cycle Stirling engine (2ZM). The CHP unit can be fuelled by vegetable oil (preferably rapeseed) and put to use in single family houses and small industrial plants. In Germany the quality requirements to be met by rapeseed oil will soon be laid down in the DIN V 51605 standard initiated by ENERLYT – the draft's date of issue will be 06/2005 with the period of objection ending on 30 September 2005.

An attractive incentive for the market was created through the amendment of the EEG (Renewable Energies Law) in Germany. The current feed-in remuneration for such biomass fuelled technology is 21.5 Cent/kWh.
The project of the 2ZM-CHP was supported by the BMWA (Federal Ministry of Economics and Labour) Germany.

Construction and function of a 2-cycle-alpha Stirling engine

The patented 2ZM utilises two Stirling cycles and employs two pistons aligned in a row. This type of engine configuration has never been constructed before and was put into operation in Potsdam for the first time worldwide. As a double-acting system with high energy density, this engine is a markedly simpler than that developed by SIEMENS, whose configuration features four integrated Stirling cycles. The close connection of both Stirling cycles makes the engine extremely adjustable. The basic construction also allows variation of the expansion space in relation to the compression space and the staggering of the phases. The basic principle corresponds to that of all Stirling engines. A given quantity of enclosed gas is heated via a constant external heat source and expands in the engine's expansion space. It is then transferred to the engine's compression space through the regenerator, which absorbs some of its heat. The gas is then cooled by the compression space's constant low temperature, contracts, and is transferred back to the expansion space, collecting heat stored by the regenerator. A particular feature of the 2ZM is that a large portion of the force required for the compression of one cycle is borne by the pistons as the other cycle expands, without exposing the gearing system to stress. This ensures that the torque at the engine's crankshaft always remains balanced. Losses caused by gas leakage in the piston ring gap are not overly harmful, as the gas flows from the expansion space of one cycle to the expansion space of the other, or from the compression space of one cycle to the compression space of the other. Other Stirling engines are disadvantageous in this respect, as leakage leads to an exchange of gas between the expansion and compression spaces which raises the temperature in the compression space and lowers the temperature in the expansion space. Both of these actions have a negative effect on engine efficiency and power output.

Development status

Development of the 2ZM started on 24 October 2001, commissioning following on 17 February 2004. Stable power output has been achieved since 25 February 2005.
A thermodynamic simulation of the engine was performed with a second order calculation system. The engine's design was then optimised with a view to preparing its serial production using conventional components and procedures. One engine is on a test rig at present, the design of a second machine has been prepared; it will be put into operation in mid-2005.
In 2006, the operation of at least 5 test machines at different users for quality assurance purposes is planned. The market launch is to follow after the evaluation of the operating results of the engines tested.

Typical applications and users

The single family house sector is estimated to offer greatest market potential for micro CHP units and resultant high potential CO2 savings. Both Bokämper[1] and the DLR[2], for example, project a market for approximately 1,000,000 heating units per year. If one considers that 8,500,000 of the 13,000,000 centrally heated buildings in 2010 will be single family houses, the expected market potential in Germany is extremely high.
The unit's design is planned to allow monovalent operation so that the house owner does not have to invest in a peak-load boiler.
Besides single family houses and other living units with central heating, small industrial operations are considered to be users.

Profitability

Assuming a CHP unit with integrated peak-load heat transfer equipment costs € 7,000 and taking into account the provisions of the EEG (German Renewable Energies Law), profitability is reached when the unit is operated for 7,000 hours per year at an electrical power of 800 W. This calculation assumes that a condensing boiler for a single family house costs € 4,000.

Combustibles

The combustible currently used is rapeseed oil to DIN V 51606. On account of the unit's external combustion, the use of other vegetable oils does not present a problem from the current perspective. A co-operation project with the Technical University of Dresden investigating the use of wood as combustible is underway.

