ALTENER Programme

Policy Recommendations
November 2004

BIOTURBINE

Opportunities for Biofuel-burning Microturbines in the European Decentralised-generation Market

Project Co-ordinator:

WIP, Sylvensteinstrasse 2, 81369 Munich, Germany

Project Partners:

ETA, Piazza Savonarola 10, I-50132 Florence, Italy

Energiedalen i Sollefteа AB, Energihuset Nipan, 33552 Sollefteа, Sweden

European Biomass Industry Association (EUBIA), Rond-Point Schuman 6, B-1040 Brussels, Belgium

---

ALTENER Contract No. 4.1030/Z/02-011/2002

Content

1. Abstract

Microturbines are small gas turbines in the range from 25 kW_e up to 250 kW_e. 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. In spite of these obvious advantages the upper limit for the microturbine market in Europe has been estimated at about 300 installed units by the end of 2003.

Today, there is an uncertainty of the market potential of this innovative technology, because microturbine electricity generation is too expensive to achieve significant market penetration. In the EU the market potential could increase substantially, if cost, efficiency, durability, reliability and environmental emissions of the existing designs are improved and pushed closer to their technological limits.

This document summarizes a set of recommendations for the future development of the (biofuel) microturbine market in Europe. Thereby, recommended actions address technology research, system development as well as the set-up of a supportive policy framework. The most important actions are:

Technology Research Recommendations

- Improvement of physical properties and economics of high-temperature and scaling-resistant metal-alloys and ceramics.
- Optimisation of combustion technology for liquid fuels improving fuel injection and spray formation.
- Application of Silicon carbide (SiC)-based components.
- Evaluation/development of low cost, high quality biofuel production processes.

System Development Recommendations

- Development of a 200 kW_e microturbine (promising future generation capacity range, especially for the use of biogas).
- Capability of fuel supply system to operate on (bio-) fuels (Dual fuel capability).
- Improvement of equipment reliability for the use of biofuels (gas compressor).
- Design of completely engineered block-type heat and power plant modules providing a simple Plug & Play option
- Flexible microturbine equipment kits for promising application types.
- Standardised interconnection and controls devices of batteries and electrical machines.
- Development of CHP equipment, such as absorption chillers, suitable for the exhaust temperatures of microturbines.

Supportive Policy Framework

- Standards for electrical interconnections of distributed power generation facilitating the access to the grid for small producers.

- Energy efficiency titles, Green certificates and emission trading certificates supporting CO_2-emission saving technologies.
- Security of biofuel supply for the users (area-wide infrastructure)
- Disseminate information on biofuel utilisation benefits and reliability

By these actions the biofuelled microturbine market will be set in the position to contribute significantly to the targets of the Kyoto Protocol to reduce the greenhouse gases emissions of Carbon dioxide (CO_2).

2. Introduction

2.1. The BIOTURBINE Project

This work was performed within the project, 'Opportunities for Biofuel-burning Microturbines in the European decentralized-generation Market' which is co-financed by the European Commission in the framework of the ALTENER programme (Contract No. 4. AL-2002-11).

The main objective of this study was to assess the technical feasibility and the market potential of biofuels-burning microturbine systems for power/heating application, which is considered a short-term option to deploy this innovative and efficient technology for distributed power generation, and which can contribute to the market development of biofuels in Europe.

This document provides help for decision-makers to define directions for R&D programs and public policies. It mainly addresses stakeholders involved in:

- microturbine systems
- utility systems
- microturbine manufacturers
- biofuel production
- government regulations and EU-decision making process (Commission, Parliament), in developing support policies
- energy consultants

2.2. Current Microturbine Market

During the last few years microturbines with a power range of 30 – 250 kW_e 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. Microturbines are well suited for the reliable provision of electricity and heat for stand-alone and grid-connected applications and they are a very attractive power supply option whenever co-generation (CHP) can be exploited. Finally, micro-turbines show a large flexibility to fuels so that they can be operated with natural gas, bio-gas, diesel, gasoline as well as with liquid bio-fuels.

By the end of 2003, the upper limit for the microturbine market in Europe has been estimated at about 300 installed units, corresponding to a generation capacity of approximately 18 MW_e. Today, many units are used for demonstration and research purposes. Companies are testing this new technology in order to determine its features and possibilities for application, but these installations are not fully commercial services.

