ENATEC micro-cogen BV

Development of a DCHP unit based on a Free Piston Stirling Engine

Generating electricity with a Condensing Boiler

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Introducing ENATEC

- **ENATEC micro-cogen BV was founded in 1997 by**

ENECO energie	**Eneco**	**(Major utility in the Netherlands)**
ATAG	**ATAG Heating**	**(Dutch boiler manufacturer)**
ECN	**ECN**	**(Energy research Center of the Netherlands)**

The objective of the consortium ENATEC is:

- **to develop a marketable dchp technology**
- **to license this technology to boiler manufacturers**

- The development phase of ENATEC is supported financially by the Dutch Ministry of Economic Affairs, through the Novem agency

Domestic CHP

- State of the art: Condensing Boiler,
  - Caloric efficiency: 107 % (LHV)
  - Gas consumption: 2100 m^3 (Dutch reference house)
  - CO_2 emission: 3.7 ton/y
  - NO_x emission: < 40 ppm

- Next step: Domestic Combined Heat and Power,
  Combination of a CB and a Prime Mover (i.e. Stirling engine)
  - Higher energy efficiency
  - Reduced environmental impact
  - No extra maintenance

Enatec solution: Stirling driven DCHP

- **Thermal system:** 6 - 24+ kW Condensing Boiler
  - **- Caloric efficiency: 97% (LHV)**
- **Electrical system:** 1 kW Free Piston Stirling Engine
  - **- Operating mode: grid connected**
  - **- By design: 50 Hz, 230 V**
  - **- Maintenance free**
  - **- Electrical efficiency: 10% (LHV)**
- **Combined DCHP system:**
  - **- Life, constant: 60,000 hours (15 years)**
  - **- Life, intermittent: 200,000 cycles (15 years)**
  - **- System efficiency: 107 % (LHV)**

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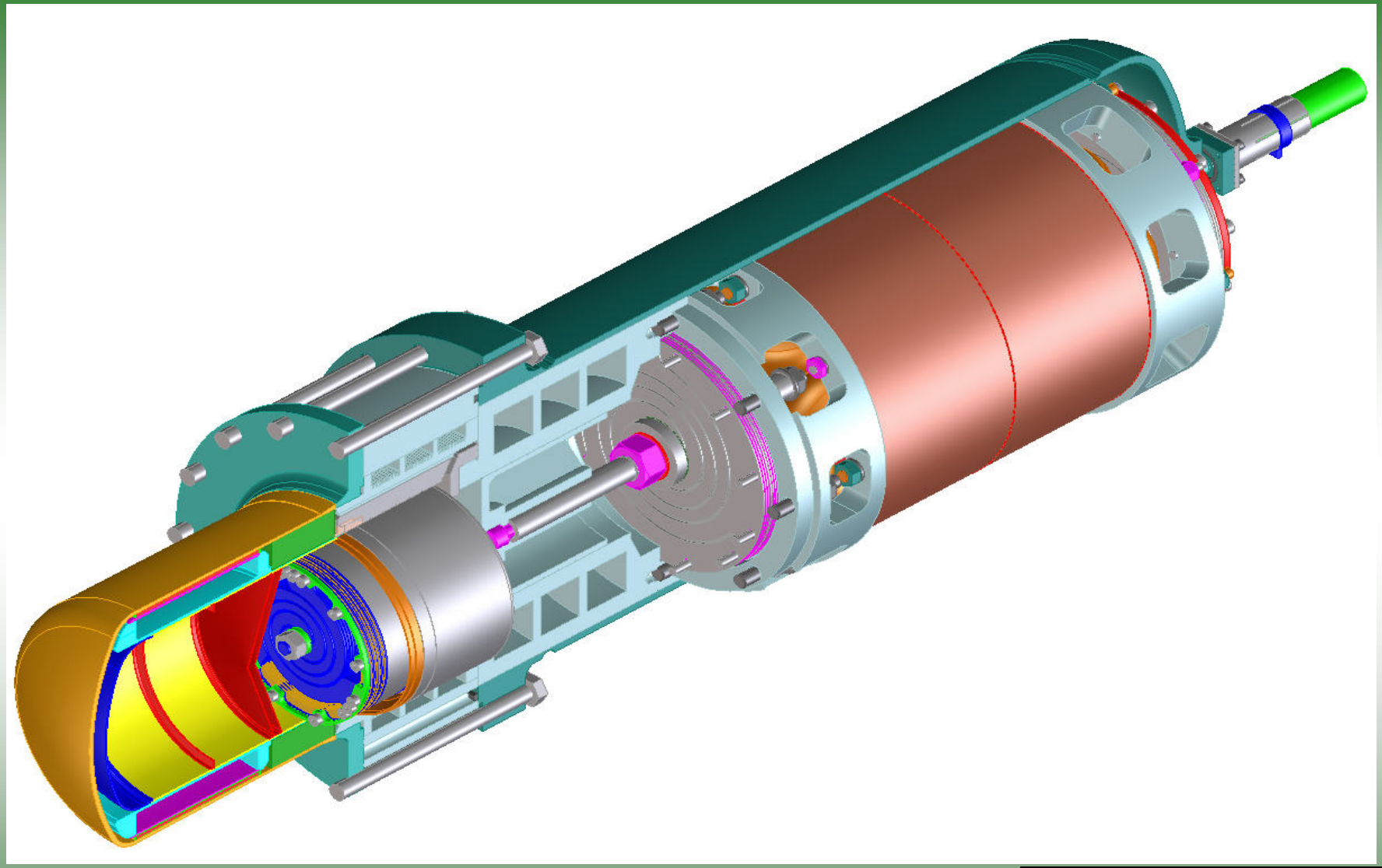

