

GasTurbineTechnologies SpA

The EOS Project: an Industrial SOFC Pilot Plant in Italy

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Roma, December 16, 2005



Our History: Engines and Power Stations



Gas Turbine Technologies, former Power Division of Fiat Group, is now a Subsidiary of Siemens acting in Power Generation business as Gas Turbines Service Provider



Our Product: Low Emission Gas Turbines





The EOS Project

(Energia da Ossidi Solidi
Energy from Solid Oxides)

Partners



EOS is the Goddess of the Dawn



Pink-fingers Eos leads the way to her brother Sun: Fuel Cells could represent the dawn of a new era in clean Power Generation



Guido Reni, 1613, affresco, Casino dell'Aurora, Palazzo Rospigliosi, Roma

Ἦμος δ' ἠριγένεια φάνη ῥοδοδάκτυλός 'Ηώς

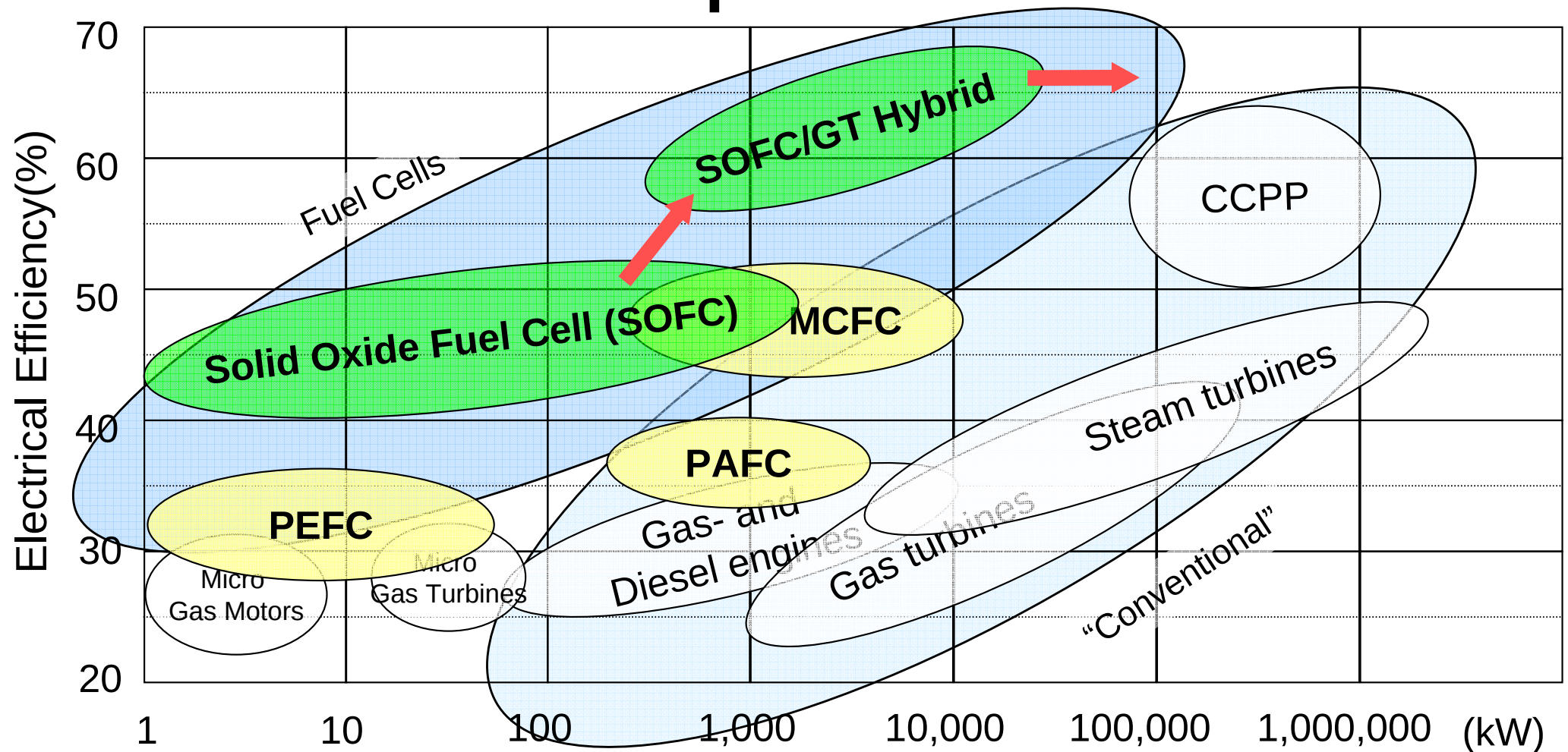
When pink-finger Eos appeared in the morning sky (Homer, Odissey, IX, 170)

