General Electric - Europe

Hybrid Power
A European Perspective

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European Union (EU)

15 EU Member States


Austria


Belgium


Denmark


Finland


France


Germany


Greece


Ireland


Italy


Luxembourg


The Netherlands


Portugal


Spain


Sweden


United Kingdom

EU Enlargement:

1957: Belgium, France, Germany, Italy, Luxembourg, The Netherlands

1973: Denmark, Ireland, United Kingdom

1981: Greece

1986: Portugal, Spain

Candidate Countries: Cyprus, Bulgaria, Estonia, Hungary, Czech Republic, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Slovakia,

EU Facts & Figures

Key Economic Data

- Total Population: 374 million
  - Largest: Germany (82 million) / Smallest: Luxembourg (424,000)
- GDP: 10 trillion$, annual inflation rate: 3%
- Average unemployment rate: 10% (regional from 2% to 28%)

Key R&D Data

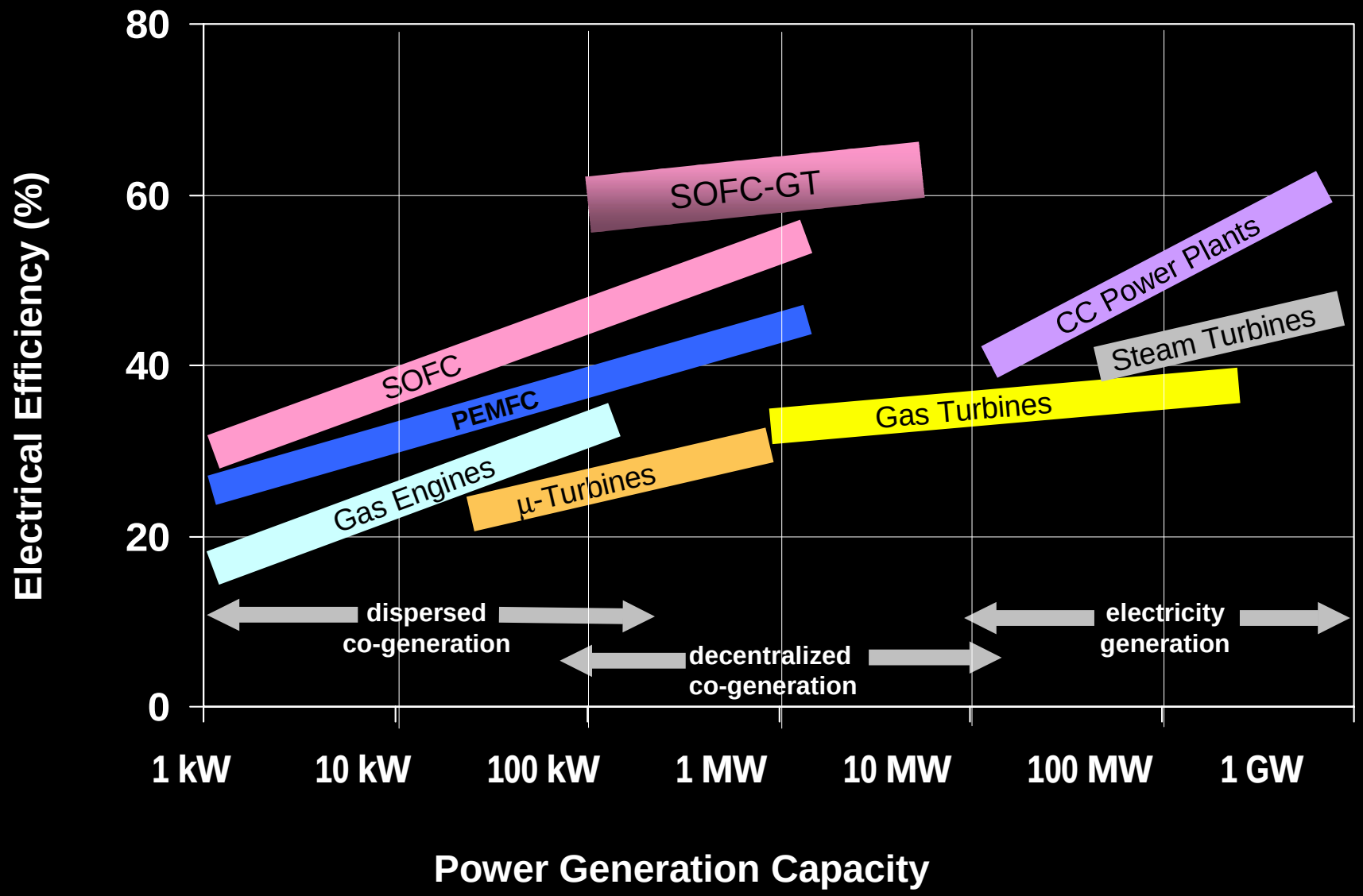
- Employment in high-tech sector (% of total): 7.8
- Total R&D personnel (% of total): 1.3
- Annual R&D expenditures:
  - EU Gov't: 4bn$
  - EU member states: $80bn (total 176bn$ = 1.9% of GDP)

