POWER, HEAT AND CHILLINESS WITH NATURAL GAS – FUEL CELLS AND AIR-CONDITIONING

P. Seifert
DBI Gas- und Umwelttechnik GmbH, Germany

K. Rühling
Technische Universität Dresden, Germany

ABSTRACT

A new and innovative concept of the supply with power, heat and chilliness will be realised in the new Malteser Hospital in Kamenz. Core of this demonstration project are a fuel cell, an adsorption refrigeration machine as well as multi-solar collectors.

The fuel cell has two functions. Primary it produces power for the demand of the hospital. The selected dimensions guarantee, that the power will be consumed nearly continuously. Secondly the produced heat of the fuel cell (and the solar-heat too) will be used for heating and preparation of warm water. In the summer, the heat will be used for the adsorption refrigeration machine, which produces chilliness for air-conditioning.

The advantage in the face of common concepts of combining power and heat is the high-efficiently use of the fuel energy for electric power generation on the one hand. Fuel cells work with high efficiency also at partial load. On the other hand, the heat produced by fuel cell and multi-solar collectors can be used also in the summer by means of the adsorption refrigeration machine.

First experiences with this concept show, that an optimised co-operation of the components with an adaptive control system based on the weather forecast as well as various storage's for heat and chilliness can be achieved. A continuously operation, high fuel utilisation and reduced environmental pollution can be demonstrated.

POWER, HEAT AND CHILLINESS WITH NATURAL GAS – FUEL CELLS AND AIR-CONDITIONING

P. Seifert
DBI Gas- und Umwelttechnik GmbH, Germany

K. Rühling
Technische Universität Dresden, Germany

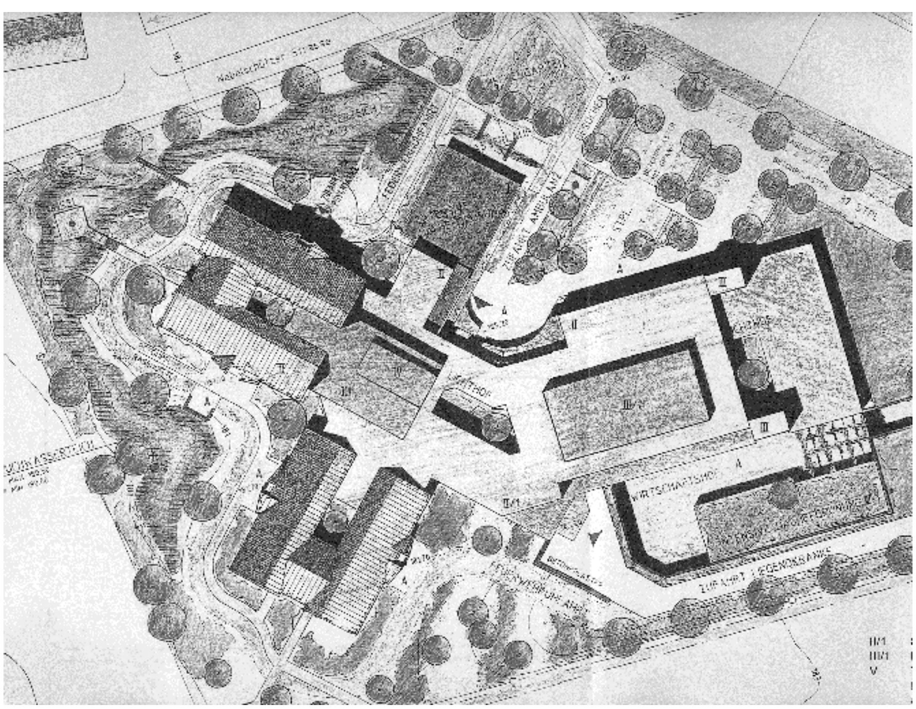
AIMS OF THE PROJECT

Fuel cells are meanwhile one of the future options of a modern energy supply. Today they are mainly powered by natural gas, in the future regenerative produced hydrogen or methanol will be used as fuel. In order to become these future options true, it is necessary to get cheap standard fuel cells and to test facility concepts, which guarantee the optimal utilisation of generated power and the full-time utilisation of the produced heat around the year.

Therefore since 1997 a consortium, consisting of DBI Gas- und Umwelttechnik GmbH (Leipzig/ Freiberg, Germany), Technical University Dresden (Germany) and GASTEC N.V. (Apeldoorn, Netherlands), is working out concept and realisation of the innovative coupled power, heat and cooling plant with fuel cell for the new Malteser Hospital in Kamenz (210 beds and 25 additional places for psychiatry day clinic).