EOS Project Scope



- Stationary fuel cells demonstration plant inside the research laboratories network of Regione Piemonte, in cooperation with Politecnico and Environment Park of Turin
- Solid Oxide Fuel Cells extended heavy duty operations in real industrial environment, proving...
- ...extremely low environmental impact (0.2 ppm NO_x, low CO₂ emission due to high electrical efficiency (net AC/LHV) of 46 %, very low noise)
- Research, develop and implement SOFC systems maintenance procedures and repair technologies
- Keep GTT leadership on power plant service moving from gas turbines to fuel cells

Efficiency potential of various PG techniques



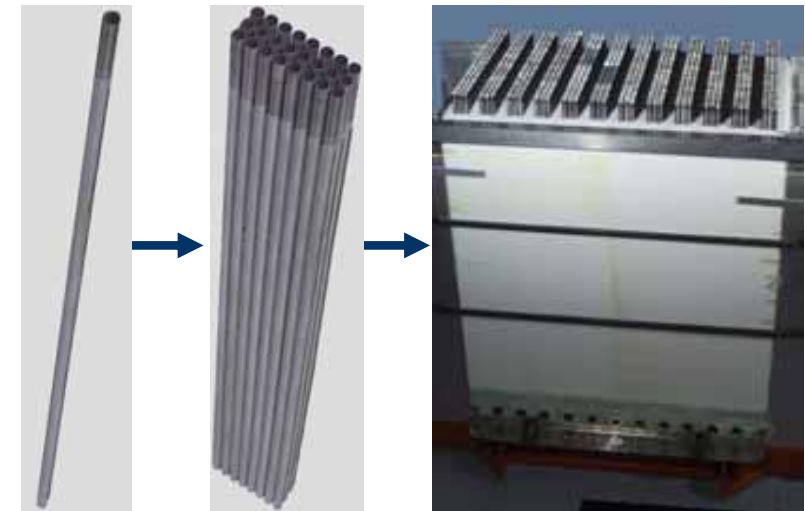
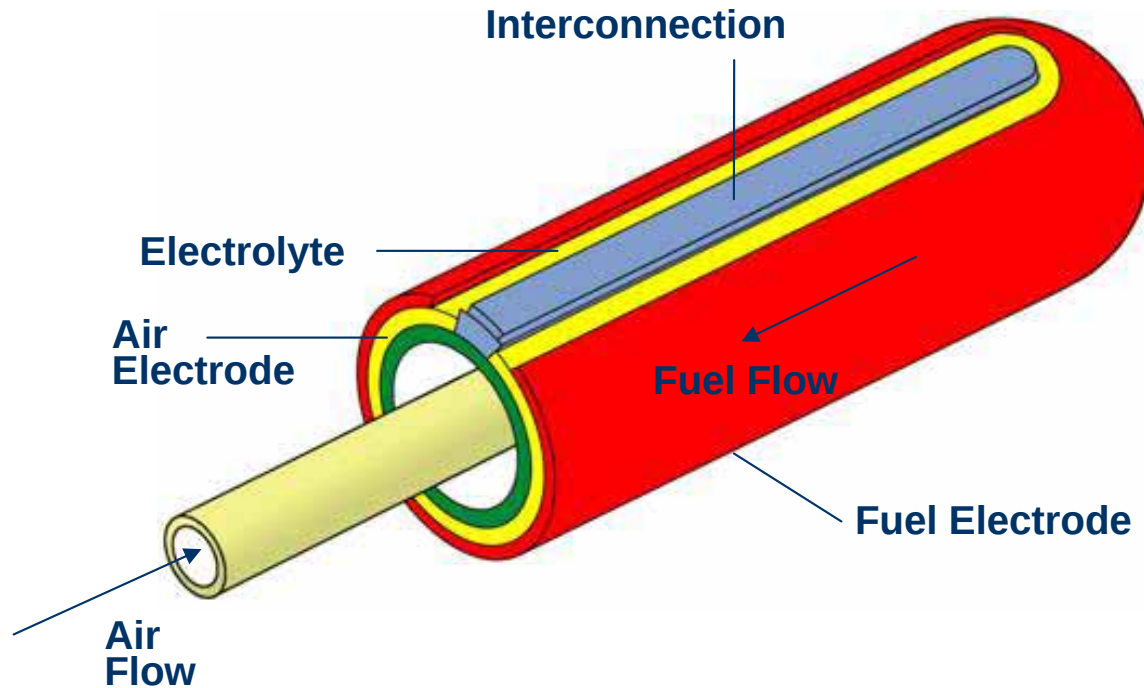
Today SOFC Technology already achieves highest electrical efficiencies in the mid to lower power rating range and has the potential to be advantageous versus central power generation in the future.