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1 Bokämper, Marktperspektiven von Brennstoffzellen-Heizgeräten (Market prospects of fuel cell heating equipment), thesis
2 DLR: Deutsche Forschungsanstalt für Luft- und Raumfahrt e. V.; Institut für technische Thermodynamik (German Air and Space Research Institution, Institute for Technical Thermodynamics)

Technical data

Mechanical power	1,000 W
Electrical power	820 W
Thermal power	3,000 W
Overall efficiency	91 %
Electrical efficiency	20 %
Rape oil consumption	22,3 hl/a (without peak-load module)
Maintenance costs	250 €/a
Thermal peak-load module	7,000 W
Mean engine pressure	15 bar
Expansion space temperature	580 °C
Compression space temperature	60 °C
Cooling	Heating return

Financial support

The high costs incurred by manufacturing a small number of units alongside additional expenditure for measuring equipment and research work required for the analysis of the test results combine to make the manufacture of the test machines extremely cost-intensive. Financial support would be very much appreciated in order to secure the test operation of the engines.

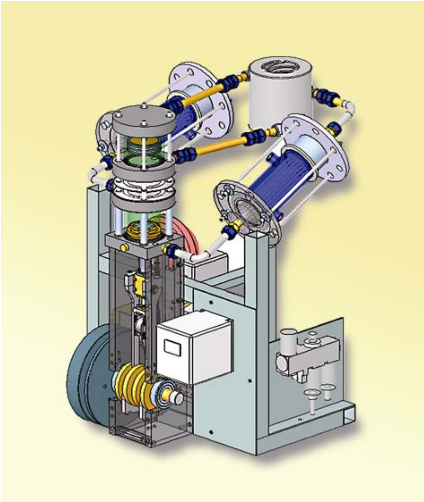

Figure 1: View of a 2-cycle Stirling engine

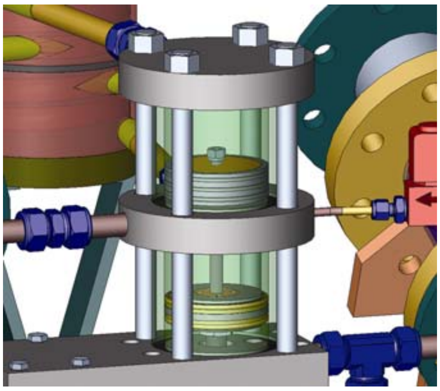

Figure 2: Presentation of two double-acting pistons, aligned in a row

For further information kindly contact:

Mr. Dipl.-Ing. Andreas Gimsa
ENERLYT Potsdam GmbH
Am Buchhorst 35A
DE-14478 Potsdam
Germany
www.enerlyt.de

Mr. Eberhard Oettel
FEE Fördergesellschaft Erneuerbare Energien e.V.
Innovationspark Wuhlheide Köpenicker Str. 325
DE-12555 Berlin
Germany
fax ++49-30-65 76 27 08
info@fee-ev.de

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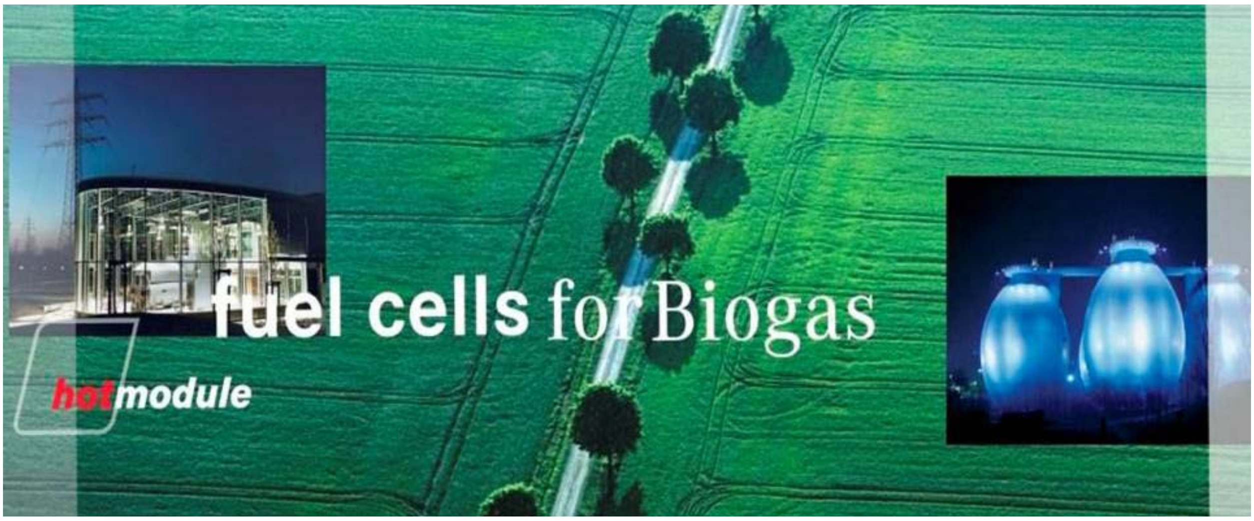


