MGT Technology Summary

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Executive Summary

1. Introduction

The MGT Technology Summary has been produced by a technical Working Group composed by MGT OEMs, Heat Exchangers Manufacturers and R&D Institutes coordinated by the European Turbine Network (ETN). The Working Group aims to bring together MGT experts, to accelerate the development and market deployment of MGT technology.

The aim is to encourage through the preparation of a detailed summary, the investment for EU Industries and decision makers in further research and development for the MGT.

The first part of the paper provides an overview of the MGT and the challenges in developing the technology further in terms of system optimisation, material selection, reduction of production costs, reduction of maintenance and part replacement costs, life extension and hence reducing the environmental impact from system and part manufacturing. The document also analyse the results of international research projects.

The second part intends to give a full understanding of how the MGT integrated with CHP and RES could contribute in reaching the EU 2030 targets.
The Expected Impact chapter aims to analyse the impacts of deploying MGT, focusing on the energy savings, the reduction of CO emissions and the higher flexibility to easy the integration of the RES into the power grid.

This summary concludes with a set of alternative potential directions and cooperation opportunities for the development of the MGT in the short and long terms.

2. MGT Vision

MGT should become a strongest commercial alternative for small scale power generation (typically less than 300 kW) both compared to todays ICE (internal combustion engines) and possible future fuel cells. Stationary power generation as well as in the transport sector.

3. MGT Technology

3.1 Technology background

The development of microturbines (MGT) started in the late 80ies. Important driver was the automotive industry which for many years had been active in development of small gas turbines with mechanical drive as an alternative for diesel and gasoline engines (internal combustion engines – ICE) for use in vehicles. Main reasons are the advantages of the gas turbine regarding low emissions, fuel flexibility and a potential to compete on cost with ICE. With use a high speed generator instead of mechanical drive the technology became very suitable of use in hybrid vehicles
However at that time (1990ies) the hybrid electrical drive train was not a technology that was mature enough for the market and the interest from the automotive

Instead other non-automotive companies picked up the MGT technology and introduced it on the decentralized power generation market where its long life and low maintenance cost could compensate for higher first cost. This is now a fast growing market.

3.2 MGT Technology challenges

- **Efficiency**
  Increase the efficiency to 35-45% depending on size. Combinations with fuel cells for over 50%

- **Emissions**
  Less than 3 ppm NOx on fossil fuels

- **Fuel Flexibility**
  Use of hydrogen if needed

- **Recuperator**

- **Power electronics**

Cost less than 500 €/kW in lower volume power generation applications and less than 50 €/kW in high volume vehicle applications

3.3 MGT Applications

Microturbines (MGT- a small gas turbine with a high speed generator) have a very large potential to become a very important power generation source for different applications in stationary as well as in transport applications.

- Combined heat and power (CHP)
- Combined cooling heating and power (CCHP)
- Resource recovery
- Peak shaving and base load power
- Thermal oxidation of very low Btu fuel or waste streams
- Premium power
- Power only applications
- Microgrid

3.4 Technologies comparison

Because the ratio between heat demand and electricity demand has a large range, various types of micro-CHP systems have been developed:

- Internal combustion engines
- Stirling (external combustion)
- Microturbines
- Fuel cells

The micro gas turbine technology (0.5 to 250 kW) is a promising technology that is finding its position in the market thanks its flexibility of RES integration and to the lower costs compared to the other technologies. In a recent benefits/costs analysis conducted by European Commission, microturbine technology for micro-CHP has shown to be the best solution in terms of costs/emissions, as shown in the table below:

Technology	Cost (€/kWe)
Internal combustion engines	1.000 (50kWe) – 3.000 (5kWe)
Microturbine	1.000 (60kWe) – 2.500 (30kWe)
Stirling engines	4.000 (3kWe) – 8.000 (1kWe)
Fuel Cell	4.500 (>20kWe) – 25.000 (1kWe)

Internal combustion engines

MGT, compared to ICE, are better on fuel flexibility, emissions, life/maintenance, size/weight and noise. Equal on efficiency and cost.

Fuel cells

MGT, compared to Fuel Cells, are better on fuel flexibility, cost, life/maintenance and size/weight. Equal on efficiency and emissions

Stirling engines

Additional information at http://www.multigen.com.au/technology-comparison/

3.5 International developments

At international level markets are mainly different applications within the decentralized power generation segment, very often aimed at applications that use different renewable fuels. There are also new market opportunities in this segment such as concentrated solar power, combinations with fuel cells and micro CHP.

Interest for the technology for vehicle applications is increasing since hybrid electrical vehicles are now a commercial reality.

In parallel there have been important technical progress within areas such as ceramic materials and heat exchangers which are areas of large importance for the MGT.