Different fuel cells types



	PEM	PAFC	MCFC	SOFC
Simple Cycle Electrical Efficiency on NG (net AC/LHV)	35%	40%	45-50%	45-50%
Simple Cycle Electrical Efficiency on H ₂ (net AC/LHV)	50%	50%	Needs CO ₂	40%
Hybrid Cycle Electrical Efficiency on NG (net AC/LHV)	T too low	T too low	55%	≥ 60%
Performance Degradation on NG (% per 1000h)	High – CO poisoning	≥ 0.5	≥ 0.5	≤ 0.1 for tubular
				1-2 for planar
Demonstrated Stack Lifetime on NG (years)	<1	5	2.5	> 2.5 for tubular
				< 1 for planar
Stack Lifetime Potential on NG (years)	1	5	3-5	5-10 for tubular
				? for planar
Power Rating Range on NG	≤ 200 kWe	200 kWe to 10 MWe	200 kWe to 10 MWe	1 kWe to 10 MWe
Today's Recurring Product Cost (\$/kWe)		4000		

SIEMENS SOFC Tubular Technology



Cell
110 W

Bundle
3 kW

Stack
125 kW

Performance of SOFC technology proven by:

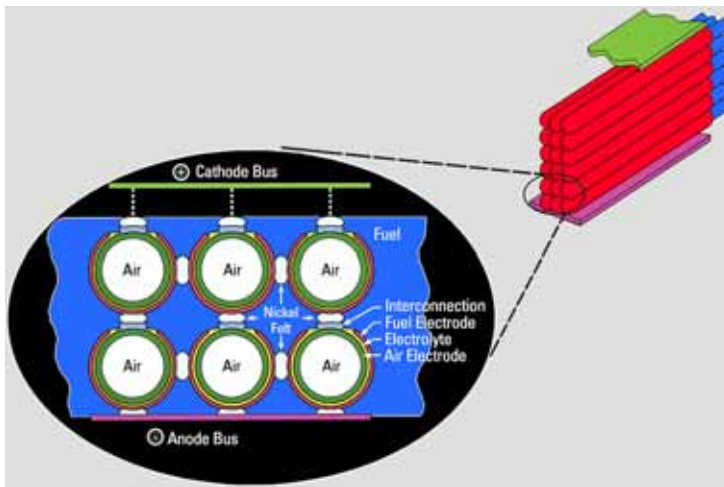
- Single cell tests over 69,000 hrs
- Voltage degradation < 0.1% per 1000 hours
- Thermal cycle capability of > 100 cycles
- Complete system operating hours > 24,800 and counting

