

**SIXTH FRAMEWORK PROGRAMME
PRIORITY 6
SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE AND ECOSYSTEMS**



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MARKET SIZE**

D12 - First Update to Literature and Patent Search

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FOR CIRCULATION TO MICROCHEAP MEMBERS

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This *First Update to Literature and Patent Search*, which contains material additional to or sections revised from the November 2005 *State of the art and Market review*, has been collated by the Work Package 2 leader, EATL.

CONTRIBUTORS

The MicroCHeaP partners who have contributed to this Work Package 2 document are:

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EATL	EA Technology Ltd.	UK
ECN	Energieonderzoek Centrum Nederland	NL

COUNTRIES

The MicroCHeaP project aims to cover the EU 25 countries plus whichever other European countries are appropriate for each work package, for example Switzerland, Norway, Iceland and Eastern European countries. Where the name of a country is not included in this document, no information is available.

MicroCHeaP Literature Search: Stirling Engines
Investigation related to Stirling engines
Contributed by ECN

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MICRO-CHEAP LITERATURE SURVEY CONTRIBUTION OF ECN INVESTIGATION RELATED TO STIRLING ENGINES

1. STIRLING ENGINES OVERVIEW

Stirling engines are closed cycle thermal machines, which use an external heat source and heat sink to produce mechanical power. The thermodynamic reference cycle, which approaches the cycle in real engines is the Stirling cycle, shown in fig. 1. The working gas is usually helium, air/nitrogen or hydrogen.

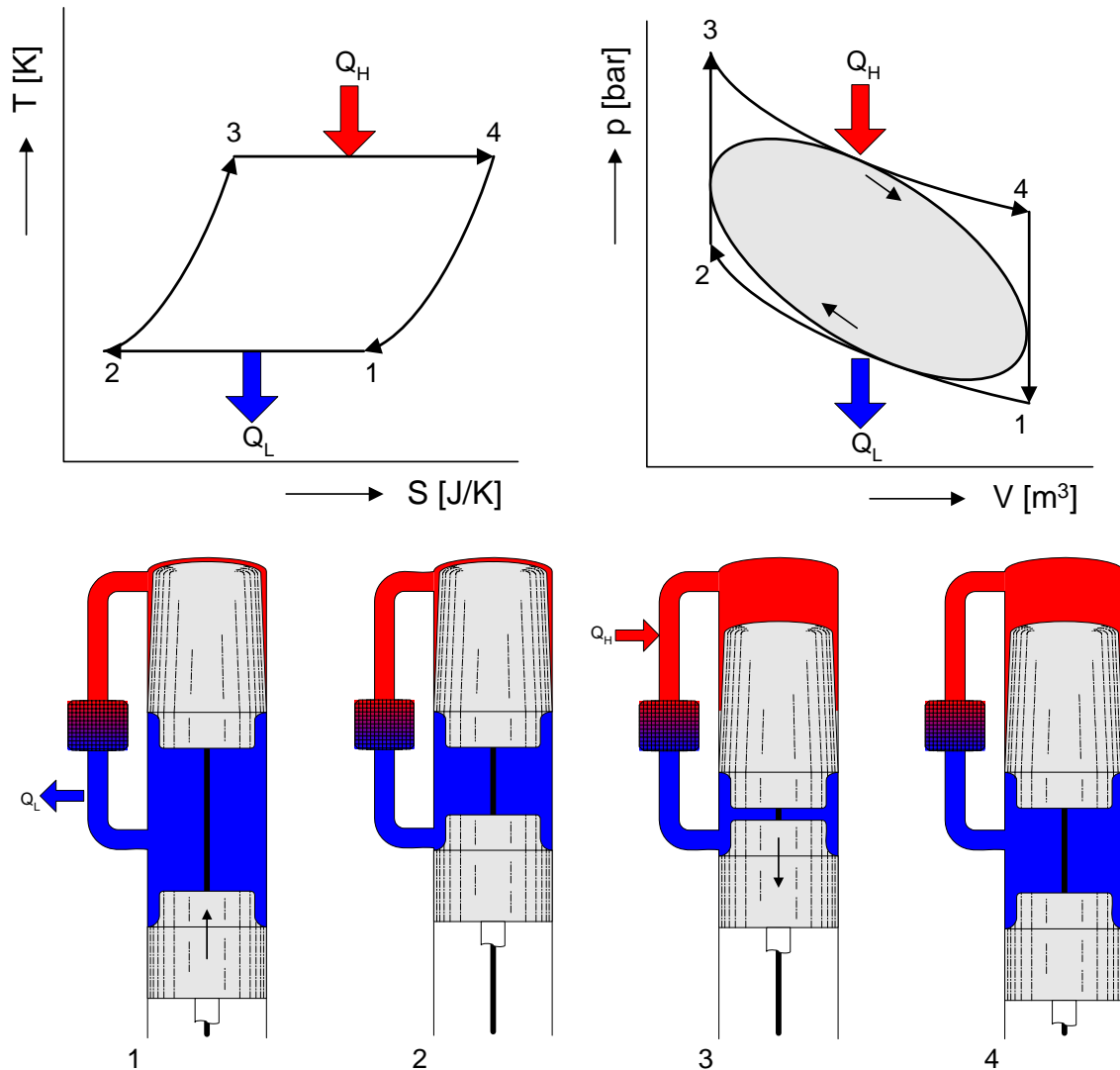


Fig. 1 Theoretical Stirling cycle in an engine with piston and displacer not running continuously; the egg shaped body in the theoretical indicator diagram shows the indicator diagram of a real Stirling engine with the piston and displacer running sinusoidally

The main components of Stirling engines that feature prominently in Stirling technology and research are: the heater (the heat exchanger connected to the external heat source), the regenerator, the cooler (the heat exchanger connected to the heat sink), the displacer piston and finally the (power) piston. The reciprocating movement of the power piston is used to drive a linear or via some mechanism a rotating load. The location of the main components in an engine is shown in fig. 2.

