BIOTURBINES – CHALLENGE FOR A NEW BIOENERGY MARKET

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ABSTRACT: During the last few years microturbines with a power range of 30 – 150 kW have been developed as a promising technology for small-scale power and heat generation. An overview study performed for all European countries showed that by the end of 2003, the upper limit for the microturbine market in Europe was about 300 installed units. Thus, today the use of microturbines in the EU is at the beginning of its development and a microturbine market is hardy existing. Many companies are testing this new technology in order to determine its features and possibilities for application, but these installations are not fully commercial services. The main reason for this situation is that currently the performance of microturbines has not reached its technological limits. The efficiency of the fuel-to-electricity conversion is approximately 30%, investment costs are between 900 and 1200 Euro per kW and the level of NO_X emissions is in the order of tens of ppm. The market potential could increase substantially, if cost, efficiency, durability, reliability and environmental emissions of existing designs are improved to meet the following main performance targets for micro-turbines: conversion efficiency for electricity generation of 40%, NOx emissions lower than 7ppm, maintenance intervals of 11.000 hours and a service life of 45.000 hours as well as system costs lower than 500 €/kW.

Keywords: gas turbines, combined heat and power generation (CHP), liquid biofuels

1 INTRODUCTION

This publication has been elaborated in the framework of the ALTENER project 'Opportunities for Biofuel-burning Microturbines in the European Distributed-generation Market (BIOTURBINE)'. The objective of this project is to assess the technical feasibility and the market potential of bio-fuel burning microturbine systems for power and heating applications.

The opportunities for liquid bio-fuels burning microturbines will be evaluated using a multi-step process which includes an assessment and review of the microturbine technology, an evaluation of the bio-fuel market and of bio-fuel applications in the heat and power sector, an assessment of cost and performance levels as well as indications for RD&D requirements.

In the following, a brief introduction to microturbine technology and applications as well as the results of a European microturbine market assessment are presented. More information on the BIOTURBINE project is available at www.bioturbine.org.

2 MICROTURBINE TECHNOLOGY OVERVIEW

During the last few years microturbines with a power range of 30 – 150 kW have been developed as a promising technology for small-scale power generation, particularly for distributed power generation. Microturbine systems offer a number of potential advantages with respect to other technologies, such as their simplicity, compactness, modularity and low noxious emission levels, as well as their potential low investment and maintenance costs. Micro-turbines are well suited for the reliable provision of electricity and heat for stand-alone and grid-connected applications and they are an attractive power supply option whenever combined heat and power (CHP) generation can be exploited. Additionally, microturbines show a large flexibility to fuels so that they can be operated with natural gas, bio-gas, diesel, gasoline and liquid bio-fuels.

Most microturbines are based on technologies that were originally developed for the use in auxiliary power systems, aircrafts or automotive turbochargers.

Microturbines have only one moving component, i.e. the high-speed rotating shaft that includes the compressor, turbine wheel and generator. The shaft is mounted on air bearings rather than lubricated bearings, which are commonly used in conventional turbines. Single-shaft models generally operate at speeds over 60.000 revolutions per minute (rpm) and generate electrical power of high variable frequency. This power is rectified to direct current and then inverted to 50 or 60 hertz (Hz) depending on the standard used in the respective countries. Cogeneration units include additional components, such as hot water exchangers, which capture heat from the microturbine exhaust to produce useful thermal energy.

Microturbines operate on the same thermodynamic cycle as larger gas turbines, known as the Brayton cycle. In this cycle, atmospheric air is compressed, heated and then expanded. The excess power produced by the expander (the turbine) is used for power generation. The power produced by an expansion turbine and consumed by a compressor is proportional to the absolute temperature of the gas passing through those devices. Consequently, it is advantageous to operate the expansion turbine at the highest practical temperature consistent with economic materials and secondly, to operate the compressor with an inlet airflow at the lowest possible temperature. However, microturbine inlet temperatures are generally limited to 1000°C or below to enable the use of relatively inexpensive materials for turbine wheels, and to maintain pressure ratios at a comparatively low 3.5 to 4.0.