Kai Klinder, MTU CFC Solutions GmbH, Munich, Germany

The *hotmodule*®: A powerful technology is gaining ground

One of today's most pressing issues is to provide a sustainable energy supply for future generations. The problems mankind faces in this context are commonly known: For one part fossil fuels are finite and their use is therefore limited. Distributed supply technologies have to conserve resources and alternative fuels have to play a more dominant role. Secondly, emissions have to be reduced to a level where the progressing climate change comes to a halt. Another focal point is the huge amount of waste which is produced every day. The task of its effective removal constitutes a problem worldwide.

The HotModule, a 250 kW Molten Carbonate Fuel Cell (MCFC) by MTU CFC Solutions addresses these problems: Due to a wide range of advantages, the innovative HotModule ranks among the most promising systems for tomorrow's decentralised power supply. It is the perfect example for a combined heat and power (CHP) system, which means that it delivers heat and power at the same time. A particular characteristic of the HotModule is the fact that it can be operated not only with natural gas, but also with "secondary gases", such as biogas, sewage gas or landfill gas, reducing climate impact of methane, ammonia and other carbon hydrate emissions.

The HotModule is based on the molten carbonate technology. The energy contained in the fuel is electro-chemically converted directly into electricity and heat. The fuel used, primarily natural gas, is utilized to the full. In future the electrical efficiency will amount to up to 50% and the overall efficiency to around 90%. This does not only produce ecological benefits, but also economic advantages.
Another important benefit: Usually biogas contains not only the fuel methane (CH_4), but larger contents of carbon-dioxide (CO_2). The inert CO_2 decreases the efficiency of piston engines and other conventional technologies. Not with the MCFC: The high CO_2 content accelerates the internal electro-chemical reaction and increases the stack efficiency. Therefore the MCFC is the preferred solution for biogas from renewable sources.

The *hotmodule*® Fuel Cell

The *hotmodule*® and environmental friendliness go hand in hand

Environmental friendliness is one of the ***hotmodule***® major advantages. According to the German emission control directive, the "Technical Instructions on Air Quality Control", the gas which exits the fuel cell can be seen as pollution-free air. This is because pollutants such as nitrogen oxides or sulphur compounds are not produced. Moreover, the level of carbon dioxide discharged from the system is about 30% lower compared to conventional technologies. This is due to the system's higher efficiency: With an electrical efficiency of about 47% and a total of approximately 90%, the HotModule reaches an outstanding value for the 250 kW class.

In autumn 2004 a project with a HotModule, which can use both natural gas and methanol as fuel, has been realised jointly by MTU CFC Solutions, Bewag, Vattenfall and E.ON in Berlin. The methanol is extracted from waste which comes from a nearby landfill. Methanol has the advantage of being liquid and easily storable, so the fuel cell can also be used at locations which are not connected to the natural gas network. Furthermore, in case of a simultaneous cut of power and gas supply, the fuel cell can continue its energy production by using methanol as fuel. And, most importantly, precious energy is won from a material generally known as pollutant causing damage to the environment.