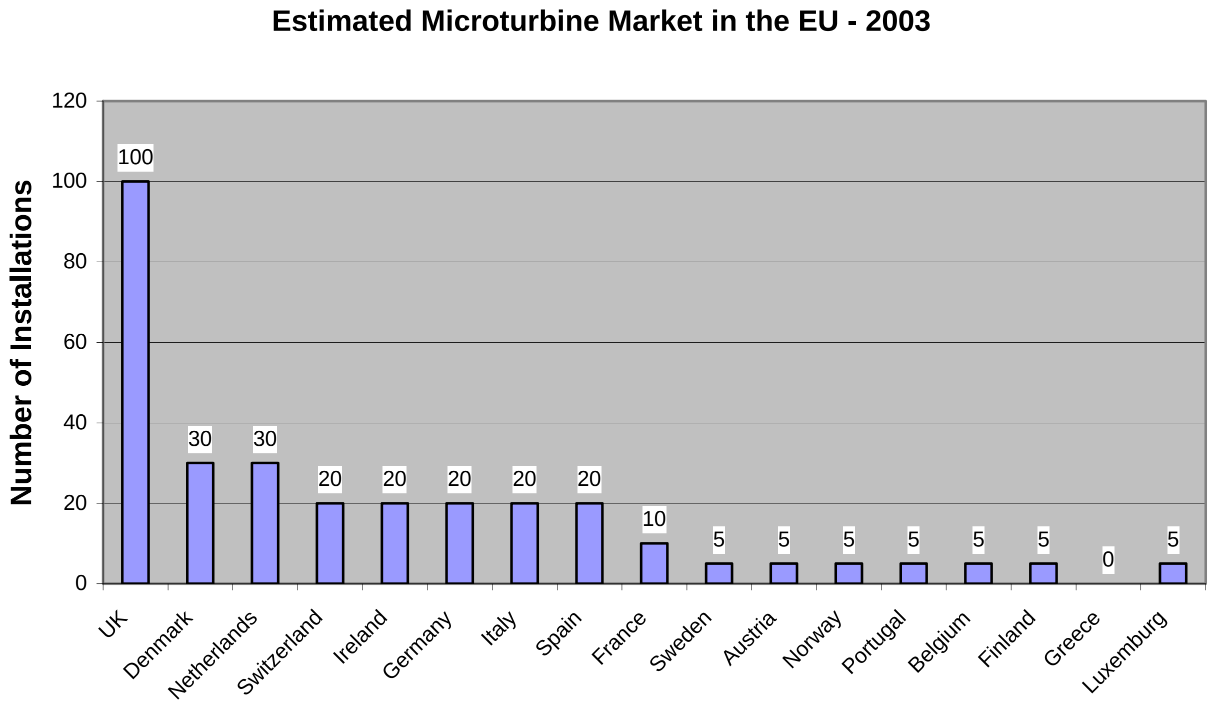

Figure 1: Estimated microturbine market in the EU -2003

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's possible to distinguish EU countries with almost no microturbine market such as Austria, Sweden, Norway, Portugal, Belgium, Finland, Greece and Luxembourg, from countries having started to commercialise microturbine systems and having already gathered significant operational experience such as Denmark, the Netherlands, Ireland, Germany, Italy, Spain and France.

At present, worldwide there are six microturbine manufacturers in business. These are :

- Turbec AB, Malmö, Sweden (owner: API Com srl, Italy)
- Bowman Power Group Limited (BPG), Southampton, United Kingdom
- Capstone Turbine Corp., Chatsworth, California, USA
- Elliott Energy Systems, Stuart, FL, USA
- Ingersoll-Rand Energy Systems (former NREC), Portsmouth, NH, USA
- Toyota Turbine and Systems, Inc., Japan

Their combined worldwide total industry shipments (excluding Toyota Turbine and Systems, Inc.) amount to over 3 500 units (Figure 2). Capstone, the largest manufacturer has 85% of this market share with its 30 kW_e and 60 kW_e models.