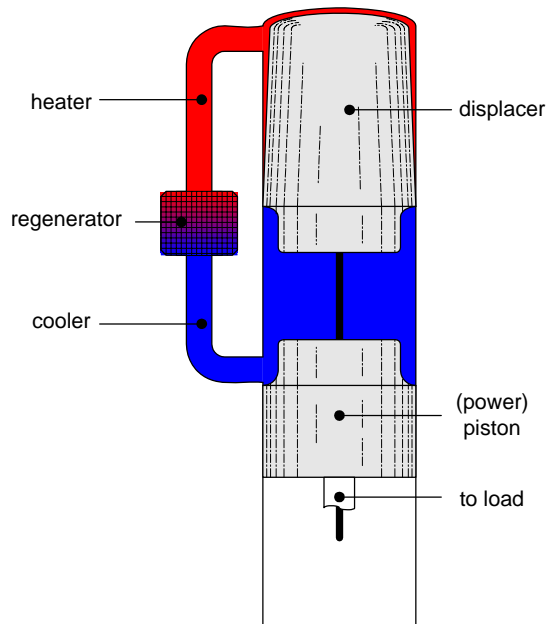


Fig. 2 Main components of a Stirling engine (single acting beta type)

The Stirling engine was first patented in 1816 by the Scottish referent Robert Stirling as an application of the regenerator he had invented. Throughout the nineteenth century, several working models were built and some were operated successfully for a while, but eventually more effective and powerful steam and internal combustion engines replaced the Stirling engines.

The development of the modern high speed Stirling engine with a pressurised gas cycle started in the nineteen thirties. The Philips electrics company did pioneering work and although Philips abandoned Stirling development in the nineteen seventies, most Stirling engines that are on the market today use solutions that were originally developed at Philips.

Among the developments that have occurred since the Philips period two main branches can be distinguished: kinematic and free piston Stirling engines.

Kinematic Stirling engines are the largest group of Stirling engines. In these engines, the reciprocating movement of the power piston is transferred to a rotating shaft by mechanical means. The engines can be used to drive an electric generator. Depending on the geometric arrangement of the pistons (and displacers) different variants are the alpha, beta or gamma engines. Depending on the interconnection of multiple cylinders these engines can operate with single or double acting pistons. Kinematic engines have been demonstrated in the power range from 0.1 to 500 kW.

In free piston engines the reciprocating movement of the power piston is used tot drive a linear electric generator. These engines are comparatively simple in mechanical terms and require little maintenance. Free piston engines have been demonstrated in the power range from 0.05 to 3 kW.

The main feature that distinguishes modern Stirling engines from competing technologies such as internal combustion engines and fuel cells is the flexibility of the heat source. Stirling engines can be heated by: concentrated sunlight, waste heat and depending on an appropriate burner design a host of different fuel types. Stirling engines are therefore well placed for applications involving:

- Concentrated sunlight: solar dish Stirling engines
- Combustion of biomass: biogas or bio-oil fired Stirling engines

Because Stirling engines are also comparatively quiet and the external burners can operate with very low emission levels Stirling engines are also suitable for use in the built environment. As a result there has been a strong push over the past decade towards the introduction of Stirling based micro-

cogeneration systems in homes and small buildings. Although these systems usually run on natural gas, biogas or bio-oil can also be used after comparative minor modifications.

Companies that have focused on the development of small micro-cogeneration systems for single homes are Whisper Tech, Microgen and Enatec. The systems of these companies have typically an electric output in the range of 1 to 1.5 kW and a thermal output between 7 to 35 kW, depending on specific operation conditions. The overall efficiency is high and may well be over 100% on LHV basis, whereas the electric efficiency can vary between 10% and 20%. These systems represent both branches of the Stirling family: Whisper Tech, with a kinematic Stirling design and both Microgen and Enatec with free piston engines.



Whisper Tech system Microgen system Enatec system

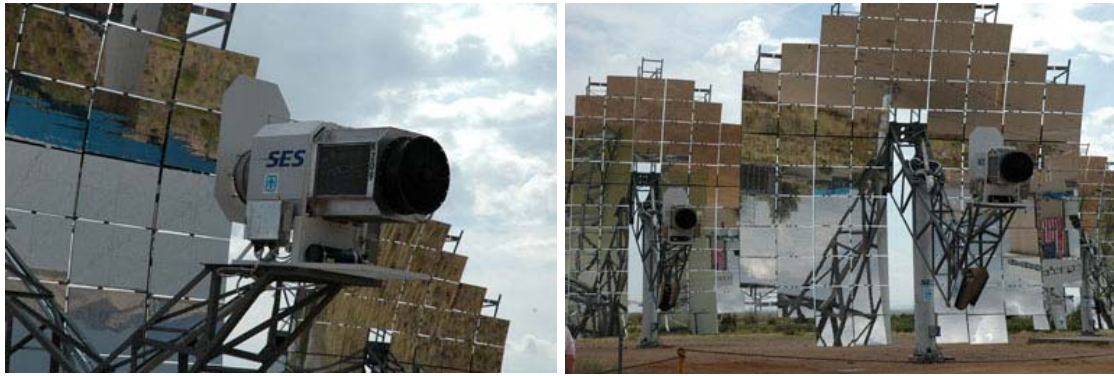
Market introduction of small Stirling based micro cogeneration systems is expected in 2007 - 2008.

Separate from the developments in the market of small micro-cogeneration systems, there is a number of companies working on larger systems with an electric output in the 5 to 50 kW range. These systems are well suited for small companies or multiple homes and are developed with special consideration for applications involving bio fuels. A typical example of the systems in this field, which received a lot of interest in the previous years, is the SOLO 161 of the SOLO Stirling company. The engine in this system is kinematic with 9.5 kW electric and 30 kW thermal power output, giving an electric efficiency 23% and a total efficiency of 30%. The engine can be heated with a whole range of liquid and gaseous fossil or bio fuels. However concentrated solar radiation may also be a viable heat source for this engine.



SOLO 161 system

A new development is the commercialisation of Solar Thermal Stirling (STM) or Solar Dish Stirling (SDS) systems. As recent as 2005 the US company Stirling Energy Systems secured contracts for two Solar Thermal power plants with an initial size of 300 and 500 MW electric output. Given a size of 25 kW electric output for a single Solar Dish System, these contracts equal a combined production of 32000 Stirling systems before 2010.



