European Commission

Biofuel-burning Microturbine

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

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Contents

The Bioturbine Project

The BIOTURBINE project, short for "Opportunities for Biofuel-burning Microturbines in the European Decentralised-generation Market", is funded by the European Commission (AL-2002-11) in the framework of the ALTENER programme.

The project is coordinated by WIP-Renewable Energies (Munich, Germany) and the partners are EUBIA - European Biomass Industry Association (Brussels, Belgium), ETA-Renewable Energies (Florence, Italy) and Energidalen Sollefteå (Sollefteå, Sweden).

The aim of the project is to assess the technical feasibility and the market potential of microturbines that run on liquid biofuels (shortly bioturbines) for power and heating applications (CHP).
These are considered a viable option for the short term future to promote an innovative, efficient and environmentally friendly technology for distributed power generation. It has the additional benefit of developing the biofuels market in Europe.

The opportunities for bioturbines have been evaluated through:

- Assessment and review of the current utilisation, technological development, technical/environmental performance of microturbine systems;
- Analysis of the liquid biofuels market and applications for power systems and the current state of development of bioturbines;
- Assessment of the potential market in Europe for bioturbines by means of identification of distributed-generation and niche electricity markets, comparison with competitive technologies, identifying the critical factors linked to technical and institutional barriers.

More information on the BIOTURBINE project can be found at:
www.bioturbine.org

Overview of microturbines technology and market

Microturbines characteristics

During the last few years microturbines in the range 20-300 kW have been developed as a promising technology for distributed power generation having some interesting characteristics like:

- Low maintenance;
- Very compact;
- High reliability;
- Low emissions;
- High flue gas temperatures useful for cogeneration;
- Flexible to use different fuels.

Microturbines are very simple systems having only one moving component: the high speed (1000 rotations per sec or more) shaft supporting the compressor, turbine wheel and generator. The shaft is mounted on air bearings rather than lubricated bearings, which are commonly used in conventional turbines. This reduces maintenance and technical complexity.

Cogeneration units include additional components such as heat exchangers to produce hot water or steam. Heat exchangers serve also to increase electrical efficiency (heating inlet air).

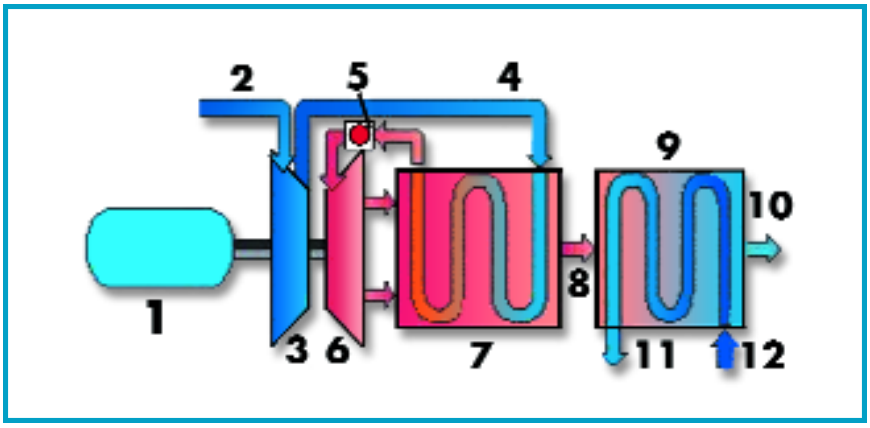


Fig. 1: Basic Microturbine elements
1- Generator
2- Air Inlet
3- Compressor
4- Air to recuperator
5- Combustion Chamber
6- Turbine
7- Recuperator
8- Exhaust gases
9- Heat exchanger
10- Exhaust gas outlet
11.- Hot water outlet
12.- Water inlet