The *hotmodule*® enters new territory

Precious energy is also gained in Europe’s first MCFC project using sewage gas as a fuel. It will soon be realized in Germany where the HotModule is supposed to produce power and heat for a municipal sewage plant. The power not needed in the buildings will be fed into the public grid. The heat generated by the fuel cell is planned to operate the digestion tower, which produces sewage gas from sewage sludge. The residual heat serves to heat the office and production building. What’s more, secondary gases can be utilized directly where they have been generated. This way, transport losses are omitted at the outset. Especially regions with weak infrastructure can benefit from the savings in transport costs and energy losses.

Furthermore, when using sewage gas, the amount of carbon dioxide released by the HotModule is no higher than was previously absorbed by nature. With such a neutral CO_2 balance, the environment profits yet again.

Fuel cell deployment strategy needs EU aid

*Hot**module*® pilot-production in the brand-new facilities at MTU CFC Solutions in Munich, Germany

The MCFC plant has proven itself as a technology with the potential to play an important role in tomorrow's heat and power supply. The first generation is on its way to early markets. Nevertheless,
deployment has to be financed in order to pave the MCFC's way towards a marketable product. In parallel the next generation has to be developed and continuous research is required.
Japan and the U.S. have identified the strategic chances the fuel cell offers and have set up huge funding programmes. If Europe does not want to fall behind we need to follow their example. Only with
substantial financial support by the EU for further research and deployment will it be possible to make the fuel cell a lasting success.

For further information kindly contact:

Mr. Dipl.-Ing. Kai Klinder
Vice President Marketing and Sales
MTU CFC Solutions GmbH
DE-81663 München
Germany
phone: +49 - 89 - 607 31564
fax: +49 - 89 - 607 31509
PC-Fax: +49 - 89 - 660 298 705
mobile: +49 -160 - 8 62 77 75
kai.klinder@mtu-cfc.com
http://www.mtu-cfc.com

Mr. Eberhard Oettel
FEE Fördergesellschaft Erneuerbare Energien e.V.
Innovationspark Wuhlheide
Köpenicker Str. 325
DE-12555 Berlin
Germany
fax ++49 – 30 - 65 76 27 08
info@fee-ev.de

Corporate Profile

Headquarter

MTU CFC Solutions GmbH
Christa-Mc-Auliffe-Str. 1
85521 Ottobrunn / Germany
T +49(0)89-607 31534
F +49(0)89-607 31509
E info@mtu-cfc.com
I www.mtu-cfc.com

Founded

January 2003

Management Board

Michael Bode (President and CEO)
Dr.-Ing. Michael Fuebi

Shareholder

74.9% MTU Friedrichshafen GmbH
25.1% RWE Fuel Cells GmbH

Staff

84

Business area

- MTU CFC Solutions is developing and manufacturing fuel cells for combined heat and power (CHP) in the range performance 200 kW to approx. 3 MW for decentralized energy supply.
- At present 8 demonstration plants are successfully in operation, thereof 7 in Germany and one in Spain.

Target Groups

- Industrial companies, hospitals, telecommunication enterprises, food industry and biogas applications.
- MTU CFC Solutions is concentrating particularly on the EU, however today we are being encouraged by an increasing interest of different market segments worldwide.

Strategic Partnerships

- In close collaboration with strategic partners from the Energy branch MTU CFC Solutions is offering complete solutions, including engineering and energy service providing.
- Within the scope of research projects 6 field trials had been carried out with governmental aid, the so-called ZIP programme and a further one by promotion of the EU.
- MTU and Fuel Cell energy, Inc., Danbury, Connecticut, USA, are partners of a technology and supply exchange agreement. MTU is a shareholder of FCE (NASDAQ – FCEL) since 1989. The sub-megawatt fuel cell power plant is a collaborative effort utilizing the Direct FuelCell® technology of FuelCell Energy, Inc. and the Hot Module® balance of plant design of MTU CFC Solutions GmbH, a subsidiary of DaimlerChrysler.