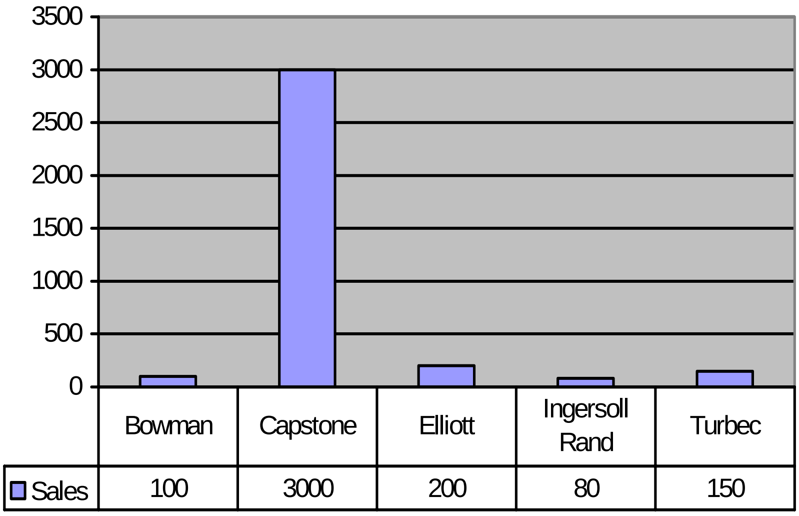

Figure 2: Approximate Microturbine Shipments (May 2003)

Microturbines have largest sales in the United States and Canada, resulting largely from a demand propelled by the US energy crisis in the western states, followed by the Asian Market and Europe.

In Europe today three manufacturers are active: Capstone Turbine Corp., Turbec AB (new owner: API Com srl) and Bowman Power Group Limited (BPG). Figure 3 presents the market share of these three companies in Europe:

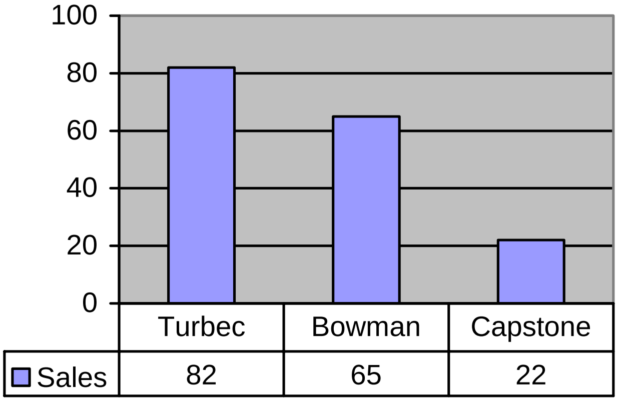

Figure 3: Market share in Europe (May 2003)

3. Barriers and future Aims

3.1. Barriers

Presently, microturbine technology is too expensive to achieve significant market penetration. The market potential could increase substantially, if cost, efficiency, durability, reliability and environmental emissions of the existing designs are improved and pushed closer to their technological limits. The main barriers are:

- The net electrical efficiency of recuperated microturbines ranges between 25 - 30 %. Conventional technology reciprocating engines show more than one third higher electrical output due to the higher electrical efficiency.
- The costs for (liquid) biofuels in the EU are often higher than for fossil fuels.
- The specific equipment cost of 1200 - 2000 Euro/kW are more than doubles the costs for conventional reciprocating engines.

Further barriers for successful microturbine application, especially for operation with biofuels:

- Operation on (liquid) biofuels requires design features, that make necessary expensive redesign and system modifications.
- Only for a few application types tailored microturbine equipment kits are available.
- Emission levels for liquid fuels or most biofuels are less favourable than for natural gas.
- Microturbine heat stream mostly has to be utilised, but adequate CHP equipment (such as absorption chillers) is rare for the adequate use of the microturbine heat stream.
- Lack of knowledge and uncertainty dissuading end-users from adopting this new technology.

3.2. Technical Aims

Currently, the performance of microturbines has not reached its 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:

- 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 concerning the improvement of costs, efficiency, durability, reliability and environmental emissions are reached, both the EU and the US microturbine market have the potential to increase substantially.

The development of the microturbine market in EU countries will during the next few years significantly depend on the improvement of technological and economical performance, the natural gas and electricity price ratio as well as the level of Governmental support.