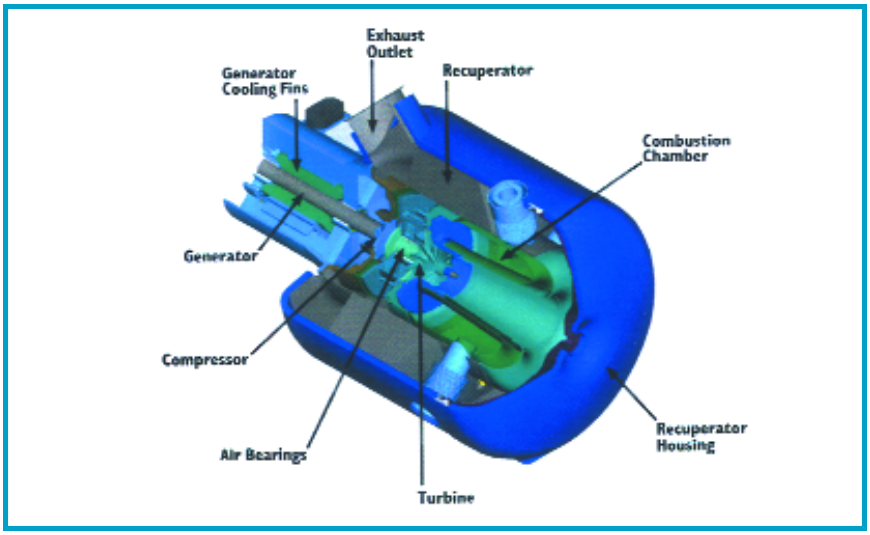
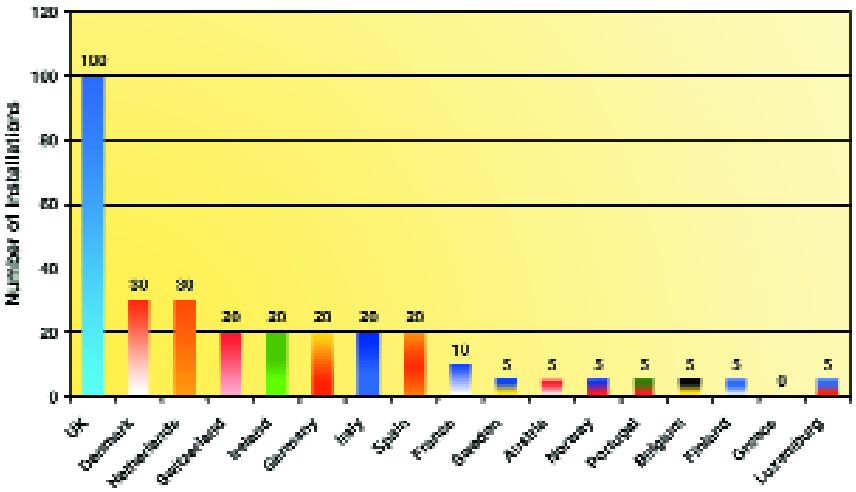


Fig. 2: Capstone Microturbine (by courtesy of Capstone)

Microturbines market in Europe

In spite of all the advantages offered, a microturbine market in Europe is hardly existing. In 2003 the total for the microturbine market has been estimated at about 300 installed units corresponding to a generation capacity of approximately 18 MWe.

Fig. 3: Estimated Microturbines 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 commercialize microturbine systems and having already gathered significant operational experience such as Denmark, the Netherlands, Ireland, Germany, Italy, Spain and France.

The main reasons for this unsatisfactory current market are lack of knowledge, high investment and high energy production costs, that make them not competitive compared to conventional power supply, and a need of further research to improve their performances, especially using biofuels. Actually microturbines have not reached their technological targets as reported in the Table below.

Performance targets	Up to now	In a few years
Efficiency of fuel to electricity conversion	30%	> 40%
Investment costs	900-1200 euro/kW	< 500 euro/kW
NOx emission	Tens of ppm	< 7 ppm

The market share by microturbines producers indicates that Swedish Turbec has the first place, closely followed by Bowman Power Systems, while Capstone, the world leader holding 85% of the market worldwide, accounts for lower sales in the EU than expected.

With respect to the type of fuel used, up to now the large majority of microturbines run on natural gas. Nevertheless activities are ongoing in several EU countries to test the performances of microturbines running on landfill gas, digester gas and biogas.

Microturbines applications

Possible applications

Microturbines offer opportunities for a variety of customers and applications in the residential, commercial and industrial sector.
They can have several potential applications as:

- **Continuous generation** (>6000 hrs operation/year)- to succeed microturbines will have to be able to generate electricity at costs competitive with grid connected power;
- **Peak power** (< 1000 hrs operation/year) for peak shaving: users can run on-site units to avoid paying high prices caused by peaks;
- **Backup power** (less than 100 hrs/year)- factors influencing microturbines application are their costs compared to diesel generator sets, their ability to start up rapidly, their reliability and the low expected operation and maintenance costs;
- **Premium power** where the process requires power with a higher quality (availability, constant voltage and frequency, no voltage dips, no harmonic distorsions) than provided from grid to avoid damages to machines, loss of data, loss of production;
- **Remote power** for far off grid applications;
- **Tri-cogeneration systems** for applications requiring thermal energy (heating and/or cooling) as well as electric power need for development of distributed generation.