SIEMENS SOFC Module Schematic

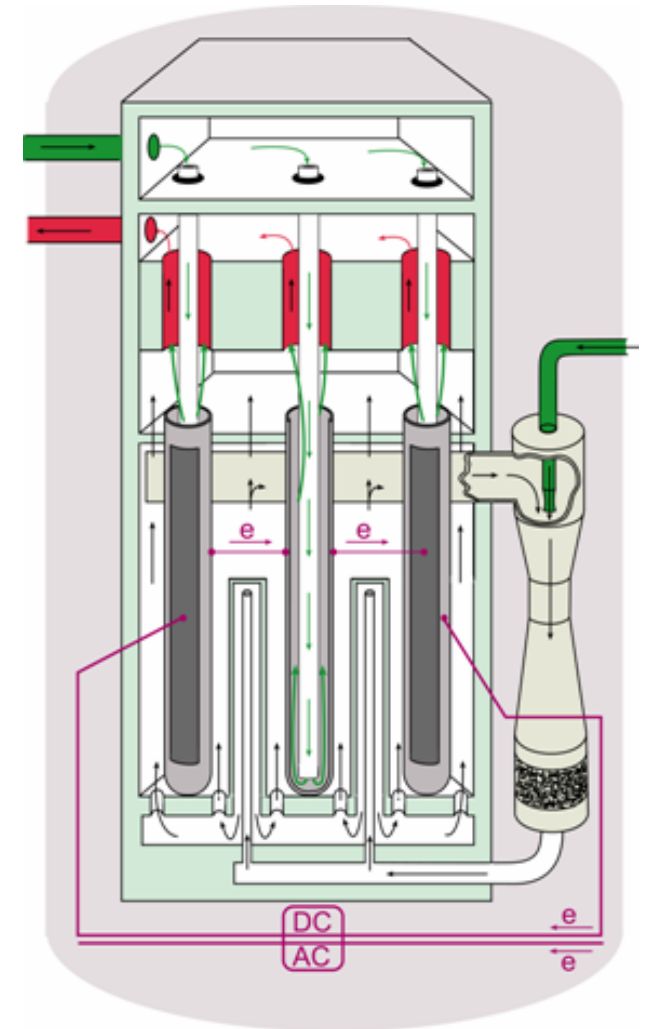


- No high temperature seals
- Internal recirculation of depleted fuel driven by fuel ejector
- No moving parts
- Choice of recirculation rate dependant on gas composition
- Internal reformation excludes the need for external water supply
- Internal recuperation reduces cost & increases efficiency of system

Bundle Configuration



Basic module design is proven, efficient and reliable. It is currently being cost reduced



Why SOFC for Distributed Generation?



- Environmentally friendly
- High efficiency
- Minimal installation
- High quality power
- High availability/reliability
- Minimum degradation
- Low noise
- Unattended operation
- Low maintenance
- Air cooled, no water
- Optional steam/hot water cogeneration
- Ease of licensing
- Natural gas fuel, H₂, biogas (Fuel flexibility)
- Also CO is a fuel
- Recovers from Sulfur poisoning



Siemens is the recognized world leader in solid oxide fuel cell technology

SOFC Demonstration Programs



Westervort (NL)
Essen (D)

Fuel:
Natural Gas

Rating:
110 kWe
46% net AC Efficiency

Operation:
1997 to 2002
16,610 + 3870 hours
No degradation

System Dimensions:

Length = 8.6 m
Width = 2.8 m
Height = 3.7 m
Weight = 32,600 kg

SIEMENS CHP100 SOFC Power System



Off Skid: PCS, HES, UPS

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SOFC Demonstration Programs



SIEMENS PH200 SOFC Power System Proof-of-Concept for SCE

- **Power Module**
 - PSOFC
 - 1152 cells
 - MTG [IRES]
- **Off Skid**
 - NG Compressor
 - Desulfurizer
 - Dissipator
- **Operation**
 - 3000 hrs
 - $\eta = 53\%$ net ac

System Dimensions

(Power Module)