3.5.1 High Efficiency Microturbine with Integral Heat Recovery

http://energy.gov/eere/amo/high-efficiency-microturbine-integral-heat-recovery

3.6 European Initiatives

In Europe there are a number of small MGT companies and companies working with different components that are used by MGTs. There are many European universities and institutes that are working with important development work in the MGT area.

The reason why it is an American company that is the leading MGT company today is that the US government had a very strong national program on small gas turbine and MGT technology in the 80ies and 90ies and that there is a larger interest in the US than in Europe to invest venture capital in small scale power generation technologies.

With that in mind and with the enormous market potential it is now suggested to form of a European network/project/cooperation between MGT companies, universities/institutes and suppliers.

The goal is to accelerate the development of the European MGT technology and thereby strengthen European industries in this area. Examples of activities are among other things joint development work. This will not only strengthen the European MGT technology but it will also help to attract investment capital.

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

3.6.1.1 BIOTURBINE Objectives

The BIOTURBINE project, short for “Opportunities for Biofuel-burning Microturbines in the European Decentralised-generation Market”, is co-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), ETARenewable 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 (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.

3.6.2 OMES – Optimised Microturbine Energy Systems

3.6.2.1 OMES Objectives

- To obtain energy savings and reduced emission through use of micro gas turbines in different CHP applications, including SME's.
- To validate data on performance, energy efficiency, availability, emission etc. during practical operation for the only European-made micro gas turbine.
- To develop and demonstrate cluster installation of microturbine CHP units.

- To demonstrate multi-fuel capacity including bio fuels and fuels with low heating value (down to approx. 5kWh/m3n).
- To develop and demonstrate flexible steam production by micro gas turbine.
- To demonstrate advantages with direct drying and/or the use of flue gas for fertilization purposes.
- To demonstrate small-scale CHP at remote locations.
- To ensure European knowledge and commercial participation in the field of development, production and implementation of micro gas turbine based CHP.
- European estimation of microturbine based CHP potential.

3.6.3 OMSoP – Optimised Microturbine Solar Power System

3.6.3.1 OMSoP Objectives

The overall objective of this project is to provide and demonstrate technical solutions for the use of state-of-the-art concentrated solar power system (CSP) coupled to micro-gas turbines (MGT) to produce electricity. The intended system will be modular and capable of producing electricity in the range of 3-10 kW. The aim is to make such a system available to provide energy needs for domestic and small commercial applications. For larger energy needs, the units can be stacked by virtue of their modular nature. It can be integrated with medium and long term energy storage and/or co-firing with conventional fuels. The primary technical challenge is to enable the production of small scale cost effective, efficient, reliable and easy to maintain units.

To achieve these objectives, research and development will be conducted in all aspects of the system leading to a full scale demonstration. The parabolic dish concentrator technology will be improved to reduce weight, improve tracking system and increase concentration ratio. A receiver suitable for this application will be optimised. This requires the development of absorption materials and improving heat transfer and cooling technology. A novel feature of this project is the replacement of the Stirling engine which is typically used in this size of application, to convert thermal energy to mechanical power, with an MGT. Stirling engines suffer from problems such as high cost, complexity and poor reliability. A recently developed MGT will be optimised in conjunction with the CSP system. The demonstration activity will focus testing on the primary components. Although thermal storage and hybridisation with other fuels are beyond the scope of this project in terms of demonstration, they will be considered in the overall system optimisation from both technical and economic points of view.

4. Policy Context

The priority of the European Commission is to develop its Energy Union Strategic Framework to ensure security of supply, affordability and sustainability of energy production. This strategy would facilitate the achievement of the goals of the 2050 low carbon economy Roadmap. The challenge of reducing greenhouse gas (GHG) emissions by at least 80% compared to 1990 levels in a secure and affordable way, would require an effective and balanced implementation of renewable energy sources (RES), increased energy efficiency improvements as well as carbon capture and storage.

Advancements in energy technology are vital if Europe's 2030 and 2050 targets are to be fulfilled. Combined Heat and Power (CHP) systems with RES are a promising technology under development, acknowledged by the European Commission in the Strategic Energy Technology (SET)-Plan. The efforts in achieving these ambitious targets for 2030 will be equally important in both the generation as well as end-use sectors.

4.1 EU Policy framework

According to the studies of the International Energy Agency, in 2012 just 43% of the energy input was converted to electricity with thermal power plant while a co-generation power plant converts 61% of input energy into final electricity and heat. It is evident that one potential path towards a decarbonisation of the energy production consists in the share of electricity production using CHP, which accounts nowadays for 11% of the total power generation in Europe. Micro-CHP has gained interest in recent years due to its potential of providing efficient, clean and cost effective energy requirements for homes and small businesses. The main advantages of such systems are the provision of electrical and thermal energy wherever it is required, eliminating transmission losses and reducing the cost of energy infrastructures. The share of CHP in the total energy mix can and should be much higher, which will highly contribute to Europe’s climate and energy goals.