Microturbines applications in the commercial/residential sector

A large market share in the microturbines market is currently occupied by the commercial/residential sector. The main reasons are that a large number of this kind of locations have suitable heat and electricity demand profiles, the gap between cost for electricity and gas is larger than in the industrial sector and there is a lower demand for return of investment than in the industrial area.
The major market potential in the commercial and residential sector is traditional CHP (combined heat and power) applications.

Fig. 4: Residential CHP-Turbec T100 (by courtesy of Turbec)

Some of the most important markets are expected to be hospitals, hotels, apartments or clusters of houses, residential homes, office buildings, schools, sport centres, supermarkets, swimming pools and sewage treatment plants.
District heating, using microturbines adopted in clusters, could be an attractive market, too.

Fig.5: Turbec T100 installed in a boiler room (by courtesy of Turbec)

Fig.6: Turbec T100-Hospitals heating (by courtesy of Turbec)

Microturbines applications in the industrial sector

Microturbines market shows a lower potential in the industrial sector due to the short payback time for investments required by industrial companies. Anyway the main market for CHP microturbines in this sector are expected to be: greenhouses, industrial laundries, SMEs having a certain heat demand, special process integrated industrial applications that need premium power.

Greenhouses have another advantage of microturbines: fertilisation with CO_2 from exhaust gas (with very low harmful content) as well as the drying potential.

Fig. 7: Greenhouses CHP- Turbec T100 (by courtesy of Turbec)

Microturbines applications in the transport sector

A very interesting application for microturbine could be the transport sector, especially when cooling is required and if trucks have an urban traject (hybrid trucks). It can also give a contribution to pollution control in urban areas and to urban emissions control in hybrid cars, being a good candidate for on board electricity generation. Hybrid cars are seen as the solution to comply with emissions standards.

Liquid biofuels

Environmental benefits from biofuels

Biofuels are liquid or gas fuels, produced from biomass through thermal/chemical processes.

Biomass denotes organic materials that are part of a short carbon cycle.
Biofuels can be considered "climate neutral" because the CO_2 balance shows that carbon dioxide (CO_2) released during combustion is absorbed from the air by crops for their growth through the photosynthesis process. No net CO_2 emissions are released to the air besides production and transport of biomass and biofuels (if not done with biofuels).

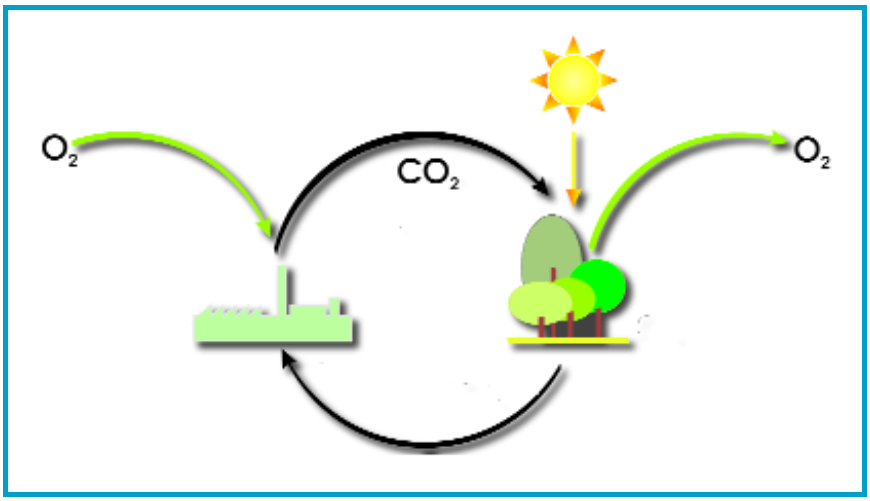


Fig. 8: Carbon Cycle

Liquid biofuels production

Biomass can be transformed into a biofuel by means of a biochemical process, involving anaerobic digestion or alcohol fermentation, or a thermochemical process, involving carbonization, gasification or pyrolysis.

The biofuels that have gained commercial potential are biodiesel and bioethanol. Other liquid biofuels under research are biomethanol, dimethylether, Fischer-Tropsch diesel, pyrolisis oil and Hydro Thermal Upgrading oil.