Length = 7.2 m

Width = 3.8 m

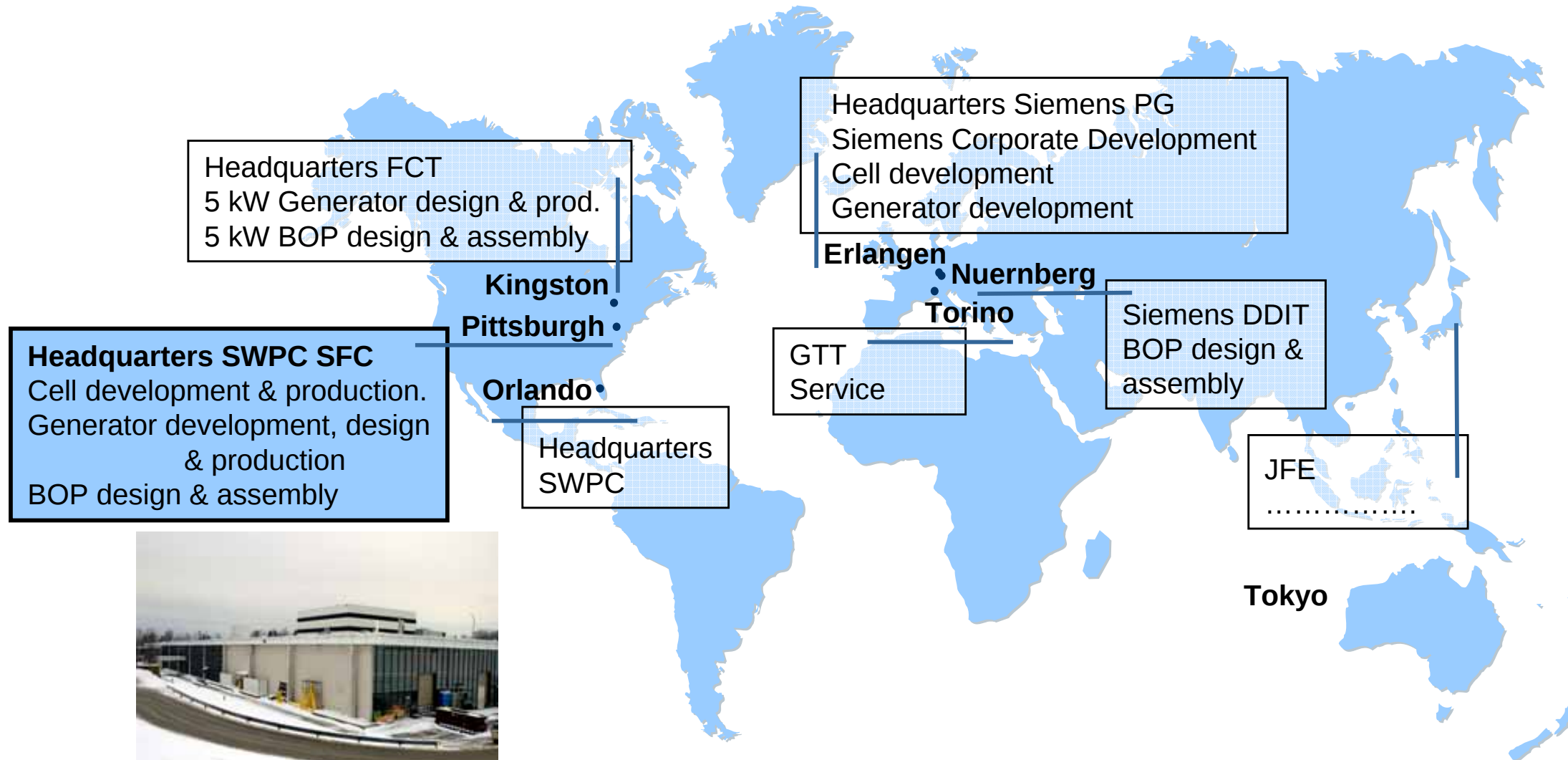
Height = 3.7 m

Weight = 33,000 kg



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SIEMENS PG SFC & Partners



Headquarters SWPC SFC
Cell development & production.
Generator development, design
& production
BOP design & assembly

Headquarters FCT
5 kW Generator design & prod.
5 kW BOP design & assembly

Headquarters Siemens PG
Siemens Corporate Development
Cell development
Generator development

Siemens DDIT
BOP design & assembly

GTT
Service

Headquarters
SWPC

JFE
.....