Figure 1 shows the schematic set-up of a microturbine co-generation system, consisting of the main components:

- Single-stage centrifugal compressor
- Low emission combustor
- Single-stage radial turbine generator
- Recuperator
- Power conditioner

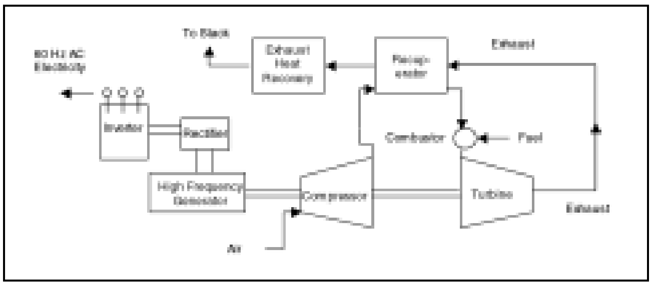

Figure 1: Microturbine based CHP system [1]

Detailed information on the microturbine technology state-of-the-art is presented in the publications 'Micro-turbine Generators' by M.J. Moore [2] and 'Mini- and Macro- Gas Turbines for Combined Heat and Power' by P.A. Pilavachi [3].

3 MICROTURBINE APPLICATIONS

Microturbines can be used in a variety of electricity and thermal energy applications due to their small size, low unit costs, and useful thermal output. Eight potential types of applications for microturbines have been identified, such as continuous generation, peak shaving, back-up power, premium power, remote power, co- and tri-generation, mechanical drive applications as well as applications using wastes and biofuels.

3.1CHP applications in the commercial/residential sector

The major market potential in the commercial and residential sector for microturbines is in traditional CHP applications, where the majority of waste heat from the gas turbine can be utilized. For microturbines in the power range 20-200 kWe, the corresponding available (exploitable) heat is in the range between 50 and 400 kW, respectively.

Heat rates this size are larger than most demands on a domestic level, implying that this huge market segment is not really potential, unless more heat customers are interconnected via a local heat distribution grid. If the houses are not arranged in a compact plan, the disadvantages in such application are the relatively large heat loss associated with such local and small district heating systems.

Some of the most important and potential markets having heat demands in the range 50 to 400 kW are expected to be schools, apartment or attached houses, residential homes, office buildings, sports centres, swimming baths, hospitals, hotels and resorts, super markets and shopping centres and sewage treatment plants.

Figure 2 shows a Capstone C30 microturbine installation operated by the German gas utility Bayerngas GmbH to provide electricity and heat for an office building in Munich. The unit was installed in October 2002 and provides 20% of the electricity consumption and 30% of the heat consumption of the office with electrical and total efficiencies of 23% and 76%, respectively [4].

Figure 2: Microturbine installation at an office building in Munich, Germany

3.2CHP applications in the industrial sector

The main markets for microturbines (CHP) in the industrial sector are expected to be:

- greenhouses
- industrial laundries
- SME's with a certain profile of heat demand

For industrial locations with annual heat demands in the range between 150 and 2500 MWh, it is expected that in most cases the major heat demand is for room heating. That is, the major part of the heat demand is seasonal, implying that full load operation is limited and probably in most cases below 2000 hours per year. Usually industrial companies require short pay back time for utility investments and consequently, most of such "possible" installations are considered not viable, even when supported [5].

A successful CHP application of a Turbec T100 microturbine at Klitte & Lund greenhouse in Sweden, is presented in figure 3. In this application flue gases are used to fertilise cucumber plantations without expensive gas cleaning equipment [6].