Main conversion processes are:

- Extraction of vegetable oils from oil crops (in Europe mainly from rapeseed), followed by esterification to produce biodiesel;
- Fermentation of sugar rich crops, such as food crops (corn, wheat, beet, sweet sorghum and barley) and the newly experimented woody biomass, followed by distillation to produce bioethanol;
- Pyrolisis of wood obtaining pyrolisis oil (diesel equivalent);
- Hydro Thermal Upgrading (HTU) of wet biomass obtaining HTU oil (diesel equivalent);
- Gasification of biomass using synthesis gas to produce biomethanol, DME and Fischer-Tropsch diesel.

The biomass feedstock necessary for biofuels production, taking into account only species with commercial potential:

Biofuel [1 ton]	Feedstock	Tons of biomass
Bio-ethanol	Grains	3
Bio-ethanol	Dry wood	3
Biodiesel	Rapeseed	2.5

Liquid biofuels market

Currently only bioethanol and biodiesel are applied on a commercial scale.
The global biofuels production is estimated about 15 million tons per year and Europe has still a small share, about 6% of the total production.

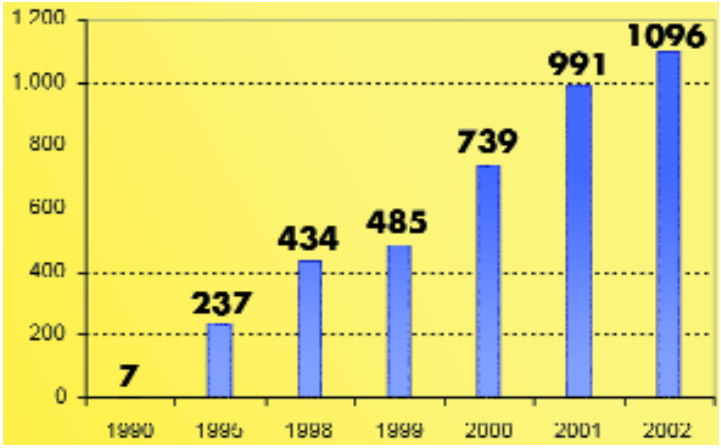
Most of the global production consists of bioethanol. The main producers are USA and Brazil, while Europe is the most important producer of biodiesel. Ethanol is, since short, quoted at the world commodity market.

Biofuels production is increasing. Biodiesel production increased from 80.000 tons in 1993 to 860.000 tons in 2001 (by eleven times), bioethanol production for automotive fuel application has grown by a factor three, passing from 47.500 tons in 1993 to 136.000 tons in 2001.

The countries producing the largest amounts of biodiesel are Germany (46%), France (40%), Italy (10%) and Austria (4%), while countries producing the largest amounts of bioethanol are France (42%), Spain (37%) and Sweden (21%).

The following table shows the trend for biofuels production for primary energy in Europe. The first producer (for primary energy utilization) is Germany (500.000 tons in 2001), followed by France (389.000 tons in 2001) and Spain (80.000 tons in 2001).

Fig.9 : Liquid biofuels for primary energy in EU. Source: IEA Statistics 2003



Current production costs of liquid biofuels depend on the used biomass prices and on the size (investment costs are higher for smaller plants) and type of production plant. For example the average production costs of bioethanol in Germany are 0.56 euro/l for a 500.000 hl plant and 0.5 euro/l for a 2.000.000 hl plant, if the used feedstock is wheat or sugar beet.

Electricity market within EU

European electricity market

The European electricity market is involved in a process of fundamental change. The previous regional and national supply monopolies are being dismantled. The EU Directive 92/96/EC concerning common rules for the internal market in electricity laid the bases for the electricity market within EU. On 26 June 2003, the European Parliament adopted the Directive 2003/54/EC, establishing 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, having a view to achieving a sustainable energy market.
According to the following data is provided by Eurostat and IEA about the energy consumption and production in Europe in 2003:

- Overall energy consumptions in Europe: 1.504,8 Mtep (52.3% imported, mostly as fuels);
- Primary input to electricity generation: 591,7 Mtep. Nuclear energy contributed with 39.3% followed by coal (28%), natural gas (19%), renewable sources (8.3 %) and oil (5.4%);
- Electricity generation: 2.723,6 TWh. Conventional thermal plants contribute with 53.3 %, nuclear with 33% and renewable sources with 13.7%;
- Greenhouse gases emissions: 3.213 Mt CO_2.

