



EMINENT²



INSTITUTE
for SOLID FUELS
TECHNOLOGY
and APPLICATIONS

Novel Microturbine Electricity and Heat Supply System

A. Katsiadakis and N. Koukouzas

Eminent 2 Final Dissemination Workshop

FUTURE ENERGY: Research, Innovation and Technology

2-3 March 2009, Lisbon, Portugal



EMINENT *Eminent* 2



Presentation Overview

- **EST Background (2)**
- **EST Description (4)**
- **Reference Technologies (1)**
- **Assessment Study (8)**
- **Dissemination (1)**
- **Conclusions (2)**



EMINENT²



EST Background (1)

- **Commercial Name of the EST:** NETZ (Low Emission Microturbine Power Supply)
- **Inventor/Developer Information:** NETZ has been developed by a consortium of Czech companies, corporations and University institutions, each one responsible for developing a specific part of the whole NETZ system:
 - **UNIS a.s.** (Head of the consortium), control unit and power converter
 - **PBS a.s. Velka Bites** (Head of the management, PR and commercial section), microturbine
 - **VUES Brno a.s.**, synchronous generator
 - **VUT Brno (Technical University of Brno)**, heat exchanger design
- **Contact Details:** Unis a.s., Jundrovská 33, 624 00, Brno, Czech Republic, Tel: +420 541 515 222, Fax: +420 541 210 361, www.unis.cz, mechsys@unis.cz, vallova.d@pbsvb.cz, macholan.m@pbsvb.cz
- **General Director:** Mr. Jiri Kovar, Unis a.s.



EMINENT²



EST Background (2)

- **Status of Development:** the development of the whole NETZ system was realized during the years 2001-2003 and was partially subsidized by the Ministry of Industry and Trade of the Czech Republic (subvention project). In 2005, the first commercial applications took place and the technology is considered commercial since then (EST current maturity stage of Eminent tool: 5).
- **Intended use:** Small-scale Combined Heat and Power (CHP) generation, Standby/emergency or peak hour power supply, Industrial applications, Practical use of NETZ system in commercial applications: business and office buildings, schools, hospitals, hotels, state buildings etc.
- **Brief Discussion of the EST:** Resource Side: Fuels (natural gas) / Demand Side: Electricity and Heating. NETZ Low-emission microturbine CHP system represents successful realization of small-scale co-generation units based on combustion microturbine directly attached to high-frequency generator which supplies electricity through power electronics to the grid or satisfies own user's demands. Output heat may be delivered through warm or hot water or saturated steam. Hot water or steam can also be used to produce cold water for an absorption cooling system (trigeneration). Overall efficiency of the system is increased by utilizing exhaust hot gases.



EST Description (1)

Inputs:

Fuel (Natural Gas)

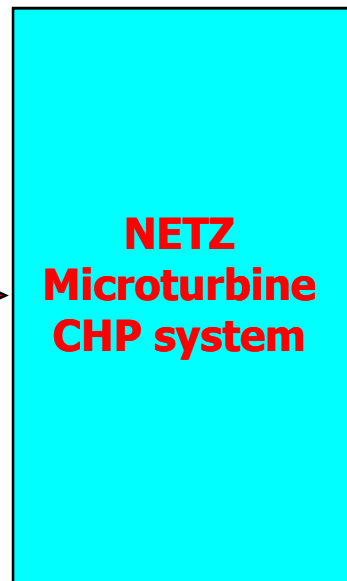


Capacity typical value: 340 kW

Based on LHV

Fuel Consumption: 25 kg/h (34.2 m³/h)

Gas phase



**NETZ
Microturbine
CHP system**

Outputs:

Electricity

AC (50/60 Hz)

Capacity typical value: 103 kW

Voltage typical value: 230 V

Voltage maximum value: 400 V

Heating

Capacity typical value: 163 kW

State of the entering medium: Liquid

State of the exit medium: Gas

Feed temperature: 15 °C

Return temperature: 130 °C

Return pressure: 2.4 bar

Conversion

Electric efficiency= 30.4%

Heat conversion=47.9%

Overall efficiency= 78.3%

Energy loss = 21.7%



EST Description (2)