A 25 kW electric output SES Solar Dish System

2. PUBLICATIONS IN JOURNALS

In recent years, a vast amount of literature has been published, covering all aspects of Stirling engines and associated technology. However, within the framework of MicroCHeaP, attention is set to focus on topics as application, system design, burner technology, and some general aspects of Stirling technology.

On the topics of application and system design areas of interest are biomass fired micro CHP systems and to a lesser extent solar dish Stirling systems, which run on direct solar heat. Fruitful search words for a literature survey into the field of biomass powered Stirling systems are 'biomass', 'wood', 'wood wastes', 'cogeneration' and 'Stirling engines'. A literature search on these subjects covering the period from 2000 to 2004 produced among others the following results:

1. H. Carlsen, J. Bovin, "Four-cylinder, hermetically sealed stirling engine for small-scale power production using biomass as fuel", VDI Berichte n 1588 (2001) 273-281, ISSN: 0083-5560
2. H. Carlsen, J. Bovin, "9 kW stirling engine for biogas and natural gas. Final report.", Danmarks Tekniske Univ., Lyngby (Denmark) Inst. for Mekanik (2201), Available on loan from Risoe Library, P.O. Box 49 DK-4000 Roskilde Denmark
3. H. Carlsen, "Progress report – 35 kW Stirling engines for biomass", Proceedings European Stirling Forum 2000 (2000) 193-200
4. H. Carlsen, J. Bovin, "Stirling engines in small CHP plants", Conference: Nordic and European bioenergy conference and exhibition, Aarhus (Denmark), 25-28 Sep 2001
5. H. Carlsen, "Status and prospects of small-scale power production based on Stirling engines Danish experiences", Seminar on Power production from biomass III., Espoo (Finland) 14-15 Sep 1998, ISBN: 951-385267-9
6. M. Paalsson, H. Carlsen, "Development of a Wood Powder Fuelled 35 kW Stirling CHP Unit
7. B. Teislev, "Aktivitaeten der Babcock and Wilcox Voelund, Daenemark in Bereich der Biomasse – Vergasung: Das Projekt 'Harboere' (2x64 kWel) und Test eines 40 kW Stirlingmotors", Gluecksburger Biomasse Forum (6-7 Mar 2001) (Available from TIB Hannover)
8. E. Podesser, "Electricity production in rural villages with a biomass Stirling engine", Proceedings of the 1998 world Renewable Energy Congress V. part 2, Renewable Energy v 16 (1-4) (Jan-Apr 1999) 1049-1052
9. E. Podesser, H. Bayer, "Anwendung und Wirtschaftlichkeit von Biomasse-Stirlingmotoren in Oesterreich", Proceeding ESF 2000 (2000), 247-256
10. E. Podesser et al., "Entwicklungsmoeglichkeiten, Technik und Wirtschaftlichkeit von Biomasse-Stirlingmotoren", Proceedings 2001 6. Kassel symposium on energy system engineering. On-site energy generation using renewable sources (2001) (OSTI)
11. N. Ebeling, C. Koenig, "Gestufte Vergasung und Verbrennung im KWK-Betrieb mit einer Stirlingmaschine (DeBit-Projekt)", DGMK –Fachbereichstagung 'Energetische Nutzung von Biomassen', Velen/Westfalen (Germany), 19-21 April 2004, ISBN: 3-936418-16-0

12. F. Preto, "Assessment of small-scale wood-fired cogeneration at sawmills: part 1, technology review", Proceedings of the Bio Energy conference and Exhibition 2004 and the Forest Expo 2004 Prince George BC (Canada) 64-78, www.forestexpo.bc.ca
13. B. Krautkremer, A. Jost, "Laendliche Elektrifizierung mit Stirlingmotoren an Kleinstbiogasanlagen, Konzept und erste Ergebnisse", Zwelftes Symposium Energie und Biomasse. Biogas, Fluessigkraftstoffe, Festbrennstoffe OTTI Regensburg (Germany) (2003) 132-139
14. J. Karl, "Konzepte fuer Kraft-Waerm-Kopplungsanlagen", OTTI Orientierungsseminar: Kraft-Waerme-Kopplung mit biobrennstoffen, OTTI Regensburg (2003) 17-44
15. M. Salomon-Popa, "Small-Scale Combined Heat and Power Plants Using Biofuels", Swedish Energy Agency, Eskilstuna (Sweden), Nov 2002 (OSTI)
16. M. Gyftopoulou et al., "Small scale heat and power (CHP) from bio-crude oil fuelled to a sterling engine", Feb 2002 (OSTI)
17. A. Demirbas, "Utilization of Biomass as alternative Fuel for External Combustion Engines", Energy sources v 26 November 2004 (2004) 1219 - 1226
18. L. Bowman, N.W. Lane, "Micro-scale biomass power", 4. biomass conference of the Americas, Oakland, Ca, 29 aug – 2 Sep 1999

In the field of biomass related Stirling technology the large number of articles published by authors associated with the Technical University of Denmark (H. Carlsen et al) stand out. An interesting overview of the technology may be given by the proceedings of OTTI orientation seminar (Staffelstein, Germany, 2003) Other organisations publishing about biomass and Stirling technology include NREL, VTT, SINTEF, Centre Renewable Sources Greece.