Electricity prices in Europe

Examining the electricity prices in Europe, using data taken from Eurostat updated to July 2003:

- For domestic consumers Denmark shows the highest prices, having the highest electricity production costs and the highest taxes, while the lowest prices are for Greece
- For industrial consumers electricity prices are the highest for Ireland and Italy, having very high electricity production costs and taxes, while the lowest prices are for Sweden.

Annual consumption	***600 kWh***		***1200 kWh***		***3500 kWh***		***7500 kWh***	
Countries	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*
Austria	17.3	12.4	15.5	10.9	13.4	9.2	12.9	8.8
Belgium	18.3	14.8	17.0	13.8	13.8	11.2	13.3	10.7
Denmark	32.5	17.0	26.2	12.0	22.1	8.7	20.9	7.7
Finland	19.4	15.2	13.9	10.6	10.6	8.0	9.0	6.6
France(A)	16.2	12.6	14.0	10.9	11.2	8.9	10.9	8.6
Germany(A)	26.0	20.4	20.9	16.0	16.9	12.5	15.5	11.3
Greece	8.2	7.6	7.7	7.1	6.5	6.1	7.4	6.9
Ireland	23.9	19.1	18.0	14.9	11.8	10.1	10.9	9.4
Italy(B)	9.6	7.8	10.0	8.1	19.8	14.7	19.3	14.3
Luxembourg	23.7	21.7	17.9	16.2	13.4	11.9	12.2	10.9
Norway	42.5	33.2	24.9	18.9	13.3	9.6	10.1	7.0
Netherlands	20.4	24.0	18.8	16.1	17.8	10.9	17.4	9.3
Portugal	13.7	12.9	15.5	14.7	13.2	12.6	11.8	11.2
United Kingdom	16.7	15.9	13.4	12.8	9.4	9.0	8.5	8.1
Spain	13.6	11.2	13.6	11.2	10.6	8.7	9.8	8.0
Sweden	30.2	21.8	20.3	13.8	13.7	8.6	12.7	7.7
European average(C)	20.0	16.3	16.2	12.8	13.5	10.3	12.5	9.4

Electricity prices (eurocent/kWh) for domestic consumers updated to 1st July 2003.
(A) Arithmetic average of prices in different regions
(B) Burdens are included in the Including taxes price
(C) Average based on national domestic consumptions in 2000

Source: AEEG elaboration based on Eurostat data- www.autorita.energia.it

Annual consumption	50000 kWh (50 kW 1000 hrs)		160000 kWh (100 kW 1600 hrs)		2 GWh (500 kW 4000 hrs)		10 GWh (2500 kW 4000 hrs)	
Countries	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*
Austria	13.1	8.9	11.5	7.6	8.4	5.0	7.2	4.0
Belgium	15.1	12.2	13.3	10.8	9.0	7.3	8.3	6.7
Denmark	11.0	6.5	11.0	6.5	11.5	6.9	-	-
Finland	8.8	6.8	8.3	6.4	7.0	5.3	7.0	5.3
France(A)	10.0	8.3	9.3	7.6	6.5	5.3	6.5	5.3
Germany(A)	17.3	13.7	14.9	11.6	10.0	7.4	9.5	7.0
Greece	9.7	9.0	9.0	8.3	6.6	6.1	6.6	6.1
Ireland	14.6	12.8	13.1	11.2	8.8	7.6	8.3	7.2
Italy(B)	14.0	10.4	12.8	9.4	11.7	8.4	11.1	8.5
Luxembourg	14.2	12.7	11.1	9.8	7.8	6.8	5.1	4.7
Norway	8.5	6.9	8.9	7.2	6.4	5.1	5.3	4.3
Netherlands	-	-	-	-	-	-	-	-
Portugal	10.6	10.1	8.8	8.4	7.1	6.7	7.0	6.7
United Kingdom	9.3	7.3	8.5	6.9	5.8	4.7	5.2	4.2
Spain	11.6	9.5	8.1	6.6	6.4	5.3	6.1	5.0
Sweden	5.8	4.6	5.5	4.4	5.2	4.1	4.9	3.9
European average(C)	12.2	9.7	10.8	8.5	8.0	6.2	7.6	5.9

Electricity prices (eurocent/kWh) for industrial consumers updated to 1st July 2003
(D) Arithmetic average of prices in different regions
(E) Burdens are included in the Including taxes price
(F) Average based on national domestic consumptions in 2000