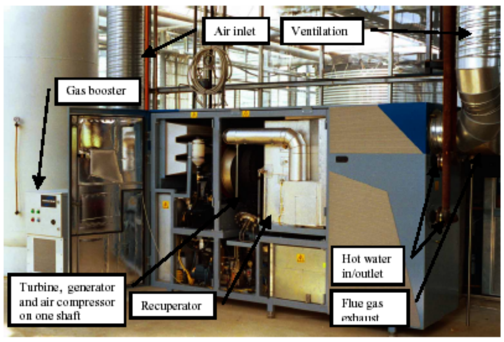

Figure 3: Microturbine installation at a greenhouse in Helsingborg, Sweden

4 EU MICROTURBINE MARKET

4.1 Microturbine installations in Europe

For the market assessment performed in the framework of the BIOTURBINE project, questionaires have been sent to all major microturbine distributors and producers. Thereby, information on approximately 170 installed microturbines in EU countries has been compiled, and a further 40 microturbines are scheduled to be installed in 2003.

Today, the use of microturbines in EU countries is at the beginning of its development and a microturbine market is hardy existing. Many companies are testing this new technology in order to determine its features and possibilities for application, but these installations are not fully commercial services. In order to achieve market progress, it is necessary to remove several barriers and, most importantly, to demonstrate the capability of the microturbine technology to potential private and public customers.

Currently, the performance of microturbines has not reached its technological limits. The efficiency of the fuel-to-electricity conversion is approximately 30%, investment costs are between 900 and 1200 Euro per kW and the level of NO_X emissions is in the order of tens of ppm. The main problems limiting the growth of the microturbine market can be summarised as follows:

- Low efficiency of fuel-to-electricity conversion, low reliability of microturbine components, short life time
- High investment costs, high maintenance costs
- Lack of suitable regulations for systems with low power output, barriers to grid interconnection
- Limited experience concerning bio-fuel driven microturbines
- Lack of customer awareness

Figure 4 shows an overview of the microturbine market in the 15 EU countries plus Norway and Switzerland. By the end of 2003, the upper limit for the microturbine market in Europe is estimated at about 300 installed units.

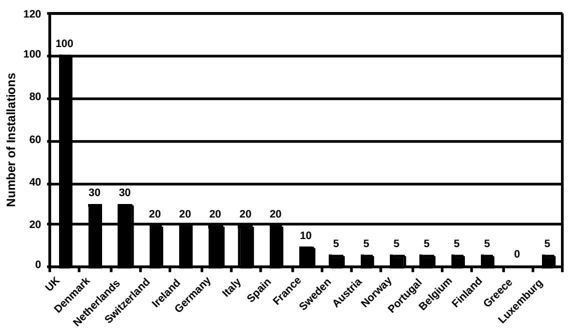

Figure 4: European microturbine market in 2003

It can be seen that only in the UK a significant microturbine market has evolved, whereas in all other EU countries the market is in its very early stages. Nevertheless, it is possible to distinguish EU countries with a microturbine market of 'almost zero', such as Austria, Sweden, Norway, Portugal, Belgium, Finland, Greece and Luxemburg, from countries which have started to implement commercial microturbine systems and which have already gathered significant operational experience, such as Denmark, the Netherlands, Ireland, Germany, Italy, Spain and France.

Finally, it has to be stated that the results of the present market assessment are in line with the findings of a market potential evaluation performed in the framework of the EC project 'Optimised Microturbine Energy Systems - OMES' [5]. This study concluded that the development of a microturbine market in EU countries will in the next few years significantly depend on the natural gas and electricity price ratio, a further reduction of the investment and O&M costs of microturbine systems as well as the level of Governmental support.

4.2 Market share by microturbine producer

The microturbine sales figures compiled in this study (figure 5) indicate that the most active producer on the EU market is the Swedish producer Turbec, closely followed by Bowman Power Systems. Capstone, the world leader in microturbine technology which holds approximately 85% of the market share worldwide, accounts for lower sales in the EU than expected. An explanation for this fact is that Capstone's marketing policy is focused on non-European countries.