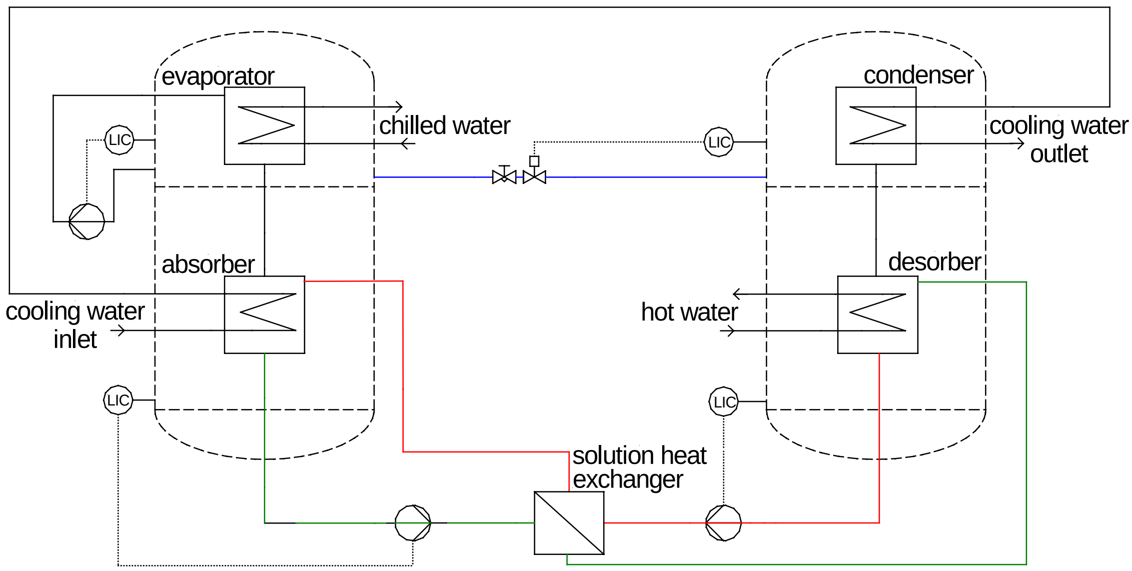
Heat powered absorption chillers for (Micro-)Trigeneration

Mathias Safarik, ILK Institut für Luft- und Kältetechnik gGmbH, Dresden, Germany

Trigeneration is the combined generation of power, heating and cooling and is a promising opportunity to further increase the energy efficiency and economics of **C**ombined **H**eat and **P**ower (CHP) installations.
A thermal powered cooling process can be used for the transformation of heat to cooling energy. One of many possible processes is absorption cooling. Absorption chillers are characterised by continuous operation and very good part load performance. For many years absorption chiller were mainly used in the high capacity range (200 kW to several MW cooling capacity). With the wider utilisation of mainly engine driven cogeneration units in recent years there is an increasing demand for cooling technologies in the low capacity range that are able to work with the heat conditions (low temperatures) of these cogeneration units.

The *Institut für Luft- und Kältetechnik (ILK Dresden)* realised several developments in this area together with the company *Energieanlagenbau Westenfeld* (Germany). A line of single effect absorption chillers with cooling capacities of 50 kW to 200 kW was developed (Wegracal SE 50…SE 200). These absorption chillers work with hot water (heating) temperatures of 86 / 71 °C reaching a COP of 0,7. They are able to provide chilled water of 9 °C to 6 °C. Figure 1 shows a plan of the principle configuration of these chillers.

Figure 1: Plan of a single effect absorption chiller (Wegracal SE 15…200)



Water is used as the refrigerant. It evaporates in the evaporator cooling the chilled water. The water (refrigerant) vapour is absorbed by a lithium bromide solution in the absorber. The absorption process is cooled by cooling water. The solution leaving the absorber has a high refrigerant content (rich solution). It is then pumped through the solution heat exchanger to the desorber/generator where the solution is heated by hot water. Water vapour is generated which is condensed in the condenser. The liquid refrigerant flow through an expansion valve to the evaporator. The solution poor in refrigerant that leaves the generator is pumped back to the absorber.