Useful search words for a survey into solar dish systems are 'solar thermal power plants', 'solar concentrators', 'parabolic dish reflector', 'parabolic dish concentrator' along with 'cogeneration' and 'stirling engines'. A literature search on these subjects covering the period from 2000 to 2004 produced among others the following results:

19. C. Andraka et al., "Dish/stirling Hybrid-Receiver Sub-Scale Tests and Full-Scale Design", Sandia National Laboratories, 34-th IECC conference (1999)
20. R.B. Driver, J.W. Grossman, "Sandwich construction solar structural facets", Renewable and advanced energy systems for the 21st century, RAES'99 proceedings, (1999)
21. D.R. Adkins, et al., "Test and Post-Test Analysis of a Thermocore Inc. Nickel Powder Wick Heat Pipe Solar Receiver", report 23 p. OSTI as DE00008377 Us Govt. Printing Office
22. J. Eyer, J. Iannucci, "Market potential for distributed solar dish-Stirling power plants operated in solar-only and solar/natural gas hybrid modes", IEEE Power Engineering Review v19 n11 (1999) 7-8
23. M. Bohn, "Burner supplements solar Stirling output", Power engineering, v 103 n 5 (1999) 46-48
24. J.B. Mayette, "The salt river project SunDish dish-Stirling system", International Solar Energy Conference 2001 p. 83-87
25. K.W. Stone, et al., "Performance of the SES/Boeing dish Stirling system", International Solar Energy Conference 2001 p. 97-103
26. K.W. Stone, et al., "SES/Boeing Dish Stirling system operation", International Solar Energy Conference 2001 p. 105-110
27. Y. Baghzouz, "Alternative energy production with grid-connected solar dish-stirling systems", Proceedings of the IEEE Power Engineering Society transmission and Distribution Conference v1 n Summer 2002 p. 129-133
28. A. Der Minassians, et al., "Low-Cost distributed solar-thermal-electric power generation", Proceedings of Spie - the International Society for Optical Engineering, (Aug 2003), p. 89-98
29. A.W. Wong, R.P. Macosko, "Refractive solar concentrators for solar thermal applications", 34-th IECEC, (1999)
30. P. Stouffs, "Design of a 1 kWe Stirling engine for solar CHP", Proceedings ESF 2000 (2000)
31. S. Ulmer, "Flux mapping for dish/stirling systems to improve absorber performance", 5. Cologne solar symposium: Solar thermal power plants and solar chemical processes – Advances and

- perspectives for international cooperation, 21 Jun 2001, ISSN: 1434-8454
32. W. Schiel, "Eine neue Technologie zur solaren Stromzeugung", *Beratende Ingenieure* (Mar 2002) v 32(3) p. 27-30
 33. K.K. Makhkamov, D.B. Ingham, "Two-dimensional model of the air flow and temperature distribution in a cavity-type heat receiver of a solar Stirling engine", *Journal of Solar Energy Engineering* (Nov 1999) v. 121 (4) p. 210-216
 34. K.K. Makhkamov, D.B. Ingham, "Analysis of the working process and mechanical losses in a Stirling engine for a solar power unit", *Journal of Solar Energy Engineering* (May 1999) v. 121 (2) p. 121-127

Most articles about solar powered Stirling engines have been published before 2003. Organisations that stand out are Sandia National Laboratory of the USA and the German Aerospace Center DLR with Plataforma Solar de Almeria. However, the research in this field seems to be concentrated in the United States.

A survey of the components shared by different types of Stirling engines for different kinds of applications may include search words addressing these components such as 'regenerator', 'heat exchanger', 'controls' etc. combined with 'Stirling engines'

Finally, important areas (and search words) for the future direction of Stirling research and development are Stirling related thermodynamics, simulation and assessment of new technology concepts.

3. PUBLICATIONS IN CONFERENCES

The following conferences deal with Stirling topics on a regular basis:

1. ISEC (International Stirling Engine Conference), International, biannual (1982, 1984, 1986, 1988, 1991, 1993, 1995, 1997, 1999, 2001, 2003) (www.isec-info.org)
2. IECEC (Intersociety/International Energy Conversion Engineering Conference), USA, annual (www.iecec.org) (www.aiaa.org)
3. ISF/ESF (International/European Stirling Forum), Europe, biannual (1996, 1998, 2000, 2002, 2004)

4. BOOKS

A number of books giving a good introduction into Stirling technology are:

1. C.M. Hargreaves, "The Philips Stirling engine", Elsevier, 1991
2. G.Walker et al., "The Stirling alternative, power systems, refrigerants and heat pumps", Gordon and Breach science publishers, 1994
3. A.J. Organ, "The regenerator and the Stirling engine", MEP, 1997
4. T. Finkelstein, A.J. Organ, "Air engines", PEP, 2001
5. G.T. Reader, C. Hooper, "Stirling engines", E. & F.N. Spon, 1983
6. M. Werdich, K. Kübler, "Stirlingmaschinen", ökobuch Verlag, 2003

5. STIRLING MANUFACTURERS AND SYSTEM INTEGRATORS

Manufacturers of Stirling engines suited for cogeneration applications are:

1. Whisper Tech (New Zealand)
2. STC (USA)
3. Sunpower (USA)
4. STM Power (USA)
5. Tamin (USA)
6. SOLO Kleinmotoren (Germany)
7. Fa. Mayer & Cie (Germany)
8. Sunmachine (Germany)
9. BSR solar technologies (Germany)
10. Microgen (UK)
11. Enatec (Netherlands)
12. Technical University of Denmark (Denmark)
13. Kockums (Sweden)
14. Stirling Energy Systems (USA)

MicroCHeaP Patent Search

Contributed by CHALEX

PATENTS ON CD AVAILABLE FROM CHALEX:

Results of Patent Search (Renewable Micro-CHP)

<u>Category</u>	<u>Number of Patents on CD</u>
Micro-Turbines	15
Organic Rankine Processes	28
Thermoelectrics	55
Thermal Heat Pumps	3
Fuel Cells	1
Internal Combustion Engines	4
Gasification	25
Biomass	7
Misc	1
Fuel Cells	18
Biomass	11
Solar	47
Geothermal	0
	<u>Total:</u> 215

EXCEL WORKSHEET REPRODUCED AS TEXT IN THIS DOCUMENT:

MicroCHeaP Patent Database - Titles 1

Micro CheaP Database Patent Titles		
Category	Year	
Micro-Turbines	2003	Micro Turbines\ON-LINE CONTROL OF DISTRIBUTED RESOURCES WITH DIFFERENT DISPATCHING LEVELS.pdf
Micro-Turbines	2002	Micro Turbines\Rotary Positive Displacement.pdf
Micro-Turbines	2002	Micro Turbines\Controlling Temperature in gas turbine apperatus during startup or shutdown.pdf
Micro-Turbines	2002	Micro Turbines\Conversion of sewage sludge into electric power.pdf
Micro-Turbines	2004	Micro Turbines\distributed electrical power management system for selecting remote or local power generators.pdf
Micro-Turbines	2003	Micro Turbines\Electrical energy-generating heat sink system and method of using same to recharge an energy storage device.pdf
Micro-Turbines	2003	Micro Turbines\enhanced conduction angle power factor correction topology.pdf
Micro-Turbines	2003	Micro Turbines\Habitat hydro scheme.pdf
Micro-Turbines	2004	Micro Turbines\Method of operating a gas turbine.pdf
Micro-Turbines	2004	Micro Turbines\Micro Reaction Turbine with Intergrated Combustion Chamber and Rotor.pdf
Micro-Turbines	2002	Micro Turbines\Microturbomachienary.pdf
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Micro-Turbines	2002	Micro Turbines\Single rotor turbine engine.pdf
Organic Rankine Processes	1981	Organic Rankine Processes\energy converter.pdf
Organic Rankine Processes	2002	Organic Rankine Processes\cogeneration system for a fuel cell 2002.pdf
Organic Rankine Processes	2003	Organic Rankine Processes\combined rankine and compression cycles 2003.pdf
Organic Rankine Processes	2004	Organic Rankine Processes\combined rankine and compression cycles 2004.pdf
Organic Rankine Processes	2004	Organic Rankine Processes\combined rankine and vapor compression cycles 2004.pdf
Organic Rankine Processes	2004	Organic Rankine Processes\Geothermal power plant and method for operating system.pdf
Organic Rankine Processes	2002	Organic Rankine Processes\method and apparatus for producing uninterruptable power 2002.pdf
Organic Rankine Processes	1989	Organic Rankine Processes\method of and apparatus for producing power in solvent desphalting units 1989.pdf
Organic Rankine Processes	1990	Organic Rankine Processes\method of and apparatus for producing power using steam 1990.pdf
Organic Rankine Processes	1996	Organic Rankine Processes\method of and apparatus for producing power using steam 1996.pdf
Organic Rankine Processes	1989	Organic Rankine Processes\method of apparatus for producing power using steam 1989.pdf

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Organic Rankine Processes	2003	Organic Rankine Processes\method of apperatus for producing power and desalinated water 2003.pdf
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Organic Rankine Processes	2000	Organic Rankine Processes\power generation with centrifugal compressor.pdf
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Organic Rankine Processes	2002	Organic Rankine Processes\preheated injection turbine system.pdf
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Organic Rankine Processes	1988	Organic Rankine Processes\system of generating electricity using a swimming pool type nuclear reactor 1988.pdf
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Thermoelectrics	2004	Thermoelectrics\double closed loop thermoelectric heat exchanger.pdf
Thermoelectrics	1995	Thermoelectrics\forced air furnace having a thermoelectric generator for providing continuous operation during an electric power outage 1995.pdf
Thermoelectrics	2001	Thermoelectrics\heterostructure thermoionic coolers 2001.pdf
Thermoelectrics	1994	Thermoelectrics\intergrated thermoelectric system with full half wave rectifier control 1994.pdf
Thermoelectrics	1999	Thermoelectrics\method manufacturing thermoelectric power generation unit 1999.pdf
Thermoelectrics	1995	Thermoelectrics\thermoelectric air cooling method with individual control of multiple thermoelectric devices 1995.pdf
Thermoelectrics	2000	Thermoelectrics\thermoelectric cooling system 2000.pdf
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Thermoelectrics	2002	Thermoelectrics\thermoelectric device 2002.pdf
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Thermoelectrics	1998	Thermoelectrics\thermoelectric element and thermoelectric cooling or heating device provided with the same 1998.pdf
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Thermoelectrics	2004	Thermoelectrics\two stage cooling system employing thermoelectric modules 2004.pdf
Thermoelectrics	2003	Thermoelectrics\thermoelectric generator 2003.pdf
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Thermoelectrics	2003	Thermoelectrics\heat fusion exchange generator 2003.pdf
Thermoelectrics	2001	Thermoelectrics\electric device fitted with power generators 2001.pdf
Thermoelectrics	1981	Thermoelectrics\thermoelectric generator and method of forming same 1981.pdf
Thermoelectrics	1981	Thermoelectrics\thermoelectric generator operating with a cooling device for converting solar energy into electric energy, and system for the use thereof 1981.pdf
Thermoelectrics	1989	Thermoelectrics\heater mechanism with thermoelectric power generator.pdf
Thermoelectrics	1989	Thermoelectrics\series inverter with shunted transformer for regulation of capacitor charging 1989.pdf
Thermoelectrics	1995	Thermoelectrics\thermoelectric generator unit and magnetic energy storage unit 1995.pdf
Thermoelectrics	1996	Thermoelectrics\cascade process heat conversion system 1996.pdf
Thermoelectrics	1996	Thermoelectrics\method and apparatus for te thermoelectric generation of electricity 1996.pdf
Thermoelectrics	1996	Thermoelectrics\multi stage thermoelectric power generation 1996.pdf
Thermoelectrics	1996	Thermoelectrics\improved thermoelectric unit with electric input output provision 1996.pdf
Thermoelectrics	1997	Thermoelectrics\high efficiency thermoelectric converter and applications thereof 1997.pdf
Thermoelectrics	1975	Thermoelectrics\thermoelectric unit with low thermal conductivity elemrnnts having a threaded exterior surface 1975.pdf
Thermoelectrics	2000	Thermoelectrics\turbine, power generation system therfor and method of power generation 2000.pdf
Thermoelectrics	2002	Thermoelectrics\aromatic burner driven generator system 2002.pdf
Thermoelectrics	1973	Thermoelectrics\thermoelectric generator 1973.pdf
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Thermoelectrics	1986	Thermoelectrics\a thermoelectric generator for converting heat energy to electrical energy 1986.pdf
Thermoelectrics	1987	Thermoelectrics\modular thermoelectric conversion system 1987.pdf
Thermoelectrics	1986	Thermoelectrics\short duration thermoelectric generator 1986.pdf
Thermoelectrics	1987	Thermoelectrics\duel fueled thermoelectric generator 1987.pdf
Thermoelectrics	1999	Thermoelectrics\thermoelectric catalytic power generator with preheat 1999.pdf
Thermoelectrics	1998	Thermoelectrics\hybrid self contained heating and electrical power supply incorporating a hydrogen fuel cell, a thermoelectric generator and a catalytic burner 1998.pdf
Thermoelectrics	2001	Thermoelectrics\thermoelectric generating electronic device 2001.pdf
Thermoelectrics	1997	Thermoelectrics\thermoelectric generator unit 1997.pdf
Thermoelectrics	2002	Thermoelectrics\thermoelectric generator and methods for the production thereof 2002.pdf
Thermoelectrics	2003	Thermoelectrics\method of enhanced heat extraction from a geothermal source... 2003.pdf
Thermoelectrics	2003	Thermoelectrics\thermoelectric generator for a vehicle 2003.pdf
Thermoelectrics	2004	Thermoelectrics\water heater having self-powered low nox burner fuel-air delivery system 2004.pdf
Thermoelectrics	2004	Thermoelectrics\low power thermoelectric generator 2004.pdf
Thermoelectrics	1975	Thermoelectrics\thermoelectric generator 1975.pdf
Thermal Heat Pumps	1998	Thermal Heat Pumps\Thermische Wärmepumpe 1988.pdf
Thermal Heat Pumps	1981	Thermal Heat Pumps\thermal heat pump 1981.pdf
Thermal Heat Pumps	1998	Thermal Heat Pumps\microwave thermal heat pump defroster 1998.pdf
Fuel Cells	2000	Fuel Cells\solid polymer fuel cell cogeneration system 2000.htm
Internal Combustion Engines	2002	Internal Combustion Engines\internal combustion cogeneration system.htm
Internal Combustion Engines	1987	Internal Combustion Engines\exhaust heat recovery device for internal combustion engine.htm
Internal Combustion Engines	2004	Internal Combustion Engines\regenerating device for internal combustion engine 2004.htm
Internal Combustion Engines	2001	Internal Combustion Engines\exhaust heat recovery device for internal combustion engine.htm
Gasification	1979	Gasification\combined compressor air storage low btu coal gasification power plant 1979.pdf
Gasification	1979	Gasification\combined compressed air storage low btu coal gasification power plant 1979.pdf
Gasification	1985	Gasification\zinc oxide char gasification process 1985.pdf
Gasification	1994	Gasification\system and method for cleaning hot fuel gas 1994.pdf
Gasification	1999	Gasification\method and apperatus for total energy fuel conversion systems 1999.pdf
Gasification	2000	Gasification\removal of acidic gases in a gasification power system with production of hydrogen 2000.pdf