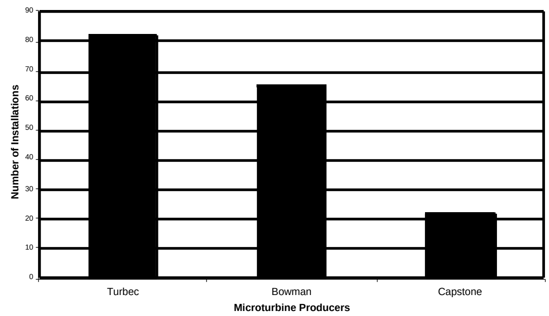

Figure 5: Microturbine market share by producer

By the end of 2003, the upper limit for the microturbine market in Europe is estimated at about 300 installed units with an installed generation capacity of approximately 18 MWe. This market is considerably lower than sales figures in the US of several thousand units. Until today, the microturbine market in Europe does not live up to its high expectations, which was documented in a variety of market potential assessments preformed in several European countries, most of them indicating even short-term potentials exceeding the current market by at least one order of magnitude [7, 8].

This unsatisfactory market development has resulted in the decision of Turbec AB to stop the production of microturbines in August 2003 due to sales figures lying significantly below the company's expectations. This decision may have a further negative impact on the European microturbine market, as with Turbec, the only fully-European market player withdraws from business, thereby complicating necessary on-site adjustments and optimisation (especially for innovative applications) for microturbine installations in the EU.

Positive signs have emerged through the fact that on December 30th, 2003 the Italian-based API Com srl has acquired all of the share capital of Turbec AB and API Com srl has shown interest to continue activities in the field of microturbines.

4.3 Market share by application, market sector and fuel

The majority of current microturbine applications is in the field of combined heat and power (CHP) production. Out of 52 investigated microturbine installations, only one is not used for CHP, but for remote power generation. Therefore, it can be concluded that CHP is currently the most promising application on the European market.

With respect to the market sector, results of the present study show that out of 60 investigated microturbines, the residential sector accounts for 7 units, the commercial sector for 29 units and the industrial sector for 24 units. This trend favouring the commercial/residential sector will become more evident during the future development of the microturbine market for the following reasons [5]:

- Large number of locations in the commercial/ residential sector have suitable heat and electricity demand profiles
- The gap between cost for electricity and gas is larger than in the industrial sector
- Lower demand for return of investment in public buildings and in the domestic sector

With respect to the type of fuel used, the large majority of microturbines today run on natural gas (50 out of 57 units for the present study). This comes as no surprise, as natural gas is the recommended fuel specified by microturbine producers, and suitable supply infrastructure exists in most EU countries.

Nevertheless, activities are on-going in several EU countries to test the performance of microturbine systems running on landfill gas, digester gas and bio-gas. These applications provide the opportunity to benefit from Governmental support for green energy, such as the German Feed-in Law and the UK Climate Change Levy exemption.

Finally, with respect to the use of liquid fuels in microturbines very few information is currently available. Performance data of two Turbec installations running on methanol in Norway will soon be published in the framework of the EC project 'OMES'.

5 CONCLUSIONS AND TECHNOLOGY OUTLOOK

Both, in the EU and the US the market potential could increase substantially, if cost, efficiency, durability, reliability and environmental emissions of existing designs are improved and pushed closer to their technological limits.

For the near future, the leading microturbine manufacturers have the ambitious plan to develop a new generation of microturbines until 2007 to 2010. This new microturbine generation aims at the following microturbine performance targets [9]:

- **High Efficiency**: Fuel-to-electricity conversion efficiency of >40%.
- **Environmental Superiority:** NO_x emissions lower than 7 ppm for microturbine systems operating on natural gas
- **Durability:** 11.000 hours of operation between major overhauls and a service life of >45.000 hours
- **Economical Competitiveness:** System costs lower than 500 Euro per kilowatt and electricity production costs competitive with the alternative technologies
- **Fuel Flexibility:** Capability of using alternative fuels including diesel, ethanol, landfill gas and other biomass-derived liquids and gases

If these ambitious targets are reached, both the EU and the US microturbine market have the potential to increase substantially during the next few years. Thereby, building upon the fuel-flexibility of microturbines, the application of liquid bio-fuels burning microturbines may provide future market opportunities in the medium- to long-term.

6 REFERENCES

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