Within the last years these single effect absorption chiller were used in cogeneration installations with different kinds of fuels for the cogeneration unit (e.g. natural gas, biogas). The chilled water is used for industrial cooling purposes, air conditioning of buildings (office and laboratory buildings, selling floors, museums etc.) and for agricultural cooling applications such as barn cooling and milk cooling.

Figure 2: Single-Effect-Absorption Chiller *Wegracal SE 50*
Nominal conditions: chilled water: 15 / 9 °C / 54 kW; heating water: 86 / 71 °C / 72 kW; cooling water: 27 / 32 °C / 126 kW; COP: 0,75

The latest development in this line is a single effect absorption chiller with a nominal cooling capacity of 15 kW. This chiller was initially developed for solar thermal cooling. In these applications solar generated heat is used to drive an absorption chiller.

Solar thermal collectors are widely used for hot water supply and heating in many parts of Europe. There has been a big increase in installed collector area in some countries. One problem is the distribution of insolation and heating demand over the year. Solar thermal plants for heating assistance produce a lot of excess heat in summer which cannot be used at this time. Storage for the winter time is possible but costly. By using this excess heat for cooling purposes the efficiency of the whole system can be increased. There is a high degree of congruence of the cooling demand and the insolation in many applications. Therefore only a little storage capacity is needed. Solar cooling is also a promising opportunity to cut electrical peak loads during the summer and to reduce fossil fuel consumption.

In most of the solar thermal installations flat plate collectors are used. The efficiency of these collectors decreases with an increase of the working temperature (temperature of the fluid used in the collector loop). Therefore the absorption chiller was designed to work with low heating temperatures (from 70 °C to 90 °C heating water input).
Heat with temperatures in this range can also be provided by Micro-CHP systems so that this absorption chiller can be used to supply cooling powered by heat of engine driven cogeneration units, fuel cells, stirling engines etc..

Figure 3: Single-Effect-Absorption Chiller *Wegracal SE 15*
Example conditions: chilled water: 21 / 15 °C / 15 kW;
heating water: 85 / 77 °C / 20 kW; cooling water: 32 / 38 °C / 35 kW; COP: 0,75

Other CHP technologies are providing heat of higher temperatures. This offers the possibility of using multiple stage absorption cooling technologies. One example are Double Effect Absorption chillers which reach a COP of ~1,2 compared to ~0,7 of Single Effect Cycles.
The HotModule called high temperature fuel cell (MCFC) of MTU provides about 1500 m^3/h exhaust air with a temperature of 360 °C. For an efficient use of this waste heat a so called Multi Effect Cycle was realised. This is a combination of a Single and a Double Effect Cycle reaching a COP of 1,1 in this application.

Figure 4. shows the principle of the chiller. The additional components needed for the Multi Effect Cycle are red coloured. The chiller uses a high temperature generator that is directly heated by the exhaust air of the MCFC.

The HotModul – Multi Effect absorption chiller combination was installed at a hospital in Bad Berka, Germany. It provides power, heating and cooling over the whole year. The ratio of heat used for heating purposes in the hospital and the heat used for driving the absorption chiller can be changed over a wide range.

Figure 4: Plan of the Multi-Effect-Absorption chiller for combination with the MTU HotModule MFCC, nominal cooling capacity: 170 kW