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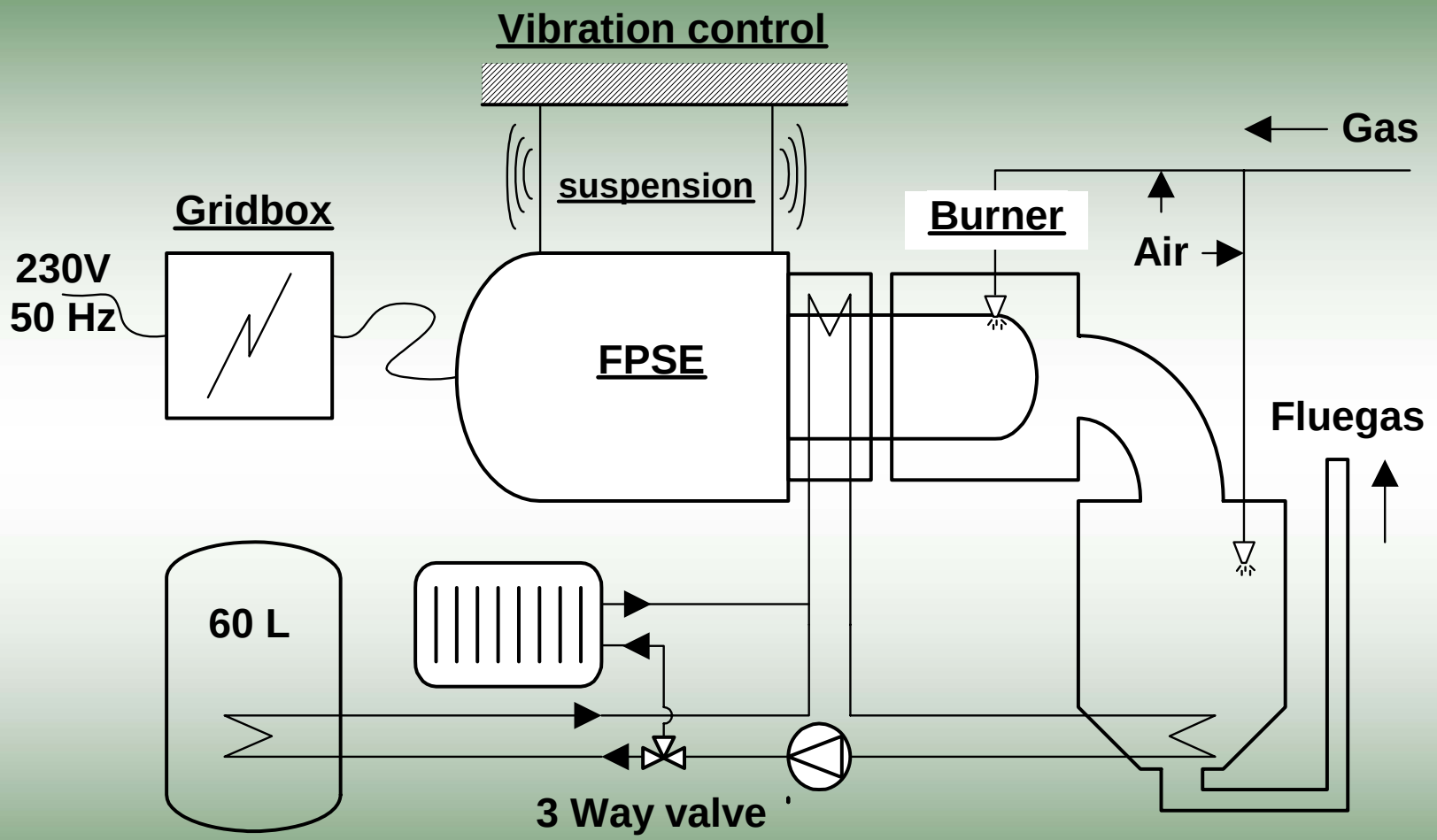
Enatec standard cogeneration system