4.2 Policy Recommendations

5. Expected Impacts

5.1 Energy savings expected for MGT

5.2 Financial cost/benefit analysis

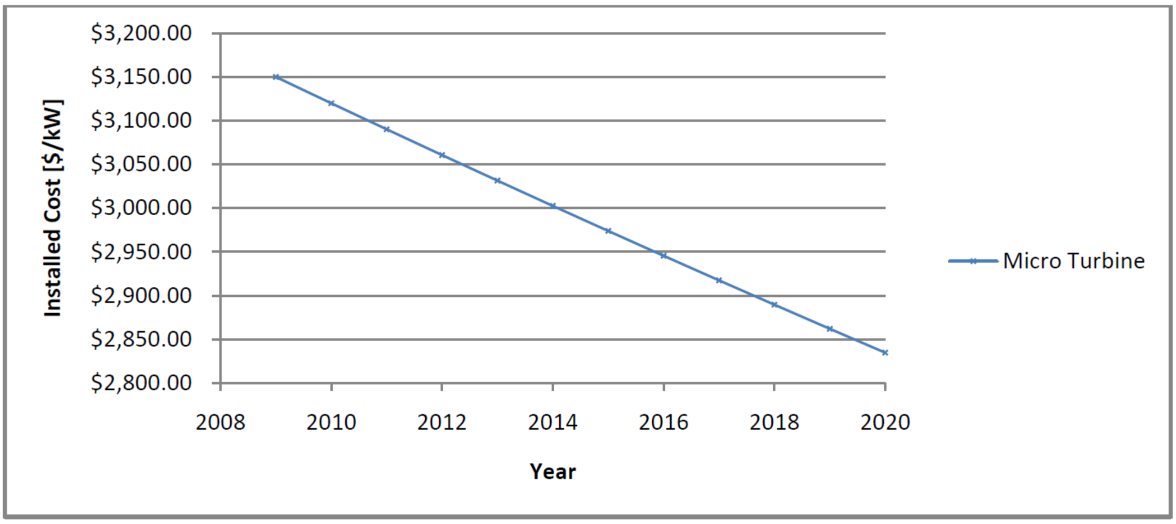

Figure 1 - Source: Cost-Effectiveness of Distributed Generation Technologies

5.3 RES Integration

The current technology allows the Distributed CHP to be adaptable with micro gas turbine (MGT) that could be integrated with RES (such as concentrated solar power (CSP) and biofuels) and would allow for CO_2 neutral power generation and cut down the cost of transport compared to centralised systems. However this poses challenges that are specific to the cycle configuration. Current technologies can handle specific types of biofuels and are commercially viable in large scale limiting their widespread deployment for distributed generation. The availability of suitable "CO_2 neutral fuel" as well as fuel flexibility (for improved reliability and availability) for small scale CHP are among the major challenges that needs to be addressed adequately to strengthen the interest for the technology. The availability of intelligent monitoring tools that can support non-expert end users is also an important challenge to address in order to enable the development for this technology.

- CSP
- Biofuels

6. Requirements on deployment

6.1 Important areas of cooperation

Cooperation between European MGT companies combined with a focused support from relevant Universities and Institutes can make MGTs an important future industry in Europe.

In the short term it is important to reduce cost of the technology. This can be done by focused development on some of the key cost drivers such as recuperators and power electronics.

In the longer term it is important to improve fuel efficiency. This can be done by use of higher operating temperatures which requires use of new materials such as ceramics. Work with more advanced cycles such as combinations with fuel cells, intercooling and polygeneration is also important.

Other key technical areas are new bearing solutions including air bearings and combustion of unconventional fuels such as biomass, volatile gases and hydrogen

6.2 Possible solutions

The future is uncertain: demonstrator/evaluation projects are run at a large variety of power scales. It is difficult to predict where the MGT will prevail and where not in a wide range of 1kWe – several MWe. So what scale to develop for?

Finding cogeneration applications where the MGT will win with its unique advantages in terms of : fuel flexibility, power density, transient performance?, low noise and exhaust gas emission potential is important.

Strong proposals for EU funding can be built around specific cogeneration and other applications demonstrating these advantages (e.g. biogas, hydrogen storage fuel….)

How the technology challenges should be tackled

Higher operating temperature by use of ceramic material

More advanced cycles for highest efficiencies- for example ICRR (intercooled recuperated reheat) and combination with fuels cells

Combustion chambers that burns all types of gases (including hydrogen) and liquid fuels. External combustion for solid fuels. Catalytic combustion.

Low cost high temperature recuperators

Heat exchangers for external combustion