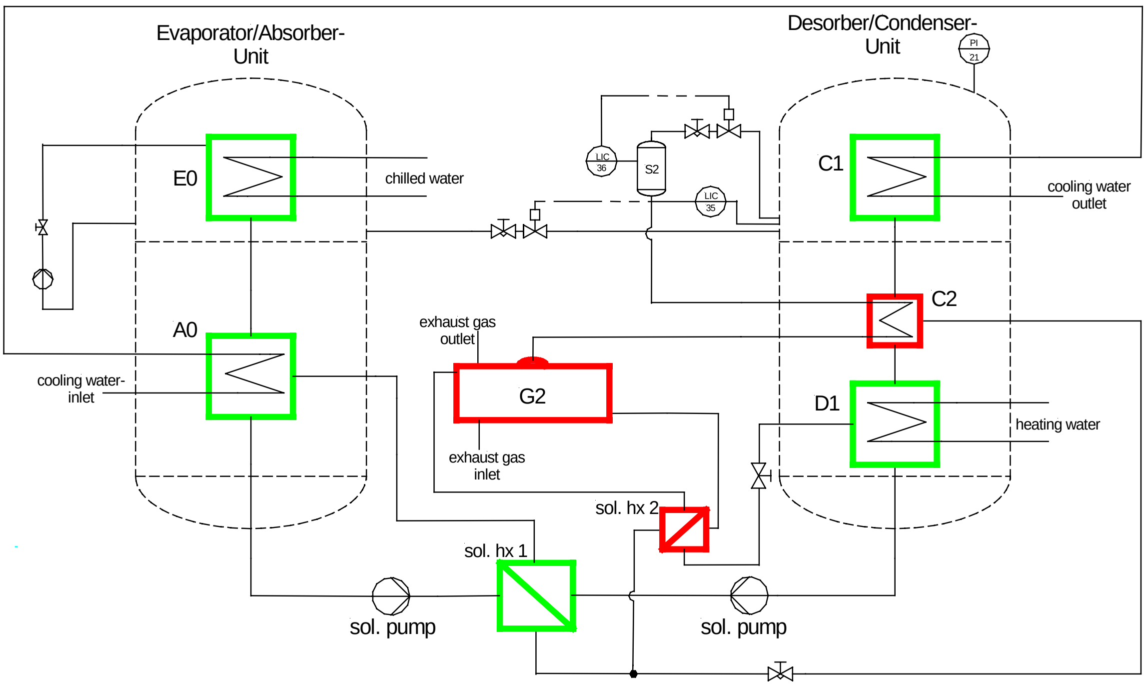


Figure 5: HotModul – Multi Effect absorption chiller combination in Bad Berka, Germany

For further information please contact:

Mr. Dr. Mathias Safarik
Institut für Luft- und Kältetechnik gGmbH
Bertolt-Brecht-Allee 20,
DE-01309 Dresden
Germany
Phone +49-351-4081-684
fax +49 351 4081-635
mathias.safarik@ilkdresden.de
www.ilkdresden.de

EAW Energieanlagenbau GmbH
Oberes Tor 106
DE-98631 Westenfeld
Germany
Phone +49-36948-84-132
fax +49-36948-84-152
info@eaw-energieanlagenbau.de
www.eaw-energieanlagenbau.de

Mr. Eberhard Oettel
FEE Fördergesellschaft Erneuerbare Energien e.V.
Innovationspark Wuhlheide Köpenicker Str. 325
DE-12555 Berlin
Germany
fax ++49-30-65 76 27 08
info@fee-ev.de

Forthcoming Events

1st European Fuel Cell Tech & Applications Conference
14th – 16th December 2005, Rome, Italy
http://www.renewableenergyaccess.com/rea/events/view?id=24979

European Biomass CHP Conference 2006
23rd January 2006, Brussels
http://www.cogen.org/events/European_CHP_Biomass_Conference2006.htm

Nordic Biogas Conference 2006
8th – 10th February 2006, Helsinki, Finland
http://www.bionova.fi/nordicbiogas/index.php?language=en&page=index

Power-Gen Europe 2006
30th May – 1st June 2006, Cologne, Germany
http://pge06.events.pennnet.com/

6th IASTED International Conference on European Power and Energy Systems
EURO-PES 2006
June 26th –28th 2006, Rhodes, Greece
http://www.iasted.org/conferences/2006/Greece/c521.htm

Next Edition…

If you have any information on recent developments, forthcoming events or anything else you think would be of interest to the network partners please send your contributions to Robert Frost (robert@chalex.com).