Churchill, Pittsburgh
100,000 sq ft
140 employees

A Full Service Company:

- **Erection**
- **Start Up**
- **Operation**
- **Maintenance**
- **Spares**
- **Repairs**

...from Gas Turbines to Fuel Cells

Serving the Distributed Generation

The EOS Program



Duration: from **May 2004** to **December 2009**

First phase: 2004-2007

- **April - June 2005:** erection and start up of CHP100 (100 kW Generator). This unit already performed 20,480 hours in Holland and in Germany. It has been refurbished in Siemens workshop, in Pittsburgh Pa, USA.
- **July 2005 – December 2007:** operation, testing, maintenance; research and modeling activities by Politecnico di Torino

Generator installed in GTT workshop of Torino (Italy), contributing to supply power and thermal energy for heating and air conditioning (60 kWt)

Unit connected to the municipality grid (through GTT workshop grid) and fueled by natural gas from the pipeline

The EOS SOFC Generator: 1st phase

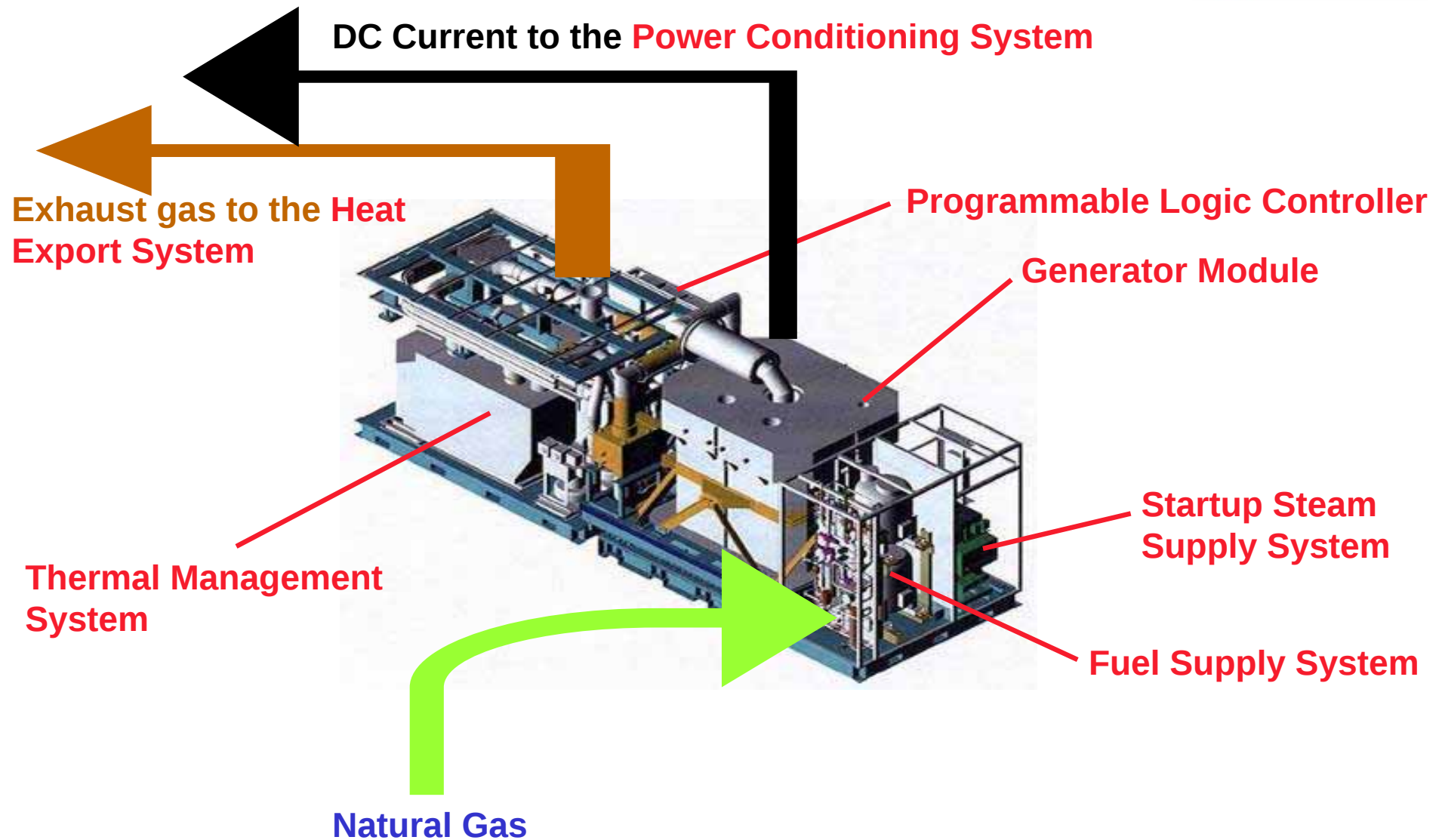


CHP 100



Siemens Fuel Cell Generator in EOS test room, GTT Torino

The EOS CHP100 Siemens Generator



The EOS CHP100 Siemens Generator



- Commissioning date: June 19, 2005
- Operational data @ December 16, 2005:
 - Run hours in GTT : 4,320
 - Total Run hours: 24,800 (including run hours in NL and D)
 - Energy produced in GTT to date: 515 MWhr
 - Generated Power, DC: 123 kW
 - Voltage, DC: 246 V; Current, DC: 502 A
 - Generated Power, AC: 113 kW
 - Power to GTT workshop grid: 103 kW (20% of the workshop requirement)