3.3. Market Aims

The market potential on EU level has been estimated in the framework of the EC co-funded project ‘Optimised Microturbine Energy Systems – OMES’. Based on the number of locations having suitable heat and electricity demand profiles, the individual cost levels of electricity and gas in the member states and assumed potential for alternative heat supply (district heating), the number of technically potential installations for CHP based on microturbines has been estimated for different sectors.

The total technical market potential in EU-15 in the commercial/domestic sector has been estimated to approximately 947.000 units. The average units size is about 60 kW_e amounting to a total installed capacity of 57 GW_e.

In the industrial sector, there is potentially a very large market if integrated solutions like CHPC (expected in the short-term), as well as direct drive applications can be further developed, technically matured and produced in large numbers, consequently reducing the production cost.

4. Microturbine Technology Development

An extensive research and technological development is essential for the European microturbine market to gain competitiveness to conventional generation technologies. The major goal of all efforts to achieve the aims mentioned above must be substantial generation cost reduction.

4.1. Approach

In the following, research and development approaches are highlighted, leading to improved characteristics of microturbine systems.

Efficiency

The microturbine overall efficiency can be increased by the efficiencies of the single components. Here, the turbine wheel efficiency ranks first, then the compressor efficiency, the recuperator efficiency, followed by the power converter efficiency.

High temperature materials that resist high temperatures over 950 °C can provide substantial improvements in terms of efficiency. This applies to the turbine blade material as well as heat exchanger/recuperator materials, since the entry temperatures determine the thermodynamic cycle efficiency. For metal selection, highly sophisticated super-alloys have to be taken into account as well as ceramics. The latter promise significant opportunities over the medium and long-term. These materials offer efficiency improvements for recuperators and turbines of over 50 %, leading to microturbine overall electrical efficiencies of about 40 %.

Ceramics are inert materials that are not affected by aggressive and corrosive compounds. This fact is especially important for many biofuel applications.

The power electronics of microturbines may cause a remarkable amount of parasitic losses. In this field, improvements can be realised by new materials, such as silicon carbides (SiC). SiC-based power devices provide the features desired in microturbine power converters, like reduced losses, higher efficiency, reduction in the heatsink size, smaller passive components, and less susceptibility to extreme ambient heat. Further investigations and tests are necessary for the development of these novel materials.

The requirements are high for gas turbine components concerning tolerances and surface quality, because these parameters have an impact on losses in the turbine. Refined manufacturing and shaping technologies will have to be applied.

Emissions

Objectives for combustion technology improvements for liquid fuels focus on highly efficient and ultra clean fuel combustion properties. Thereby, the improvement of fuel injection and spray formation (for liquid biofuels as well as for liquid fossil fuels) are the central topic to be addressed. Due to the relatively high viscosity of liquid fuels, spray formation is adversely affected leading to a lower quality of the fuel/air pre-mixture. Since the fuel/air pre-mixture has a large impact on combustion emissions, improvements would facilitate lower NO_X and other pollutant emissions.

Fuel Flexibility

Microturbines shall be capable to operate on several fuels of similar properties (fuel switching capabilities). This includes the capability of using alternative fuels such as diesel, ethanol, landfill gas and other biomass-derived liquids and gases. In order to guarantee a maximum fuel flexibility fir microturbines, further research on combustion technology is necessary.

An important research area addresses the improvement of bio-fuel quality. In particular, the content of impurities (i.e. solids, alkali/alkaline metals, siloxanes, sulphur, chlorine and phosphor) are to be reduced, since they can cause deposits, erosion and corrosion problems. Cleaning and filtration are required for satisfying operation results.

Durability

Microturbine equipment such as gas compressor and fuel pumps seriously affect the system durability. An improved reliability will lead to lower O&M costs and longer service intervals. Furthermore, appropriate installation, which may not be realised due to a lack of experience, is crucial to ensure a long system life time.

Economic Competitiveness

Economic competitiveness demands both, competitiveness of investment and generation costs. Specific investment costs can be reduced by means of scaling-up of microturbine systems. For example, gas cleaning units for biogas microturbine applications show fix costs independent of system rated output. Furthermore, system redesign towards cheaper component production costs and less assembly work can reduce system costs. This applies to the key components recuperator/heat exchanger, turbine wheel and auxiliary equipments.