The project is supported by:

- European Union
- Freistaat Sachsen
- Verbundnetz Gas AG
- Thyssengas GmbH
- Gasversorgung Sachsen Ost GmbH



Picture 1: Ground plan of the Malteser Hospital in Kamenz (Architects Schweitzer + Partner, Braunschweig)

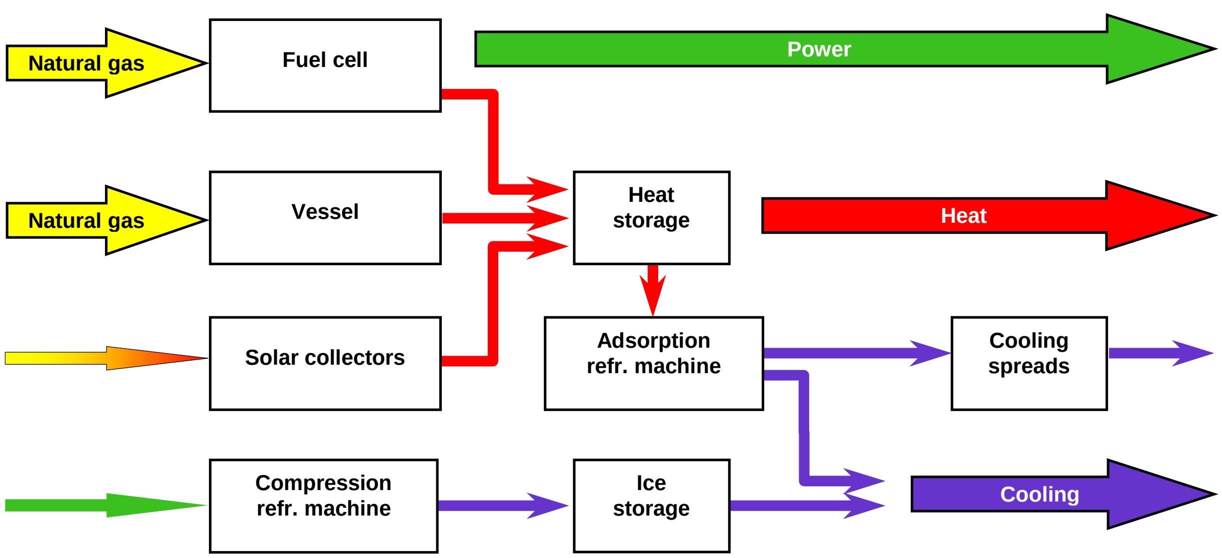
Some of the hospitals, which have been build in Germany in the last five years, have a modern energy supply based on coupled heat and power plants and absorption refrigeration machines. The central energy supply of the Malteser Hospital has a new concept with the following parameters:

- 1800 kW heating/air-conditioning/warm water treatment
- 440 kW electrical power
- 220 kW cooling

Two low temperature vessels (900 kW output each) guarantee heating, air-conditioning and warm water treatment. The innovative coupled power, heat and cooling plant with fuel cell and solar support combines the main components given in Table 1. Every component, with exception of the solar technique produced in Saxony, was still applied in a pilot project. The aim of this project is to design and to build a novel system (see Picture 2), which has technical, commercial and ecological advantages compared with conventional solutions. The consortium has to demonstrate this in a monitoring phase of two years.

Table 1: Technical parameters and manufacturer of the main components

Component	Characteristic		Manufacturer
Phosphor acid fuel cell (PAFC)	Electrical output	200 kW	ONSI
	Heat output	220 kW	
Adsorption refrigerating machine	Cooling effect	105 kW	MYKOM
Compression refrigerating machine	Cooling effect	80 kW	YORK
Ice storage	Capacity	400 kWh	FAFCO
Heat storage	Volume	20 m^3	FLAMCO / SOLVIS
TWD-collectors	Area	115 m^2	SSL Eibau
Multisolar-collectors	Area	15 m^2	SOLARWATT Dresden



Picture 2: Main components of the project

PRINCIPLES OF THE MAIN COMPONENTS

Phosphor acid fuel cell

In opposite to the mostly used plants for decentral production of power and heat (coupled heat and power plants) based on a thermal processes, fuel cells convert the chemical fuel energy directly to electrical power (without a roundabout way over thermal energy). Fuel cell have high efficiency, but on the market is only the phosphor acid fuel cell PC 25 model C of the American manufacturer ONSI.