EU Gov't Energy Policy Targets

- Security of Supply and Diversification of Energy Sources
  - *Green Paper COM (2000) 759 final*
- Renewable Sources of Energy
  - *White Paper COM (97) 599*: Increase from 6 to 12% by 2010, equivalent: 12 to 22% for electricity
- Meeting Kyoto Objectives
  - 8% CO2 reduction (2010 vs 1990 levels)
- Energy Efficiency
  - *COM(2000) 247:* Improve by 18% by 2010 vs 1990
- Markets Liberalisation & Industrial Competitiveness

Energy policy drives R&D and regulation

EU Power Generation



Major EU R&D Programs

EU Framework 5 (1998-2002)

Life Sciences	**2,400 M€**
Information Technology	**3,600 M€**
Manufacturing, Production, Transport	**2,700 M€**
Energy	**2,125 M€**
– Cleaner energy systems, including renewables	**479 M€**
– Economic and efficient energy	**547 M€**

EU Gov't R&D only 5% of total R&D in Europe

Budgets for FC R&D

EU Gov't (Framework 5): **15M€/yr**

- Focus: All fuel cell types, cost reduction, application development
- 23 current projects, average project: 600K/yr funding (3-4M total contract value, 1.5-2M Gov't costshare, 3 yrs, 5-6 partners)

National Member States: **30M€/yr**

	Country	Budget/yr	Application
e.g.	France	8M	All types
	Germany	5M	Large scale electricity generation, CHP
	Spain	3.5M	Large…small scale electr. gen., transport
	UK:	2M	Transport, CHP, distributed generation

Industrial Programs: **10…15M€/yr**

Total EU R&D in fuel cells ~ 60…70M€/yr

EU Hybrid Fuel Cell Strategy

Hybrid SOFC/MCFC Gas Turbine

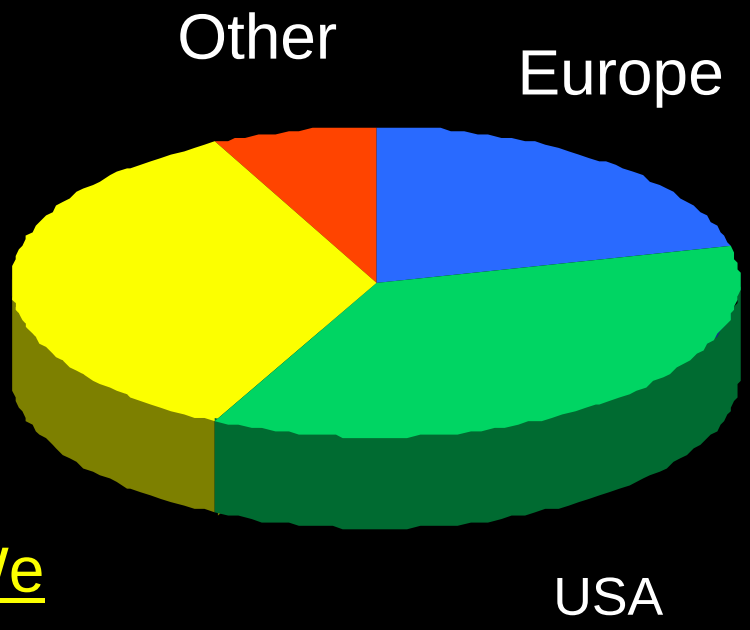
- Foreseen Application
  - Decentralized power generation: Electricity and CHP at medium/large scale for industrial, commercial and residential applications: 100kW … 10MW
- 2005 Cost & Durability Goals
  - **500 €/kW** (stack), **1,000-1,500 €/kW** (system), **40,000 hrs**
- R&D Activities:
  - Design and development of simple, modular SOFC and MCFC systems in combination with a gas turbine
  - Focus on modeling and integration
  - Demonstration of reliability & maintenance