 - Cogeneration: Hot water 98°C, Power 60 kWt
 - Availability to date: 99.8%

The EOS CHP100 Siemens Generator

Environment advantages



In one year of operation the Solid Oxide Fuel Cell Generator fuelled by natural gas avoids:

- the production of 272 tons of CO₂
- the environmental pollution of 1035 kg of NO_x.
- the import of 121 equivalent oil tons

EOS for Research & Education



At Politecnico di Torino:

- 10 Professors involved
- 3 Ph.D.s, 4 Doctorate Students involved
- 9 Engineering Students working on their thesis
- Relations with other 6 Universities in Italy and 1 in USA
- Publication of papers

Public events in cooperation with Regione Piemonte:

- Porte Aperte all'innovazione (Torino, October 2005): open doors to all the persons interested to innovation
- University and High School Classes visiting EOS test room
- Relations with Museo A come Ambiente of Torino
- Ecological Sunday on November 27, 2005, in Torino

The EOS SOFC Generators: 2nd phase

2007-2009



- Net AC Power = 125 kW
- Electrical efficiency (average) = 46% (net ac/LHV) depending on load
- Total efficiency = ~ 80%, incl. heat recovery
- Base load service
- 60% turndown from maximum load (~75kWe) with extremely high efficiency
- Electric power output independent of hot water system availability
- Natural gas fueled power system
- No SOx or CO and < 0.2 ppm NOx
- Attended start-up, unattended operation
- Optional heat exchange equipment for the production of hot water: 85 kW