The fuel cell used for the project works at a working temperature of 200 °C and between 50 and 100 % electrical output with a nearly constant electrical efficiency of 40 %. The really measured emissions (NO_x, CO, SO_2, C_xH_y) are 2 to 5 % compared with gas motor based coupled heat and power plants [1, 3].

The standard type of the fuel cell (FC) PC 25 C delivers thermal energy with temperatures between 70 and 75 °C. In the project the option will be used to have 50 % of the thermal output (110 kW) at high temperature (90 to 110 °C). The other 110 kW will be gained at 60 – 70 °C (low temperature). The optimal return temperature for the low temperature customer cycle is 30 °C to get optimal working conditions for the FC. The high temperature customer cycle allows temperature drops up to 40 K. These are optimal connecting conditions for sorption refrigeration machines, which use heating media temperature drops of 10 K.

Adsorption refrigeration machines

Sorption processes are non-polluting procedures for the production of chilliness. They use thermal energy instead of electrical power. The thermal energy may come from waste heat, coupled power and heat plants and solar energy. Whereas absorption refrigerating machines need heating media temperatures at least of 95 °C, adsorption refrigerating machines (AdRM) can work still at 75 °C with comparable cooling ratios [2]. Therefore AdRM are especially qualified for co-operations with the FC. Disadvantageous are the actual prices: 760 – 1330 € per kW cooling output.

Solar collectors

A collector field will be installed on the top of the energy production central, the thermal output will be used for heating and warm water treatment in the winter. In summer the heat is directly used for the thermal supply of the AdRM. There are two types of collectors: nearly 90 % are flat collectors with a transparent heat insulator (closely packed glass tubes, Ø 1 cm, wall thickness 0,1 mm). This type of collector allows working temperature of 180 °C and higher.

The other type are the hybrid collectors Multisolar® (15 m^2). They are comparable with conventional collectors, the surface is covered with crystalline photocells. The photocells use a part of the sunlight spectrum and convert it to electrical power. The other waves are converted to thermal energy in the thermal adsorption layers. One Multisolar® module produces 150 to 180 W_p with an optical efficiency of 68 %. The solar electrical power will be used to supply the pumps of the collector cycle.

MAIN PRINCIPLES OF THE PLANT

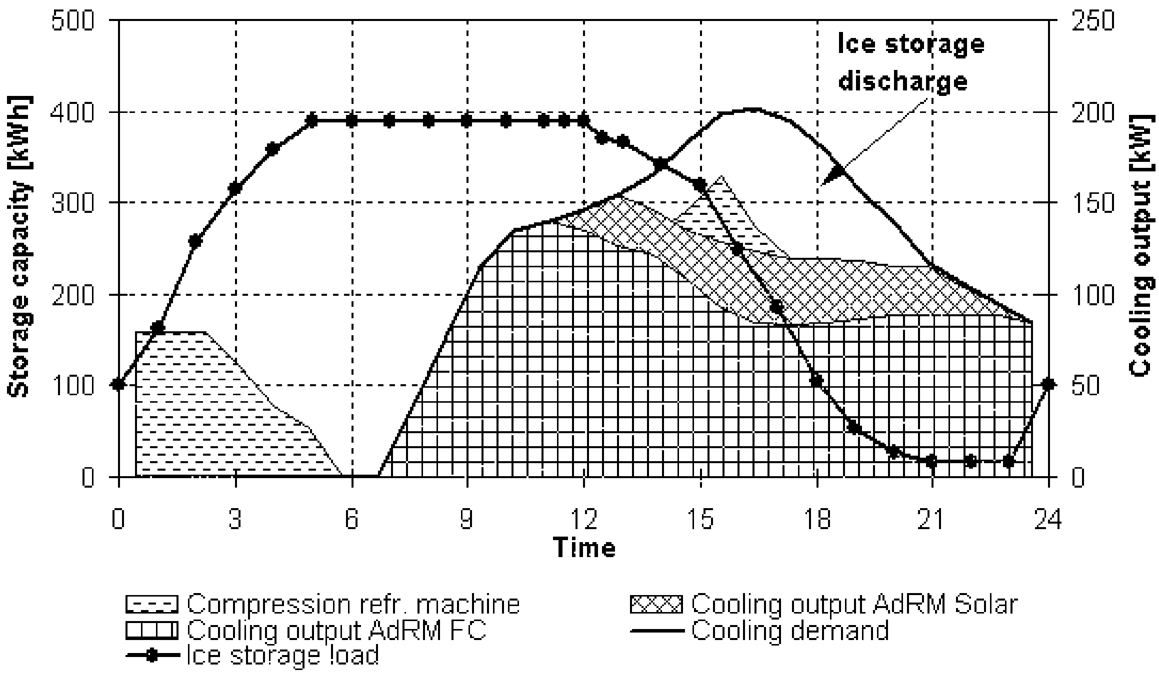
Aim of the project is to use the electrical power and heat produced by the FC all over the year. Due to the electrical demand of the hospital, continuous operation of the fuel cell is possible.