Source: AEEG elaboration based on Eurostat data- www.autorita.energia.it

Annual consumption	24 GWh (4000 kW 6000 hrs)		50 GWh (10000 kW 5000 hrs)		70 GWh (10000 kW 7000 hrs)	
Countries	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*	*Including taxes*	*Without taxes*
Austria	6.8	3.7	6.9	3.8	6.4	3.4
Belgium	6.9	5.6	6.2	5.0	5.4	4.4
Denmark	-	-	-	-	-	-
Finland	6.6	5.0	5.7	4.2	5.6	4.1
France(A)	5.7	4.5	-	-	-	-
Germany(A)	8.5	6.1	8.9	6.4	8.2	5.8
Greece	5.6	5.2	5.2	4.8	4.6	4.2
Ireland	7.4	6.4	7.1	6.1	6.5	5.6
Italy(B)	9.7	7.7	9.1	7.3	8.6	6.8
Luxembourg	4.5	4.0	4.7	4.3	4.3	3.8
Norway	4.5	3.6	4.2	3.4	4.1	3.3
Netherlands	-	-	-	-	-	-
Portugal	5.9	5.6	5.4	5.2	5.0	4.8
United Kingdom	4.9	4.0	4.7	3.9	4.3	3.6
Spain	5.8	4.8	5.7	4.7	5.6	4.6
Sweden	4.6	3.7	4.7	3.7	4.5	3.6
European average(C)	6.8	5.3	6.8	5.3	6.4	4.9

Electricity prices (eurocent/kWh) for industrial consumers updated to 1st July 2003
(G) Arithmetic average of prices in different regions
(H) Burdens are included in the Including taxes price
(I) Average based on national domestic consumptions in 2000

Source: AEEG elaboration based on Eurostat data- www.autorita.energia.it

Opportunities for bioturbines in the EU

As already mentioned the number of installed microturbines in Europe up to now is quite low, but they have a good potential market, especially if bioturbines are considered.
The most interesting applications are identified as buildings, hospitals, municipalities, hotels, food processing industries and greenhouses.
Two applications that have, after due efforts for innovation, extremely large potential, are: district heating, using microturbines adopted in clusters and the transport sector, especially if applied with hybrid technology.

The following actions are recommended in order to have the right framework for this innovative technology development, improving market chances:

- A standardisation and biofuels characterisation is necessary;
- A secure supply of biofuels will stimulate its credibility;
- Further research has to be done to improve the performances of bioturbines;
- Demonstration of the capabilities of this technology to potential private and public users;
- Increasing potential users awareness, by means of a specific information addressed to local authorities, citizens, energy companies and industries regarding distributed cogeneration and advantages of renewable energies;
- A precise legislative framework for renewable energies, energy efficiency and cogeneration promotion;
- Regulations concerning the electricity exchange with the grid and a simplifying of the authorization requirements;
- Incentives have to be put on biofuels so that an increasing demand will induce lower production costs.
- Adequate taxes differentiation between biofuels and fossil fuels;
- Acknowledgement of ultralow emissions of microturbines;
- Incentives and market stimulation for co-generation as an important energy efficiency technology.

Anyway the advantages shown by microturbines (low maintenance, being very simple and compact devices, high reliability, low noise and vibrations, low emissions, fuel flexibility) are expected to provide a successful development of this technology, especially if bioturbines are considered.
European and national environmental policies are favourable to their promotion.

The opportunities of the technology are consistent with the goals set by the EC.

Opportunity	*Corresponding EC goal*
Fuel flexibility leading to energy production from renewable sources	European countries have to get a certain contribution from renewable sources to the overall primary energy by 2010
Electricity generator for hybrid technology in transport	Directive 2003/30/EC on the promotion of the use of biofuels in transport
Reduce greenhouse gas emissions	Obligation to greenhouse gases reduction within the period 2008-2012, according to the Kyoto Protocol
Improve energy efficiency by means of distributed generation	Directive 2004/8/EC on the promotion of cogeneration based on useful demand in the internal market is pushing European countries to analyse the national potential and to define objectives to be achieved
Security in energy supply, lowering the dependence from fossil fuels, that means from non European countries, implying high electricity prices increasing in time	Green Paper on a European strategy of energy supply, 2000

Moreover the already started process of delocalisation of power in the electricity management and the electricity market liberalisation can favour the distributed generation and also the renewable energy sources promotion.

Another favourable factor for distributed generation can be arise as a consequence of the very frequent blackouts and a not very good power supply due to a distribution network not appropriate to satisfy the increasing demand of electricity. End users could get electricity with the reliability they need.

Bioturbines are therefore going to be a strategic option to face all legislative constraints and to push a sustainable energy production.

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