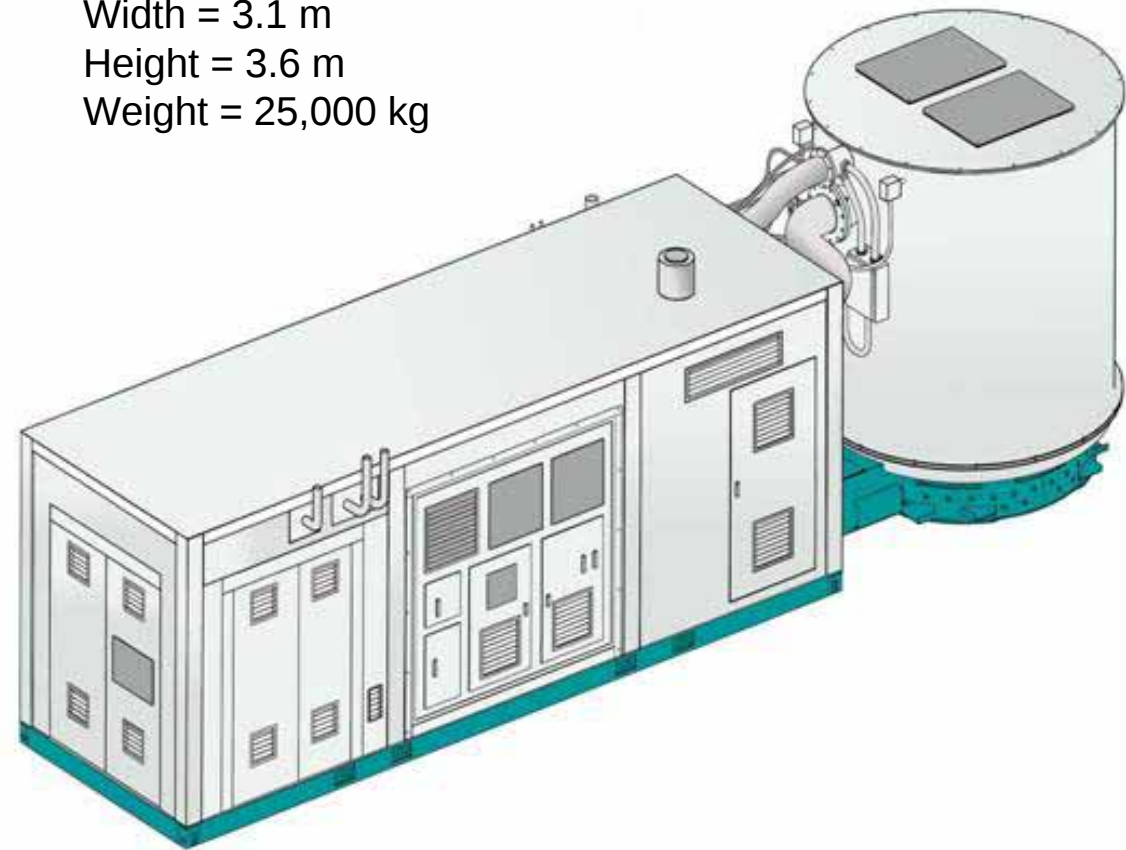
System Size

Length = 11.4 m

Width = 3.1 m

Height = 3.6 m

Weight = 25,000 kg



SFC200

Residential Applications: CHP5 SOFC



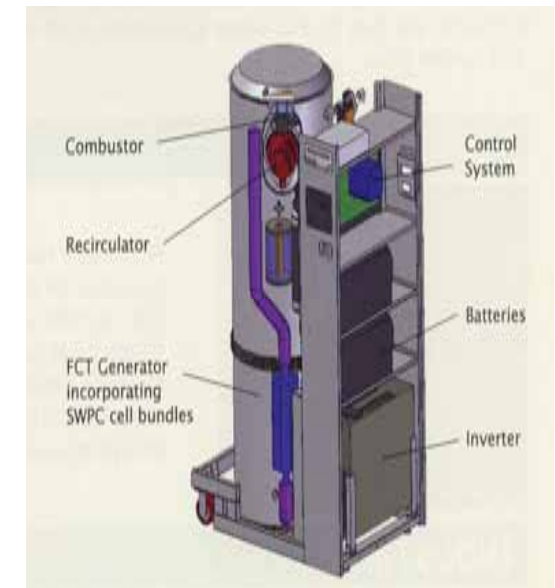
Overall Dimensions	117 cm wide x 82 cm deep x 209 cm high
Weight	1000 kg (including batteries)
Electrical Output	1 to 5 kW @ 120/240 VAC 50/60 hz, grid independent or grid connected Up to 10 kW surge capacity
Thermal Output	Approximately 6 kW available for domestic hot water or heating
Electrical Efficiency	Approximately 42% at nominal 3 kW
Overall Efficiency	Approximately 85% at nominal 3 kW
Fuels Currently Used	Natural gas, hydrogen, methane
Service Interval	Every 6 months

Balance of
Plant by:



Tubular
Cells by:

SIEMENS



Pilot Plant micro CHP 5 kW SOFC: The EBE Project



- **EBE** means (in Italian): **E**nergia a **B**asse **E**missioni (Low Emission Energy)
- **EBE** is the Goddess that carries drinks to the Gods

- GTT will install at early 2006 a 5 kW micro CHP in its canteen, in a Research Program with the Partners:



SOFC Technology Developments



New High Power Density Cells improve specific power

GTT foresees the testing in Italy of a 300 kW sofc generator and a 1000 kW pressurized hybrid

Conclusions



- GTT started in Torino (Italy) the EOS research activity, on the promising Siemens SOFC technology, complementary to the product development progressing in Pittsburgh (USA), in cooperation with Politecnico and Envipark of Torino
- EOS is focused on real industrial operations of fuel cells systems, generating clean energy and aimed also to develop operation & maintenance procedures and repair technologies
- EOS will allow GTT to keep in future Stationary Fuel Cells Power Plants the leadership presently owned in Gas Turbines Service

Thank you!

Questions?

**...and we invite you to visit
Gas Turbine Technologies
Solid Oxide Fuel Cells operations
in Torino!**

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www.siemens.it/gtt

www.eos.polito.it