Gasification	2001	Gasification\ultra low emission power plant.pdf
Gasification	2004	Gasification\method for converting thermal energy into mechanical work 2004.pdf
Gasification	1978	Gasification\production of water gas as a load levelling approach for coal gasification power plants 1978.pdf
Gasification	1979	Gasification\coal gasification power plant and process 1979.pdf
Gasification	1984	Gasification\coal gasification power generating plant 1984.pdf
Gasification	1990	Gasification\coal gasification power generator 1990.pdf
Gasification	1992	Gasification\combined power generating plant 1992.pdf
Gasification	1992	Gasification\combined power generating plant 1992.pdf
Gasification	1994	Gasification\coal gasification power generator 1994.pdf
Gasification	1996	Gasification\coal gasification power generator 1996.pdf
Gasification	1997	Gasification\high pressure combustion turbine and air separation system intergration 1997.pdf
Gasification	1997	Gasification\high pressure combustion turbine and air separation system intergration 1997.pdf
Gasification	1998	Gasification\operation of intergrated gasification combined cycle power generation systems at part load 1998.pdf
Gasification	1998	Gasification\coal gasification power generator 1998.pdf
Gasification	1999	Gasification\operation method for intergrated gasification combined cycle power generation system 1999.pdf
Gasification	1998	Gasification\gasification power generation process and equipment 1998.pdf
Gasification	1990	Gasification\a composite coal gasification power plant 1990.pdf
Gasification	2001	Gasification\gasification power generation system using preheated gasifying agent to gasify fuel 2001.pdf
Gasification	2000	Gasification\gasification power generation process and gasification power generation equipment 2000.pdf
Biomass	1996	Biomass (inc gas and liquid)\fermentation plant 1996.pdf
Biomass	1980	Biomass (inc gas and liquid)\method and apparatus for processing animal waste 1980.pdf
Biomass	1983	Biomass (inc gas and liquid)\method for generation of biogas 1983.pdf
Biomass	1997	Biomass (inc gas and liquid)\method and apperatus for utilising biofuel or waste material in energy production 1997.pdf
Biomass	1982	Biomass (inc gas and liquid)\production of methanol from organic waste material by use of plasma jet 1982.pdf
Biomass	2004	Biomass (inc gas and liquid)\system and method for extracting energy from agricultural waste 2004.pdf

