ARPA-E
Workshop on Small Engines
Case Study: Marathon Engine Systems

Chicago, Il.
May 28, 2014
Background and History

- **1984**— GRI approached Battelle Columbus to design an engine driven NG heat pump.
- **1988**—Triathlon prototypes were started w/ potential suppliers: York Intl, Briggs & Stratton, Honeywell, Copeland.
- **Key Marathon engine specifications**:  
  - 4,000 hr oil change interval (11 liter sump. Equivalent to 160,000 miles)  
  - Ten year life or 40,000 hr. (Equivalent to 1.6 million miles).  
  - 7.5 hp, 272cc, 12.8/1 compression.  
  - 1200-3600 rpm. Single cyl. No belts.  
- **1998**—HyPro, Inc. bought the engine and started MES for remote power application.
- **2001**—Teledyne Brown sold Minotaur for cathodic protection. MES bought that also.
Evolution of ecopower

- 1998- Call to Briggs from ecopower Energy Solutions AG, Swiss venture backed company with a microCHP--new product - in need of a long life engine.
- mCHP starting in Europe.
- Two engines were sold for testing. Worked well.
- 150 sold in Europe– but...
- 2002– ecopower AG--bankrupt,
- MES bought world rights and Vaillant (German boiler Co.) bought European rights-using the Marathon engine--until 2011– now use German engine.
- MES tried to market the ecopower in US but had no idea of the barriers.
ecopower™ Microcogen Appliance

- Electrical output 2.2 - 4.4kWe/hr modulating
- Heat output is 20,000 -- 47,000 BTU/hr
- Maintenance interval: 4,000 hours – Oil, filters, spark plug
- Engine life – 40,000 hours.
“Energy cannot be created or destroyed. Only converted from one form to another”

First Law of Thermodynamics
Private Residence – Dover, Massachusetts

- 9,000 sq.ft.
- 28,000 gallon pool @ 85°F (Grandkids)
- Full in-floor radiant heating system in the house
- Geothermal system as backup.
- In 20 months of ecopower use -- generated 40 MWh of electricity @ $0.23/kWh savings of $9,000
Domestic hot water for a 56 Unit, LEED Platinum apartment building. Bronx, NY

- Two units: 9.4kWe and 78,000Btu/hr total.
- Installed August 2009
- Can generate: 6.5 Mwh/mo
- Current electric rate is $0.25/kwh
- In the first 12 months – 69Mwh.
- **Savings of $17,000** + per year in electrical costs.
Commercial Hot Water Applications

- LEED Platinum, 125 unit apt. in NYC.
- 3,000 gal buffer tank
- Units generate 9-12,000kWh per month
- Savings of up to $2400/mo. in electric costs.
- Discounted gas

- YMCA swimming pool complex in Wisconsin
- New install – awaiting data.
Commercial Market is stronger and shows promise

- Multifamily apartments
- Nursing Homes/ Assist. Living
- Health Clubs
- School District Swim Pools
- Restaurants/ Truck Stops
- Medium Size motel
- Hydroponic farms
- Greenhouses
- Laundries
- Car Washes
- Large Building Reheat
- Larger Homes w/ pools.
Current MicroCHP Manufacturers Marketing in the US

- **Marathon Engine Systems.** manufactures and marketed the ecopower 4.7 kW(e) ICE
- **Yanmar**— Two products in the market – a 10kWe ICE unit and now a 5kWe.
- **ClearEdge**— Fuel Cell (5kWe) and is on hold. Recently filed for bankruptcy.
- **Climate Energy/ Freewatt**— Marketed by ECR but now in a reorganization. Most applications in the Northeast with 300 + installs. 1.2 kWe ICE (Honda)
- **Capstone Turbine**— a family of six units 30kWe to 1000kW. Sales worldwide.
- **EC Power**— Danish ICE based system. Four sizes: 6, 9, 15, 20kWe. In Canada now, starting a US office 1Q2014.