Lower generation costs can be achieved by the provision of low cost fuels. Here, further development of cheap biofuel production processes and adequate feedstock utilisation is necessary as well as the establishment of a suitable biofuel distribution infrastructure.

4.2. Recommended actions

The following actions are recommended to stakeholders from European research, policy and industry in order to establish a competitive microturbine technology and open up new markets. Central to these efforts is funding of extensive research and technology development that provides know-how and experience, that cannot be generated by private investors alone.

Basic R&D efforts should address several fields:

- Improvement of physical properties of component materials like high-temperature and scaling-resistant metal-alloys and ceramics. This includes the improvement of tensile strength, creep growth behaviour and methods of material examination, as well as durability and material costs.
- Optimisation of combustion technology for liquid fuels focusing on the improvement of fuel injection and spray formation. This includes new,

innovative combustion technologies, such as Catalytic Combustion, Porous Burner and Trapped Vortex combustion.

- Development of manufacturing and shaping technologies. As the requirements are high for gas turbine components are high, the achievable forming tolerances and surface qualities have to be improved.
- Application of Silicon carbide (SiC)-based components.
- Evaluation and development of low cost, high quality biofuel production processes.

Specific design and development projects should address:

- Development of a 200 kW_e microturbine.
- Flexible design of fuel supply system, capable to operate on several (bio-) fuels (Dual fuel capability).
- Design of biofuel capable compressors.

5. Market Development

This chapter summarises the current legislative framework, that affects the microturbine market in the EU and proposes activities, that address the following topics:

- Microturbine applicability for customers.
- Microturbine manufacturing industry in the EU.
- Development of (liquid) biofuel market in the EU.

5.1. European Legislative Framework

Several EC directives are suitable for promotion of microturbine application and biofuel utilisation:

Renewable Energy Sources (RES)

Several recent EC directives – regarding the promotion of electricity from RES, cogeneration, the promotion of biofuels, the liberalisation of the energy markets – will have a significant impact on the microturbine sector:

- Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market;
- Council directive 2002/58/EC established the share of greenhouse gas reduction among the EC countries to achieve the targets of the Kyoto Protocol;

- Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport;
- Directive 2003/54/EC concerning common rules for the internal electricity market;
- Directive 2003/55/EC concerning common rules for the internal natural gas market;
- Directive 2003/87/EC regarding emission trading;
- Council directive 2003/96/EC concerning the taxation for energy production has significant implication in pushing renewable energies;
- Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market.

The recent Directive 2004/8/EC on the promotion of cogeneration has the purpose to increase energy efficiency and improve security of supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power based on useful heat demand and primary energy savings in the internal energy market. Microturbines are one of the technologies explicitly considered by the directive (Annex 1, (f)), which therefore provides a very positive framework for further development. However, no mandatory target is fixed.

With regards to microturbine technology the liberalisation process can play a fundamental role. The European electricity market is involved in a process of fundamental change. The EU Directive 2003/54/EC establishes the common rules for the generation, transmission, distribution and supply of electricity. The resulting benefits may be in terms of efficiency gains, price reductions, higher standards of service and increased competitiveness. The restructuring of (mostly state owned) large utilities may lead to an appearance of new actors in the market. Expected results are increased innovation, greater customer choice as well as less government intervention and subsidies.

The diversification of energy supply options will create a variety of opportunities for small- and medium-scale power and heat generation, in distributed generation applications as well as in certain niche markets.

Today, the main obstacles in achieving a fully operational and competitive internal market relate to the crucial issues of grid connection price policies and different degrees of market opening in EU member states.

Biofuel Market

In May 2003, the European Parliament and the Council adopted a directive for the promotion of biofuels for transport. This was the first directive in this field; its main objective is to raise the part of biofuels used for transport purposes from the current 0,6% to 5,75% by 2010. Biofuels include bioethanol, biodiesel and any fuel for transport produced from renewable energy sources. National Governments should, according to the directive introduce measures to promote the production and use of biofuels in their territory. This directive is expected to have an impact in the medium term, decreasing biofuel production costs. The next generation of liquid biofuels burning microturbine is therefore expected to benefit from it.