Degree of Recuperation: 85%

Amount of air (dry): 3178 kg/h

$T_{air, in} = 180\text{ }^{\circ}\text{C}$

$T_{air, out} = 578\text{ }^{\circ}\text{C}$

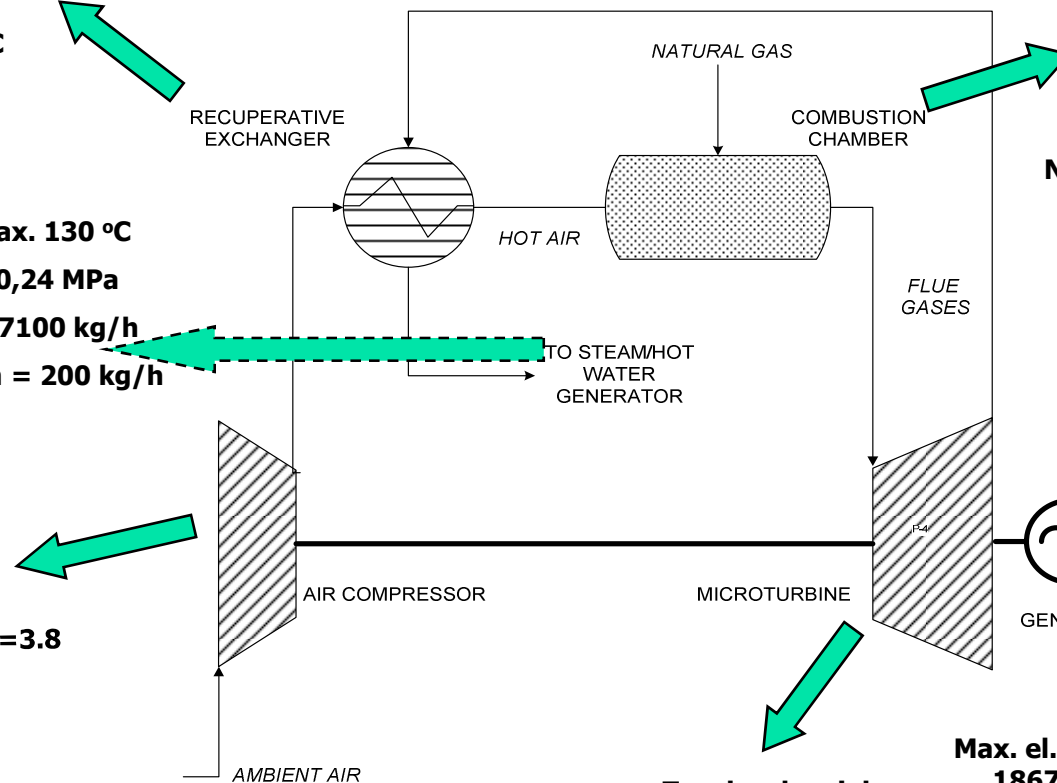
Water Temperature = max. 130 °C

Saturated steam: max. 0,24 MPa

Amount of water = max. 7100 kg/h

Amount of saturated steam = 200 kg/h

Radial, Pressure Ratio=3.8



Cylindrical type,

low-emission,

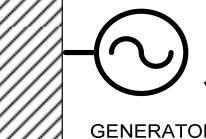
head loss = 5%,

$\text{NO}_x < 9\text{ ppm}$,

$\text{CO} < 15\text{ ppm}$,

NG consumption = 25 kg/hr

(34.2 m³/h)



Synchronous Generator:
Max. el. output on switchboard = 105 kVA,
1867 Hz, Overall efficiency = 95.1%