**Total Sales: Worldwide** — 212,000
- Japan — 155,000 units
- Europe — 45,000 units
- Rest of the World — 12,000
- US — 600 units

(* Source: Delta-ee)
New Entrants in the Market

- **Qnergy** – an Israeli company has developed a 7.5kWe Stirling engine (FPSE) for use in the mCHP market as well as remote power. Will enter in 2015.
- **Microgen** – a consortia of companies have taken the 1kWe Stirling engine developed by Microgen and a number of them are considering the NA market. In addition **NRG Energy and DEKA** are set to market a 10-15kWe (6kWe) Stirling.
- **Fuel Cells** – a number of small fuel cell product mfgs (1-3kWe) are looking seriously at the NA residential market.
- **Thermal Acoustic/Electric Generators** are in development and could enter in the next two years.<3kWe
- **M-Cogen** – Houston based company that has developed a Trigen system using an ICE and an adsorption cooling system. Heat, power and cooling. 6kW(e) and 5 tons of cooling.
### Advantages and Disadvantages of microCHP Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Usage in the World</th>
<th>Major Advantage</th>
<th>Major Disadvantage</th>
<th>Electrical Efficiency</th>
<th>Overall Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE</td>
<td>78% Now 66%*</td>
<td>Proven technology</td>
<td>Needs long life engine</td>
<td>20-30%</td>
<td>85-92%</td>
</tr>
<tr>
<td>Stirling</td>
<td>18% Now 6%*</td>
<td>High heat Fuel Agnostic</td>
<td>Difficult to Manufact.</td>
<td>10-20%</td>
<td>Low 80’s</td>
</tr>
<tr>
<td>Organic Rankine</td>
<td>&lt;2%</td>
<td>Low Cost Hi Heat</td>
<td>Poor Elect Efficiency</td>
<td>~10%</td>
<td>90+%</td>
</tr>
<tr>
<td>PEM Fuel Cell</td>
<td>2% Now 25%*</td>
<td>Low Emissions</td>
<td>Hi Price Reformer?</td>
<td>30-35%</td>
<td>77-80%</td>
</tr>
<tr>
<td>Micro-Turbine</td>
<td>&lt;1%</td>
<td>Hi heat out Long life Multi-fuel</td>
<td>Hi press gas. Hi price</td>
<td>Mid 20’s</td>
<td>80-92%</td>
</tr>
</tbody>
</table>

*Delta ee* Change because of 23,000 FC sales in 2012 in Japan
Opportunities
• Large Market
• Proven/positive track record
• Spark Spread is very favorable.
• Clean Emissions – significantly less CO₂, NOx and SO₂. Carbon Credits (?)
• Good Niches– Hot water apps.
• High Efficiency
• Leasing is becoming viable
• Backup power can be an option.
• Smart Grid / Demand Response
• Multiplexed for larger needs.

Barriers to Entry
• Large Capex for install– High costs because of being an emerging technology. Can be $3k-8,000/kW.
• Utility Reluctance. Slow to change
• Sales Channel-- can be difficult because of understanding new technology.
• Education – of all parties-- customer, dealer, legislators, utilities
• Stigma-- because of not being renewable.
• Legislation-- is slow to change and inconsistent. Fifty sets of rules.
• Heat Driven therefore limiting to colder climes
• Cooling technology – some exist but are expensive and not practical.

* “I hate making predictions– especially if it’s about the future “
Lawrence Peter Berra
**HOELVECHS**

**Concept Schematic**

- **Long life** 5kW engine generator
- Capable of running 4,000 hours between maintenance needs.
- Natural gas or propane fueled.
- Electric vehicle charging capable – Level 1 & 2.
- Therefore, no grid strain
- Backup power capable for grid outages. May have a battery complement. (Optional)
- Is Smart Grid compatible, the 5kW would be dispatchable power and controlled by the utility.
- Ultimately will be vehicle to grid (V2G) capable

*Home Electric Vehicle Charging System*

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**ARPA-E focus on 5-10kWe Genset (June 2011):**

- 60,000 hr life,
- 40+% Elec Efficiency,
- EPA Emissions,
- Install costs $10,000,
- ROI in 2-3 yrs,
- One maintenance/ year, 99.1% uptime.
- Fuel flexible, (Propane, NG)
- 120v/60Hz
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