Furthermore, in order to foster the development of biofuels, the Council adopted in October 2003 a new fiscal directive on the taxation of energy products. This widens the scope of the EU minimum rate system, previously limited to mineral oils, to all energy products including coal, natural gas and electricity and updates the minimum rates for mineral oils unchanged since 1992. Energy products are taxed only when used as a fuel or for heating. Among other provisions the Directive allows Member States to exempt renewable energy sources, including biofuels.

5.2. Products and Application

Microturbines are ideally suited for distributed generation applications, referring to small-scale generation of electric power by a unit sited close to the load being served. Types of applications include:

- Continuous Power (base load power grid parallel), operated at least 6000 hours per year;
- Peak Power (peak shaving grid parallel), operated between 200-3000 hours per year during periods of high electricity price or high site demand;
- Combined heat and power (CHP), where waste heat is used for heating and/or cooling
- Premium Power, providing a higher level of reliability and/or power quality than typically available from the grid;
- Back-up/stand-by power, providing ancillary service including spinning/ non-spinning reserves, reactive power, voltage control, and local area security;
- Green Power, intending to reduce environmental emissions and impacts;
- Stand-alone power, serves a micro-grid based on one or more microturbines;
- Resource recovery, utilising essentially free fuels;
- Hybrid Electric Vehicle Power.

A comparison of the requirements of the single application type with the microturbine characteristics, leads to the conclusion that the microturbine fits best for CHP and Green Power applications, followed by Continuous Power, Premium Power, Stand alone Power, Resource Recovery, and Hybrid Electric Vehicle Power if cooling is required on board.

5.2.1 Requirements

Microturbine manufacturers will have to add features targeted for increasing customer satisfaction, matching conventional technology and expanding their entire niche markets. The enhancing of microturbine’s capability in the following key areas will make it a broader based product.

An important capability is the customer friendliness of microturbine application. Since microturbine units are small-scale, they have to be designed as far as possible for installation, operation and maintenance by not experienced non-technical staff. This requirement concerns the capabilities as follows:

Plug & Play Capability: Microturbine customers require that the microturbine can be installed, started-up and operated simple. The microturbine must be smart enough to operate unattended and advise customers in case of trouble-shooting and maintenance. This helps to reduce maintenance costs.

Furthermore, completely engineered block-type heat and power plant modules, which are dimensioned for specific heat and power demands for the utilisation of natural gas or biogas will be advantageous especially for not experienced small customers. The microturbine, gas compressor, heat exchanger, electronics, fuel conditioning, etc. have to be adjusted in size and capacity and mounted as one complete module. Such a “plug & play” module (e.g. in a weather-proof container) allows simple and flexible installation close to fuel source for distributed generation.

Low supervision requirements: Microturbine start and stop, control of load and output voltage/frequency, speed, and fuel flow should be done automatically without the need for supervision. A connection to a personal computer and to a remote control and monitoring service for a distributors supervision is important. In this context the installation of a virtual power plant is a favourable option, where many microturbines are controlled in remote mode. Virtual power plants present promising advantages in part load operation and district heat supply.

Modularity: In many applications microturbines require to work in parallel with other microturbines, energy sources or storage devices, such as fuel cells, photovoltaic systems, batteries, etc. This either demands for standardisation of interconnection devices or for devices capable for various input and output voltages and currents. Modularity increases the application flexibility:

- Energy users have energy demands that can grow, so they may decide to add production capacity as demand rises or as new opportunities arise for cogeneration;
- Standard size units will lead to reduction of their cost;
- Distributed power has the advantage of installing smaller units in more places instead of only one large unit in one place and exploit the best local opportunities (virtual power plants). This will require modular units with reasonable cost in order to compete with the central production capacity approach;
- Biofuel is storable, so any electricity production technology with biomass is a good complement for non programmable renewable sources, like sun, wind etc.

Modularity also contributes to a reduction of engineering costs, if custom tailored application kits were available. Today, the adjustment and dimension of microturbine plants requires additional engineering work. Also, the implementation of specific functional application requirements often causes problems. An example for this is the implementation of the seamless transition from grid-connect to stand-alone mode. Many manufacturers offer this option but, voltage fluctuations in most arrangements remain. In some products, the transitions even range from a few seconds to a few minutes. Here, a flexible product line of pre-adjusted components and devices in a modular conception could be of help.