Expected Market Development

Distributed Generation

w/HT Fuel Cells

(source: EC Thermie project)



Total estimated demand/yr: 1400 MWe

Expected market introduction: 2005

Volume:1.2 billion €/yr

Automobile fuel cell market 10…50 higher

EU Project: Study of Fuel Cell/GT Hybrid

Objectives

- Assess the performance of FC/GT hybrids using a novel approach of close integration of system and stack models
- Understand performance requirements for FC/GT hybrids and necessary system specifications for different sectors of the market
- Verify life environmental impact

Partners

- Rolls Royce (prime)
- ABB Turbo
- Alstom Power
- Turbec
- Turbomeca
- Enel + others

Timing: 2001 - 2003

Budget: 3 M€ (incl. 1.2M Gov't cost-share)

Description of Work

- Focus is on natural gas fuelled systems + investigation of bio-gas use
- 3 subsystems are considered:
  - < 1 MWe for DG
  - 1-3 MWe for CHP
  - 20-30 Mwe for DG
- Link market to product requirements
- Development of generic modeling capabilities
- Validation of detailed finite volume thermal and chemical models
- Development of fuel cell models for use in integrated system modeling
- Preliminary system design

EU Project: 1 MW Class SOFC Fuel Cell Hybrid

Objectives

Common project between USA and Europe

- Design, manufacture and test a 1 MW SOFC hybrid power system
- Phase 1: Atmospheric SOFC/MTG power system, 50…53% efficiency
- Phase 2: Pressurized SOFC/MTG power system, 60% efficiency

Partners

- Energie Baden-Wuerttemberg (prime)
- Gaz de France
- Electricite de France
- Tiroler Wasserwerke
- Siemens, Siemens Westinghouse

Timing: 2000-2004

Budget: 27 M€ (incl. 4M EU Gov't cost-share)

Milestones & Expected Results

- Emission targets:
  - SOx --- < 0.1 ppm
  - NOx --- < 0.5 ppm
  - CO --- 0
  - Particulates --- 0
  - CO2 --- < 350 kg/MWh
- Ground noise level at 5 m < 75 dBA
- Power output stability: < 1% (of rated power)
- Part power operation down to 50% load
- Unattended operation
- Semi-automatic operator assisted startup

National Programs: Germany / Italy

300 kWe Prototype Hybrid SOFC Systems

- Partners: Siemens Westinghouse, RWE Power AG, Thyssengas (Germany), Edison Spa (Italy)
- Application: CHP (district heating applications)
- Technical Data:
  - Tubular cell design: dia 2.2cm x 150cm; 1000 C operating temp.
  - Fuel: Natural Gas
  - Electrical Efficiency: 58%
  - Power Output: 300kWe (250kW SOFC, 50kW microturbine)

Microturbine Turbec 100

Source: Thyssengas

Important stepping stone to commercialization

The Way Forward….

Framework Program 6 (2003 - 2006):

Total budget: 17.5 billion Euro (expected)

Status: Negotiations between Commission, Parliament and Council are on track

Timing: Calls for proposals start Nov/Dec 2002 -- earliest project start: Q2, 2003

Framework 6 Budget

Budget Overview (main programs) in million Euro:

Genomics and biotechnology for health:	**2.200**
Information technologies:	**3.600**
Nanotechn., nanosciences, materials, prod. processes:	**1.300**
Sustainable development (energy & transport):	**2.100***
Aeronautics and space:	**1.100**
Structuring the European Research Area: (mobility of researchers, innovation, links to national and regional initiatives)	**3.050**

*energy budget is 600….800 million Euro

Energy R&D will focus on user efficiency/savings

Priority Areas: EU Energy R&D 2003-2006

Short-to-medium term:

- Renewable energy sources and integration
- Energy saving and energy efficiency
- Alternative motor fuels (hydrogen etc)

Medium-to-Long Term

- Fuel cells (transport & stationary)
- Hydrogen technologies (as energy carrier and storage)
- Advanced photovoltaics
- Advanced use of biomass
- Disposal of CO2 associated with cleaner fossil fuel plants

EU Gov't technology roadmap not yet finalized

EU FC R&D '03-'06

Objectives:

- Long-term cost target (stack):
  - ➔ 50€/kW for road transport, 300 €/kW for stationary
- R&D Focus:
  - ➔ Cost reduction in fuel cell production
  - ➔ Applications development for buildings, transport and decentralized electricity production
  - ➔ Advanced materials for low and high temp FCs

Budgets for future fuel cell R&D not yet finalized

Thank you!