Because of the highly different heat and cooling demand of the hospital around the day, a 20 m^3 heat storage and an ice storage are used. The fuel cell has the first priority to produce heat, the low temperature vessels will be putted into operation, if the heat demand exceeds 220 kW.

The Institute of Thermodynamic and TGA of the TU Dresden developed a calculation programme based on TRNSYS® to simulate the co-operation of these components for heat and cooling storage and distribution.

The calculation of heat and cooling demand peaks, of solar field immission and outside temperatures has shown, that solar thermal energy is needed for operation of the AdRM at 105 kW (nominal power) in the hottest hours of the year, because full power of the AdRM causes a temperature drop of the FC preliminary heat, the output decreases. The AdRM can produce at these hottest days (10 to 15 days with temperatures over 32 °C) 82 % of the demanded cooling output. Only at these days the compression refrigeration machine (CoRM) has to work between 9 and 18 o'clock for 5 hours. The cooling demand peak will be filled by use of the ice storage.

The CoRM charges the ice storage during the night (23 – 6 o'clock) with 390 kWh. Therefore the night power of the FC will be used. Up to 13 o'clock the AdRM supplies the cooling needs. Then the discharging of the ice storage begins. Between 14 and 18 o'clock all components of the cooling production are used. After 21 o'clock the AdRm can work alone again (see picture 3).



Picture 3: Contribution of the main components to the cooling output

PREVIEW

During writing of these paper, the energy production central is under construction. Heating of the building site has been started in October 1999, the delivery of the fuel cell is announced for November 1999, test operation for the complete system including cooling production and solar technique starts in March 2000.

Costs of the whole system including delivery, installation and putting into operation are:

Fuel Cell (1 € = 1,087 $)	846700 €
Heat / cooling production (with exception of low temperature vessels)	281700 €
Control technique for innovative components	95100 €
Sum total	**1223500 €**

Because of liberalisation of energy markets we have to ask for the market price of 1 kWh produced energy. A calculation for the fuel cell (without the other aggregates) is given below. Table 2 shows the capital appropriations for the project. The amounts for maintenance and the fix costs are taken from an existing fuel cell of the same type and from [3]. Without financial support by the authorities and sponsors there are expected yearly deficits of 36300 €.

Table 2: Evaluation of the expected economic efficiency for the fuel cell (June 1999)

Fuel cell	€	846700
Replacement of cell stack after 5 years	€	127800
Interest rate	%	8
Operating life time	a	10
Yearly costs for maintenance	€	25500
Fix costs	€	5100
Natural gas price	€-Cent/kWh	1,74
Price for avoided purchase of electrical power	€-Cent/kWh	10,2
Heat price	€-Cent/kWh	2,81
Full load hours	h/a	7500
Yearly electrical operating rate	%	39

More exactly analysis are suitable after 1 or 2 operating years. They will show, whether the chosen system configuration for these demonstration project can reach the predicted results. Part of the EU THERMIE project is a monitoring phase, in which measurement data for the system will be collected for putting into operation and for one complete operating year. Therefore measurement data collection and adaptation of operating regime and control have to be combined.

Because fuel cell and AdRM are not economic without financial support at the moment, the project has to demonstrate a clear benefit referring to minimal consumption of primary energy – compared with other projects. The novel concept of coupled power, heat and cooling plant can be established in Europe only in this case.

REFERENCES

[1] Technical description fuel cell modul ONSI PC 25, model C.
EES GmbH Essen; C.L.C. S.r.L. Genova

[2] Gassel, A.: Use of adsorption refrigeration machines (SiO_2/H_2O) in facilities for solar air-conditioning. Short presentation 11th International Solar Forum, Köln, 1998

[3] Krein, S.: Fuel-cells in the decentralised energy market,
Conference of VNG Verbundnetz Gas AG (connected with “TERRATEC 99”),
04.03.99, Leipzig

[4] Gummert, G.: Design, putting up and operation of fuel cell power plants.
Presentation for colloquium: Fuel cells for the energy supply, TU Dresden, 19.03.1998