Biomass	2003	Biomass (inc gas and liquid)\system for the drying of damp biomass based fuel 2003.pdf
Misc	2002	Misc\method for the cogeneration of heat and power in conjunction with decentralised.pdf
Fuel Cells	2004	Fuel Cells\fuel cell cogeneration sysem 2004.htm
Fuel Cells	2001	Fuel Cells\fuel cell cogeneration system 2001.htm
Fuel Cells	2002	Fuel Cells\fuel cell cogeneration system and starting method for fuel cell cogeneration system 2002.htm
Fuel Cells	1997	Fuel Cells\method for producing electric energy in a biofuel powered fuel cell 1997.pdf
Fuel Cells	1976	Fuel Cells\pacemaker with biofuel cell 1976.pdf
Fuel Cells	2002	Fuel Cells\enzymatic fuel cell 2002.pdf
Fuel Cells	2003	Fuel Cells\biological fuel cell and method 2003.pdf
Fuel Cells	2001	Fuel Cells\biological fuel cell and method 2001.pdf
Fuel Cells	1998	Fuel Cells\biomass fuel cell cogeneration apparatus and method 1998.pdf
Fuel Cells	2002	Fuel Cells\fuell cogeneration system of electrical energy and hot water 2002.pdf
Fuel Cells	2004	Fuel Cells\fuel cell cogeneration system of electrical ennergy and hot water 2004.pdf
Fuel Cells	2005	Fuel Cells\co-generation of electricity by the seebek effect within a fuel cell 2005.pdf
Fuel Cells	1999	Fuel Cells\solid polymer electrolyte fuel cell cogeneration system 1999.pdf
Fuel Cells	2002	Fuel Cells\solid polymer electrolyte fuel cell cogeneration system 2002.pdf
Fuel Cells	2000	Fuel Cells\solid polymer electrolyte fuel cell cogeneration system 2000.pdf
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Fuel Cells	2003	Fuel Cells\fuel cell cogeneartion system 2003.pdf
Fuel Cells	2002	Fuel Cells\cogeneration system for a fuel cell 2002.pdf
Biomass	2002	Biomass (inc gas and liquid)\procss and apparatus for conversion of biodegradable organic materials into product gas 2002.pdf
Biomass	2002	Biomass (inc gas and liquid)\additive for biodiesel and biofuel oils 2002.pdf
Biomass	2002	Biomass (inc gas and liquid)\method for nox reduction by upper furnace injection of biofuel water slurry 2002.pdf
Biomass	1999	Biomass (inc gas and liquid)\combined cycle powerplant with intergrated cfb devolatiser and cfb boiler 1999.pdf
Biomass	1997	Biomass (inc gas and liquid)\combined cycle powerplant with intergrated cfb devolatiser and cfb boiler 1997.pdf
Biomass	1996	Biomass (inc gas and liquid)\biodiesel fuel 1996.pdf
Biomass	2004	Biomass (inc gas and liquid)\biomass power generation system 2004.htm

Biomass	2004	Biomass (inc gas and liquid)\cultivated biomass power system 2004.pdf
Biomass	2003	Biomass (inc gas and liquid)\parallel dc power sources with different characteristics 2003.pdf
Biomass	1997	Biomass (inc gas and liquid)\biomass gasification system and method 1997.pdf
Biomass	1996	Biomass (inc gas and liquid)\biomass fuel turbine combustor 1996.pdf
Solar	1979	Solar (Electric, Thermal)\solar energy collector system and method 1979.pdf
Solar	1992	Solar (Electric, Thermal)\solar thermal propulsion engine 1992.pdf
Solar	1977	Solar (Electric, Thermal)\solar thermal radiation absorption and conversion system 1977.pdf
Solar	1975	Solar (Electric, Thermal)\panel for selectivly absorbing solar thermal energy and the method of producing said panel 1975.pdf
Solar	1997	Solar (Electric, Thermal)\solar thermal cell 1997.pdf
Solar	1987	Solar (Electric, Thermal)\intergrated solar thermal energy collector system 1987.pdf
Solar	2003	Solar (Electric, Thermal)\solar photoreactor 2003.pdf
Solar	2003	Solar (Electric, Thermal)\solar heat harnessing system 2003.pdf
Solar	2002	Solar (Electric, Thermal)\installation for producing solar thermal energy 2002.pdf
Solar	1996	Solar (Electric, Thermal)\solar thermal water heating system 1996.pdf
Solar	1984	Solar (Electric, Thermal)\passive solar heating and cooling means 1984.pdf
Solar	1979	Solar (Electric, Thermal)\solar thermal electric systems 1979.pdf
Solar	1979	Solar (Electric, Thermal)\solar thermal powerplant 1979.pdf
Solar	1983	Solar (Electric, Thermal)\solar thermal power plant 1983.pdf
Solar	1979	Solar (Electric, Thermal)\solar thermal electric power plant 1979.pdf
Solar	2002	Solar (Electric, Thermal)\solar power enhanced combustion turbine power plant and methods 2002.pdf
Solar	2000	Solar (Electric, Thermal)\solar concentrator for heat and electricity 2000.pdf
Solar	1999	Solar (Electric, Thermal)\solar power enhanced combustion turbine power plant and methods 1999.pdf
Solar	1994	Solar (Electric, Thermal)\high efficiency steam generator 1994.pdf
Solar	1992	Solar (Electric, Thermal)\solar thermal powered water pump 1992.pdf
Solar	1992	Solar (Electric, Thermal)\solar thermal energy reciever 1992.pdf
Solar	1987	Solar (Electric, Thermal)\solar energy collector having an improved thermal reciever 1987.pdf
Solar	1985	Solar (Electric, Thermal)\thermal energy storage system 1985.pdf
Solar	1982	Solar (Electric, Thermal)\solar power convertor with pool boiling reciever and integral heat exchanger 1982.pdf

Solar	1982	Solar (Electric, Thermal)\solar heater with integral heat rapg glazing 1982.pdf
Solar	1981	Solar (Electric, Thermal)\solar energy collector 1981.pdf
Solar	1981	Solar (Electric, Thermal)\solar air heater 1981.pdf
Solar	1981	Solar (Electric, Thermal)\highly solar energy absorbing device and method of making the same 1981.pdf
Solar	1981	Solar (Electric, Thermal)\solar electrical generator 1981.pdf
Solar	1980	Solar (Electric, Thermal)\solar thermal and wind energy power source 1980.pdf
Solar	1980	Solar (Electric, Thermal)\solar energy conversion 1980.pdf
Solar	1989	Solar (Electric, Thermal)\header for a solar energy collection system 1979.pdf
Solar	1993	Solar (Electric, Thermal)\solar electric conversion unit and system 1993.pdf
Solar	1982	Solar (Electric, Thermal)\solar electric generator 1982.pdf
Solar	1978	Solar (Electric, Thermal)\solar electric power plant and an improved thermal collector of solar energy 1978.pdf
Solar	1997	Solar (Electric, Thermal)\solar electric alternating current generator 2004.pdf
Solar	2004	Solar (Electric, Thermal)\exothermic heat generating apparatus 1997.pdf
Solar	1997	Solar (Electric, Thermal)\therr function heat pump system 1987.pdf
Solar	1987	Solar (Electric, Thermal)\solar power generation 1987.pdf
Solar	1976	Solar (Electric, Thermal)\solar electrical generating system 1976.pdf
Solar	1979	Solar (Electric, Thermal)\self supporting active solar energy system 1979.pdf
Solar	1986	Solar (Electric, Thermal)\solar power generation 1986.pdf
Solar	1976	Solar (Electric, Thermal)\gas dissociation thermal power system 1976.pdf
Solar	1975	Solar (Electric, Thermal)\solar thermal energy collection system 1975.pdf
Solar	1977	Solar (Electric, Thermal)\solar energy collectors 1977.pdf
Solar	1979	Solar (Electric, Thermal)\method of storing energy 1979.pdf
Solar	1979	Solar (Electric, Thermal)\method of storing energy 1979.pdf
Geothermal	1991	Geothermal\silencer for geothermal power plant and method fo using the same 1991.pdf
Geothermal	2001	Geothermal\method and apperatus for producing power form geothermal fluid 2001.pdf
Geothermal	2001	Geothermal\geothermal power generator 2001.pdf
Geothermal	2000	Geothermal\geothermal power generating sstem 2000.pdf
Geothermal	2001	Geothermal\geothermal power generation 2001.pdf
Geothermal	1997	Geothermal\geothermal powerplant desulphurisation system 1997.pdf
Geothermal	1983	Geothermal\geothermal power plant 1983.pdf