Fuel Flexibility: Microturbines will need to operate efficiently on a variety of fuels. At present, natural gas is the most common fuel type. Units are also available for diesel, propane and biogas. In order to exploit the whole application and market potential of microturbines, in particular the capability for liquid biofuels and low heating value biogas is necessary. This will give the opportunity to provide a microturbine operating on vegetable oil avoiding hazardous substances (e.g. motor oils, fossil fuels). This allows operation in nature parks and water protection areas, where no conventional combustion engines are allowed.

Furthermore, the possibility will be needed to fuel microturbines with different fuel types, to switch between fuels and to fuel the microturbine simultaneously with two fuels (dual fuel mode). This can be used for a smooth microturbine start-up and for pipe and nozzle washing with a second fuel. Dual fuel systems also enable the use of low value fuels, that can only be fired supplementary to a primary fuel.

5.2.2 Recommended actions

- Design of completely engineered block-type heat and power plant modules providing a simple Plug & Play option.
- Flexible connection devices: Only a few manufacturer's units have a feature for connecting several microturbines (or other energy sources). This interconnection requires devices, that are capable for different inputs, i.e. variable DC voltage input and devices, that are able to control these energy sources.
- Research on best connection methods: Possible approaches are e.g. to convert power of each different energy source first to DC or high frequency AC, before connecting. Or each unit can be connected to the grid separately. These and possible alternative solutions have to be investigated.
- Standardised devices: E.g. liquid biofuelled hybrid electrical vehicles require interconnection devices and controls of batteries and electrical machines. Standardised devices would simplify and reduce the prices of these systems.
- Units equipped with a dual fuel system for low and high value gases and for common liquid biofuels (vegetable oils, biodiesel or ethanol) and a conventional fuel. The tank for liquid biofuel should include a fuel preheating possibility.
- Production of high quality biofuels, reducing the required adaptations of microturbine systems with respect to standard fuels.
- CHP equipment, such as absorption chillers, suitable for the exhaust temperatures of microturbines.
- Provision of tailored microturbine equipment kits for promising application types.
- Provision of remote control option and services.

5.3. Business Environment

5.3.1 Current Situation

Presently, microturbine technology only shows a good economic efficiency for a few applications in Europe, the USA and Asia. These applications include distributed generation with the use of essentially free fuels (e.g. at oil platforms, landfills and sewage plants), as well as co- and trigeneration applications. Other applications require subsidies to be competitive with other generation technologies.

An economic analysis for continuous electricity-only and cogeneration application (full load at 90 % availability), assumed to run microturbines on bio-ethanol at 0,20 Euro per litre, found generation costs as presented in Figure 4.

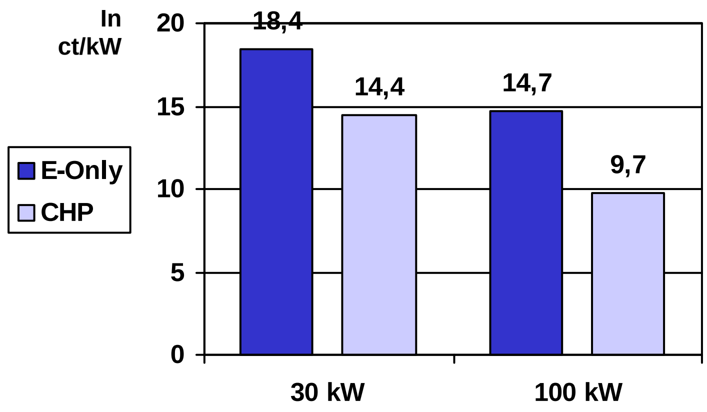

Figure 4: Liquid Bio-fuelled Microturbine electricity generation costs

Electricity generation costs of 14,7 – 18,5 ct/kW (electricity-only) and 9,7 – 14,4 ct/kWh (CHP) are higher than current industrial consumer prices, that base on large-scale electricity generation facilities. It is important to note, that the specific consumption costs (fuel costs) have the most significant impact on the generation costs.

5.3.2 Recommended actions

In the current initial market phase subsidies for green electricity generation are necessary to make biofuelled microturbines economically feasible. Also, competitive conditions for small scale electricity producers utilising biofuels need to be supportive. Recommended actions are:

- Support to microturbines through equal commodity prices for large and small power producers. In this way, the margin for profit will allow also small IPPs (independent power producers) to join the power production capacity and contribute to the EC target of distributed generation.