Output converter:
Max. el. output to grid = 103 kW,
Converter efficiency = 95%

Two level, axial,
 $T_{max, in} = 900\text{ }^{\circ}\text{C}$,
56000 rpm, Efficiency
= 33.7% (with
recuperation)



EMINENT²



EST Description (3)

Advantages of NETZ CHP system include:

- Can be used as an intermittent service with relatively low number of service hours during the calendar year, (reducing costs during the periods of peak demand or high electricity prices)
- The generated electricity satisfies of a NETZ user's demands, and its potential surplus may be fed into the distribution network. Outgoing combustion heat can be recovered to produce heating and cooling providing extra flexibility.
- According to customer requirements the NETZ system can be connected with: GSM module, relay interface, www interface. High quality and reliable control systems.
- Compared to piston-type engines, the major advantages of microturbines with a power output in the class of 100-250 kW include:
 - smaller proportion ($L*W*H=2.3*0.86*1.66$ m) and cheaper maintenance
 - longer effective life and a lower level of noise
 - lower NO_x (< 9 ppm) and CO (< 15 ppm) emissions
- Reduced impact of the unit on the living environment, NETZ burns less fuel -compared to separate production of electricity and heat by conventional methods- and thus it produces a lower amount of emissions.



EMINENT²



EST Description (4)

Data inserted in EMINENT tool database for NETZ (assessment basis):

- Upon inserting the input (fuel) and output values (electricity, heating), the conversion matrix of the tool resulted in: 30.4% electric efficiency, 47.9 % heat conversion and 78.3% overall efficiency
- Variable cost = 0.223 €/kWh electricity output (mainly concerns fuel cost)
- Total investment of around 120,000 € (including capital cost, engineering works and installation) results in 1,165 €/kW electricity output
- Fixed annual cost = 10-20 €/kW electricity output (typical for these kind of machines)
- Technical lifetime= 20 years
- Annual maintenance cost= 2% of total investment (2,400 €/year)
- Operators required to operate the EST = 1
- Additional operator required if EST becomes part of a complete co-locate system = 0
- Ambient temperature range = Min: -20 °C, Max: 45 °C, Typical: 20 °C



EMINENT²



Reference Technologies (1)

- Turbec 100 PH. A CHP microturbine in the same class of 90-110 kW. Demonstration system. (Sintef, Turbec spa/Italy)
- Micro turbine. A CHP unit for household use (1 kW). Lab experiment. (TNO, MTT/Netherlands)
- ORC cycle combined with 450 kW ICE. (Sintef, Waukeasha Enginator/Norway)



EMINENT²



Assessment Study (1)

General specifications for the assessment study:

- *Shadow cost of CO₂ (€/ton CO₂):* 10 €/ton CO₂ (reflecting current price of CO₂ allowances in the European carbon market according to www.pointcarbon.com)
- *Shadow cost of fossil energy (€/MWh fossil energy):* 25 €/MWh (reflecting the average primary energy cost for natural gas in Europe in the year 2006)
- *Assessment year:* 2009

Resource records selected: 11 resource records for Fuels (Natural Gas) were already included in the database and used as input records in the resource side for the assessments. Resource country records included: Czech Republic, Denmark, Germany, Greece (included by the authors), Hungary, Latvia, Netherlands, Norway, Portugal, Russian Federation, United Kingdom.

Demand records selected: Various demand records for electricity and heating for many different sub-sectors in each of the above 11 countries were selected in order to establish full and consistent energy supply chains.

EST to be evaluated: NETZ Microturbine electricity and heat supply system. No peripheral technologies selected.