MicroCHeaP Patent Search – First Update

Contributed by CHALEX

PATENTS ON CD AVAILABLE FROM CHALEX:

Results of Patent Search – First Update (Renewable Micro-CHP)

<u>Category</u>	<u>Number of Patents on CD</u>
Biomass – biogas	4
Biomass – pyrolysis	7
Micro-CHP	4
Solar CHP	1
Thermal Heat Pumps	3
	<u>Total:</u> 19

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MicroCHeaP - Work Package 2 Deliverable 12 - First Update to Patent Review

The purpose of this exercise was to ascertain the extent of existing Intellectual Property, Patents and Copyrights in the field of combined heat and power, specifically micro-CHP energy reclamation and reuse systems.

A worldwide patent search was conducted using the Delphion and Esp@ceNet patent servers. The time restriction imposed upon this search was up until 01.01.2005 - 21.02.2006, thus overlapping the initial investigation 12.05.1973 – 13.01.2005.

The patent collections searched consisted of German (Applications - Full text), German (Granted - Full text), European (Applications - Full text), European (Granted - Full text), INPADOC, Abstracts of Japan, US (Granted - Full text), WIPO PCT Publications (Full text), US (Applications - Full text). 43,871,095 patents were searched in total, of which 55,969 were relevant to some degree and 19 were wholly relevant.

Terminology used whilst conducting the search has been tabulated as `Search Term` against the total number of patents any additional search terms, and the subsequent number of corresponding patents. The centres of activity are also defined.

Search Term	Patents	Addition	Patents	Addition	Patents	Centres of Activity	
Biomass	4,171	+pyrolysis	7	+chp	0	DE 14% NL 14% SE 14% US 58%	
> Biogas	423	+biomass	4	+chp	0	DE 50% US 50%	
> Pyrolysis	2,998	-	-	+chp	0	-	
Gasification	1,313	-	-	+chp	0	-	
Fuel cell	11,863	-	-	+chp	0	-	
Geothermal	625	-	-	+chp	0	-	
Internal combustion engine	18,545	-	-	+chp	0	-	
Micro-chp	4	-	-	+chp	1	Massachusetts, US	
Micro turbine	127	-	-	+chp	0	-	
Organic rankine process	0	-	-	+chp	0	-	
Solar	12,235	-	-	+chp	1	Tel Aviv, IL	
Stirling	921	+engine	265	+chp	0	-	
Thermal heat pump	3	-	-	+chp	0	California, US	
Thermoelectric	2,741	-	-	+chp	0	-	
Totals:	14	55,969	3	276	1	2	-

Figure in bold indicate patents available in the full text - others available on request.



Category	Year	Description	Country	Patent Number
Biomass > Pyrolysis	2005	Process and apparatus for biomass gasification	US	WO05047436A1
Biomass > Pyrolysis	2005	Method for producing hydrocarbons and oxygen-containing compounds, from biomass	SE	WO05040392A1
Biomass > Pyrolysis	2005	Method for producing hydrocarbons and oxygen-containing compounds from biomass	US	US20050112739A1
Biomass > Pyrolysis	2005	Process and apparatus for biomass gasification	US	US20050095183A1
Biomass > Pyrolysis	2005	Apparatus for separating fouling contaminants from non-condensable gases at the end of a pyrolysis/thermolysis of biomass process	US	US20050039599A1
Biomass > Pyrolysis	2005	Method and system for gasifying biomass	NL	EP1419222B1
Biomass > Pyrolysis	2005	Method for gasifying organic materials and mixtures of materials	DE	EP1226222B1
Biomass > Biogas	2005	Method to accelerate biodegradation of aliphatic-aromatic co-polyesters by enzymatic treatment	US	WO05118693A1
Biomass > Biogas	2005	Method to accelerate biodegradation of aliphatic-aromatic co-polyesters by enzymatic treatment	US	US20050261465A1
Biomass > Biogas	2005	Mehrphasenmedium-waermetauscher und verfahren zur hygienisierung flieBsfahiger biomasse	DE	DE10343415A1
Biomass > Biogas	2005	Fermenter, biogaskraftwerk sowie verfahren zur fermentierung von biomasse zu biogas	DE	DE10345600A1
Micro-CHP	2005	System and method for hydronic space heating with electrical power generation	US	WO05106339A1
Micro-CHP	2005	System and method for warm air space heating and electrical power generation	US	WO05047776A1
Micro-CHP	2005	System and method for hydronic space heating with electrical power generation	US	US20050161521A1
Micro-CHP	2005	System and method for warm air space heating with electrical power generation	US	US20050098643A1
Solar CHP	2006	Small-scale, concentrating, solar CHP system	IL	EP1623164A2
Thermal Heat Pumps	2005	Thermal conversion device and process	US	WO05088080A1
Thermal Heat Pumps	2005	Self-contained microfluidic biochip and apparatus	US	US20050221281A1
Thermal Heat Pumps	2005	Thermal conversion device and process	US	US20050198960A1