- Development of standards for electrical interconnections of distributed power generation facilitating the access to the grid for small producers. The recommended action is to create standardized certifications and authorization protocols to create a mechanism to reveal undeserved refusals to IPP.
- Increase of support to CO_2-emission saving technologies.
  Energy efficiency titles, Green certificates and emission trading certificates have been defined, but concrete application is hindered by lack of information and knowledge on these issues.
- Specific support of very low emission technologies.
  At the moment, there is no formal legislative recognition of the very low emission technologies, such as microturbines. One particular way to recognise this specific benefit could be to reward it through taxation on NO_x emission, a tax-exemption mechanism, or any other fiscal incentive to support low-NO_x technologies. In general, more severe emission limits would help microturbine development.

Market will develop only if needed support is given through long lasting guaranties upon power pricing from biofuels plants and the possibility of feeding into the grid.

5.4. Biofuel Market

At the moment, liquid biofuels are already playing a certain role in several countries, in most cases for automotive applications. The most common biofuels are ethanol, ethyl tertiary-butyl ether (ETBE), and biodiesel. A large ethanol market exists in North America and Brazil, where ethanol is used in different concentrations as blends in gasoline.

The European market for liquid biofuels is dominated by Germany and France, followed by Spain, Italy, Austria and Sweden. The European production of biofuels increased remarkably, especially the past three years. As from the year 1993, the European production level of biodiesel increased by almost eleven times, from 80.000 tons in 1993 to 860.000 tons in 2001. The European production of ethanol for application as an automotive fuel grew by 3 times as from 1993, namely from 47.500 tons in 1993 to 136.000 tons in 2001.

The utilisation of liquid biofuels for primary energy supply (i.e. for electricity generation and for heat generation) grew from 7.000 tonnes to 991.000 tonnes between 1990 and 2001 in European Union.

5.4.1 Requirements

An important pre-requisite for the up-take of liquid biofuelled microturbines is the existence of a suitable biofuel infrastructure in Europe. It can be expected that the new EU Biofuels Directive will have a positive impact in this respect.

Biofuelled microturbine technology should be presented as an opportunity to create additional demand for liquid biofuels (in addition to transport applications) to potential future biofuel producers (from agriculture and industry) as well as to distributors and consumers. Thereby, investors for the set-up of regional and local biofuel supply infrastructures could be motivated.

5.4.2 Recommended actions

The following activities are important to support the development of a EU biofuel market with the special focus of using biofuels in microturbines:

- Guarantee security of biofuel supply for users (area-wide infrastructure)
- Continue activities aiming at the processing of liquid biofuels into clean fuels, which are suitable for direct use in microturbines
- Disseminate information on bio-fuel utilisation benefits and reliability
- Agricultural programming for energy crops stimulation

6. Future Green Electricity Market

The Kyoto Protocol demands from the countries of the world to ensure that their aggregate anthropogenic emissions of the greenhouse gases such as Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O) do not exceed certain amounts. These amounts for overall emissions of such gases are endorsed with reduction commitments by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.

In contrast to this, it is likely that the EU will miss the first target of 12% renewable energy contribution until 2010. In 1997, in the EU-15, the share of renewable energy was 5,4%; by 2001 it had reached 6% (for comparison, oil contributes 40%, natural gas 23%, nuclear power 16% and solid fuels 15%). The European Commission assumes that the share of renewable energy in energy consumption will only rise up to 10%, less favorable scenarios even only to 9%.

Green electricity generation, intending to reduce environmental CO_2 emissions and impacts, is an application that shows good opportunities for microturbines. For green electricity application microturbines offer significant advantages with respect to the existing distributed generation technologies capable of using liquid biofuels, such as reciprocating engines, Stirling engines and fuel cells. Microturbines have considerably lower emission levels than the cheaper reciprocating engines, whereas the substantially higher investment and O&M costs for fuel cell technology, today exclude fuel cells from high volume utilisation.

Thus, biofuelled microturbines offer, among all biofuelled distributed generation technologies, the best cost-performance ratio in the field of green electricity generation.