EMINENT²



Assessment Study (2)

- The assessment tool worked optimally (full results in terms of energy, environmental and economic parameters) for the following countries: Netherlands, United Kingdom, Portugal, Latvia and Greece. Only the abovementioned country cases, which produced full results in all evaluation criteria, will be further discussed and ranked on a common basis.
- *Netherlands*: 20 valid chains for electricity and 2 valid chains for heating
- *UK*: 6 valid chains for electricity and 1 valid chain for heating
- *Portugal*: 56 valid chains for electricity and 6 valid chains for heating
- *Latvia*: 1 valid chain for electricity and 0 valid chains for heating
- *Greece*: 1 valid chain for electricity and 1 valid chain for heating



Assessment Study (3)

Economic analysis: Ranking of supply chains according to increasing specific costs of delivered energy (electricity)

Chain description	Country of resource	Country of demand	Sector	Chain costs (ex. shadow costs)	€/MWh (incl. shadow costs)
Fuels (NG)_NETZ_Electricity	U.K.	U.K.	Manufacture of basic metals and fabricated metal products	209,117,734,353	743.05
Fuels (NG)_NETZ_Electricity	Netherlands	Netherlands	Manufacture of vegetable and animal oils. fats	8,377,178	747.30
Fuels (NG)_NETZ_Electricity	Greece	Greece	Activities of households	3,529	857.51
Fuels (NG)_NETZ_Electricity	Latvia	Latvia	Agriculture, hunting and forestry	137,153	890.72
Fuels (NG)_NETZ_Electricity	Portugal	Portugal	Manufacture of pulp, paper and paperboard	3,877,783,178	906.55



Assessment Study (4)

Environmental analysis: Ranking of supply chains according to increasing specific CO₂ emissions per unit of delivered energy (electricity)

Chain description	Country of resource	Country of demand	Sector	kg CO ₂ /year	kg CO ₂ /MWh
Fuels (NG)_NETZ_Electricity	U.K.	U.K.	Manufacture of basic metals and fabricated metal products	167,545,024	0.595
Fuels (NG)_NETZ_Electricity	Netherlands	Netherlands	Manufacture of vegetable and animal oils. fats	6,674	0.595
Fuels (NG)_NETZ_Electricity	Greece	Greece	Activities of households	-	0.718
Fuels (NG)_NETZ_Electricity	Portugal	Portugal	Manufacture of pulp, paper and paperboard	70,929,711	16
Fuels (NG)_NETZ_Electricity	Latvia	Latvia	Agriculture, hunting and forestry	90,863	586



Assessment Study (5)

Energy analysis: Ranking of supply chains according to increasing specific fossil fuel consumption per unit of delivered energy (electricity), CED_{NR} dimensionless

Chain description	Country of resource	Country of demand	Sector	CED_{NR}	Consumers	EST's per end user
Fuels (NG)_NETZ_Electricity	U.K.	U.K.	Manufacture of basic metals and fabricated metal products	1.69	200	311,667
Fuels (NG)_NETZ_Electricity	Netherlands	Netherlands	Manufacture of vegetable and animal oils. fats	3.35	35	18
Fuels (NG)_NETZ_Electricity	Latvia	Latvia	Agriculture, hunting and forestry	3.37	1,230	1
Fuels (NG)_NETZ_Electricity	Portugal	Portugal	Manufacture of pulp, paper and paperboard	3.37	6,960	5,433
Fuels (NG)_NETZ_Electricity	Greece	Greece	Activities of households	3.45	3,832,996	1



Assessment Study (6)

Selected chain in U.K. for activities of households as employers of domestic staff, reflecting suitable sector for potential NETZ application.

Energy analysis

Parameter	Value
Chain Description	Fuels(Natural Gas) -> [NETZ Microturbine electricity and heat supply system] -> Electricity
Sector Code	P95
Sector Description	Activities of households as employers of domestic staff
Country Resources (Natural Gas)	U.K.
Country Demand (Electricity)	U.K.
T1 name	NETZ Microturbine electricity and heat supply system
Total chain efficiency (%)	30 %
Main chain efficiency (%)	30.4 %
Non renewable energy used (MWh)	13954
Specific fossil energy consumption (MWh/MWh delivered)	169.3 %
efficiency of T1	30 %
Energy type of resource	Fuels
Energy type of demand	Electricity
Full load hours usage of resource	8000
Full load hours usage of demand	8000
Power of resource (kW)	3388
Power to demand (kW)	1030
Energy from resource (kW)	27105.3
Energy to demand (MWh)	8240
Full demand is deliverable from chain	1
number of techn 1 per end user	10
number of ESTs per end user	10



EMINENT²



Assessment Study (7)

Selected chain in U.K. for activities of households as employers of domestic staff, reflecting suitable sector for potential NETZ application.