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Development programma

Phase 1 (1997-1999)

- Evaluation of STC technology (350 W, 60 Hz)
- Market application
- Basic design of burner
- Basic design of system
- Basic design of gridbox

Phase 2 (1999-2001)

- Prototype 1 kW Stirling
- Prototype system and testing
- Evaluation and go/nogo

Development programma

Phase 3 (2001-2004)

- Building of ten Stirlings
- Building of ten systems
- Fieldtrial 2002-2003
- Improvements
- Fieldtrial 2003-2004
- Evaluation

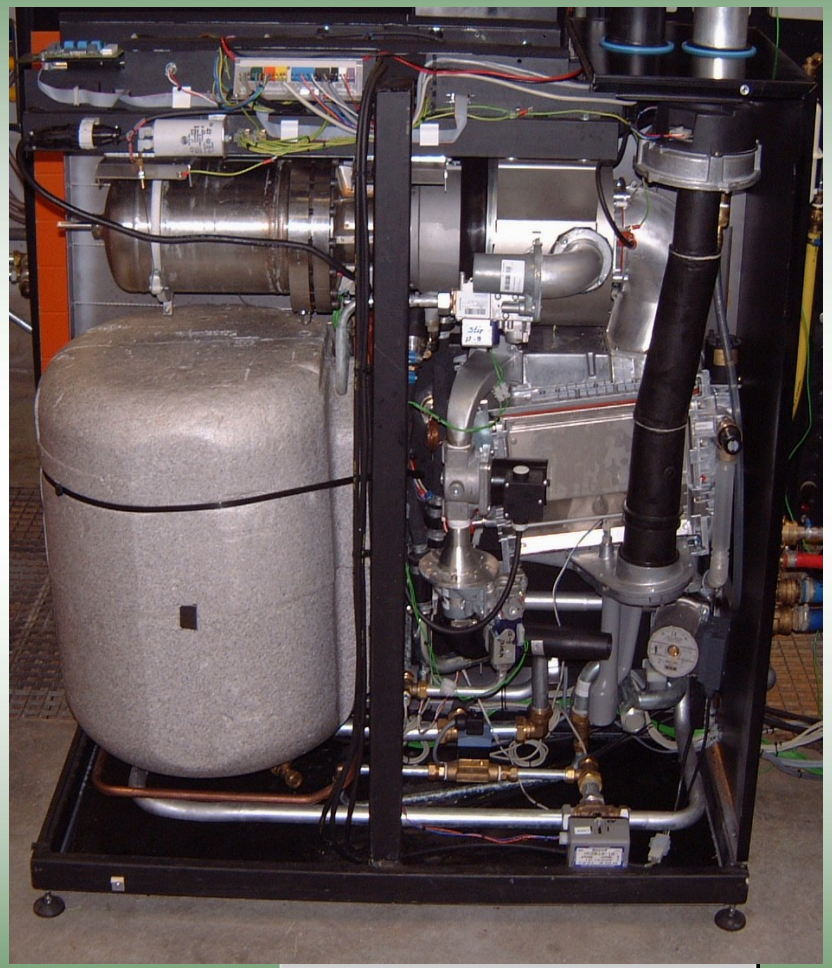
Phase 4 (2001- 2007)

- Metric Stirling
- Aluminium Stirling
- Cost effective Stirling

Field trial of Enatec prototype system

- Field trial with 10 units (2002-2004)
  - 7 units in private residences
  - 3 units in laboratory environment

- Results
  - proof of concept
  - reliability of main components demonstrated
  - ongoing optimization of system and components, including the Enatec building blocks



Enatec building blocks

- Free Piston Stirling Engine
  - Basic development by Infinia (former STC, Kennewick, WA/USA)
  - Maintenance free
- Radiant Burner (patented)
  - Ceramic foam type
  - Basic design by ECN
- “Gridbox”, interface between grid and FPSE (patented)
  - Establishment of grid connection
  - Verification and supervision of operation when grid connected
- System integration know-how (patented)
  - Guidelines for DCHP control
  - Assembly guidelines

Present status and future development

- **Stirling**

Efficiency	13.5 %	was 10 %
Weight	55 kg	was 76 kg
Price at 10.000	0.3 X	was X

- **Contract signed with Rinnai for:**
  - Further development of Stirling
  - Development of micro CHP system for Asia
  - Massproduction of Stirling in October 2007
  - Massproduction and sales in Japan as from end 2007
  - Delivery of Stirling to Europe through Enatec

- **Contract with two major European boiler manufacturers for :**
  - Development of micro CHP systems for Europe
  - Massproduction and sales as from 2008

Thank you for your interest!

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