Environmental analysis

Parameter	Value
Total CO ₂ emission for single end user (kg/y)	4905
Specific CO ₂ emission (kg/MWh delivered)	0,6
CO ₂ emission from resource (kg/y)	4905
CO ₂ emission from T1 (kg/y)	0



Assessment Study (8)

Selected chain in U.K. for activities of households as employers of domestic staff, reflecting suitable sector for potential NETZ application.

Economic analysis

Parameter	Value
Total investment for single end user (Euro)	1201207
Total depreciation for single end user (Euro/y)	60060
Total maintenance for single end user (Euro/y)	24024
Total costs for single end user excl shadowcosts (Euro/y)	6129959
Total costs for single end user incl shadowcosts (Euro/y)	6130008
Specific costs excl shadowcosts (Euro/MW h delivered)	743,93
Specific costs incl shadowcosts (Euro/MW h delivered)	743,93
investment for T1 (Euro)	1201207
Costs of resource (Euro)	1401
Operational costs of T1 (Euro/y)	6068498
relative size of T1 as compared to typical capacity	0.997
Year from which this chain is possible	2005
Number of consumers in this sector	25795174
Total number of ESTs that can be sold in this sector	257951740



EMINENT²



Dissemination (1)

- Two of the companies that had crucial role in the development of the complete NETZ system, UNIS a.s. together with PBS Velká Bíteš a.s., were awarded the *Gold medal* of the International Engineering Fair in Brno, Czech Republic, in 2003, for their low-emission microturbine electric power supply.
- The National Technical University of Athens (NTUA), School of Mechanical Engineering, is considering to obtain the NETZ system for application in a hybrid CHP system, including also a PEM fuel cell, for demonstration and educational purposes. The project is at the evaluation stage. The results of the Eminent tool assessment will be delivered to NTUA in order to enhance their proposal and choice of technology.



EMINENT²



Conclusions (1)

- NETZ advantages include: Low-emission operation, low maintenance costs, higher overall efficiency due to recovery of waste heat by the recuperation heat exchanger, flexible CHP (or trigeneration) operation depending on coupling possibilities with the steam generator
- Upon assessing the NETZ technology in Eminent tool, U.K and the Netherlands produced the best evaluation criteria in full supply chains, in respect of economic, environmental and energy parameters.
- The U.K. basic metals manufacturing sector produced the best performance figures for this EST, though it is unlikely that a small-scale CHP unit would be applied in such a large energy-consuming sector (too many units per end user required).
- Therefore, another sectors more suitable to NETZ scale and capabilities were also examined in detail, i.e. the household and services sector in U.K. The analysis in such sector produced similar attractive evaluation figures.



EMINENT²



Conclusions (2)

- When NETZ was compared against reference technologies (Turbec 100 PH) the tool's results for NETZ were favorable only on environmental terms (kg CO₂/year and kg CO₂/MWh). Energy figures were similar and cost figures were lower for Turbec.
- When NETZ was compared with ICE (ORC cycle combined with 450 kW ICE), the tool produced better performance results for the gas engine concept for all categories.
- Eminent assessment tool has a very user-friendly interface and can be easily handled by non-experts.
- It gives a first good picture of how a new technology may feel to a specific demand sector, taking into account the available resources.
- However, the results of the assessments should be carefully further evaluated and validated in order to proceed to final investment decisions.



EMINENT *Eminent* 2



Thank you for your attention !

Contact: katsiadakis@lignite.gr

koukouzas@certh.gr