RESIDENTIAL COMBINED HEAT & POWER (CHP) TECHNOLOGIES - AN OVERVIEW

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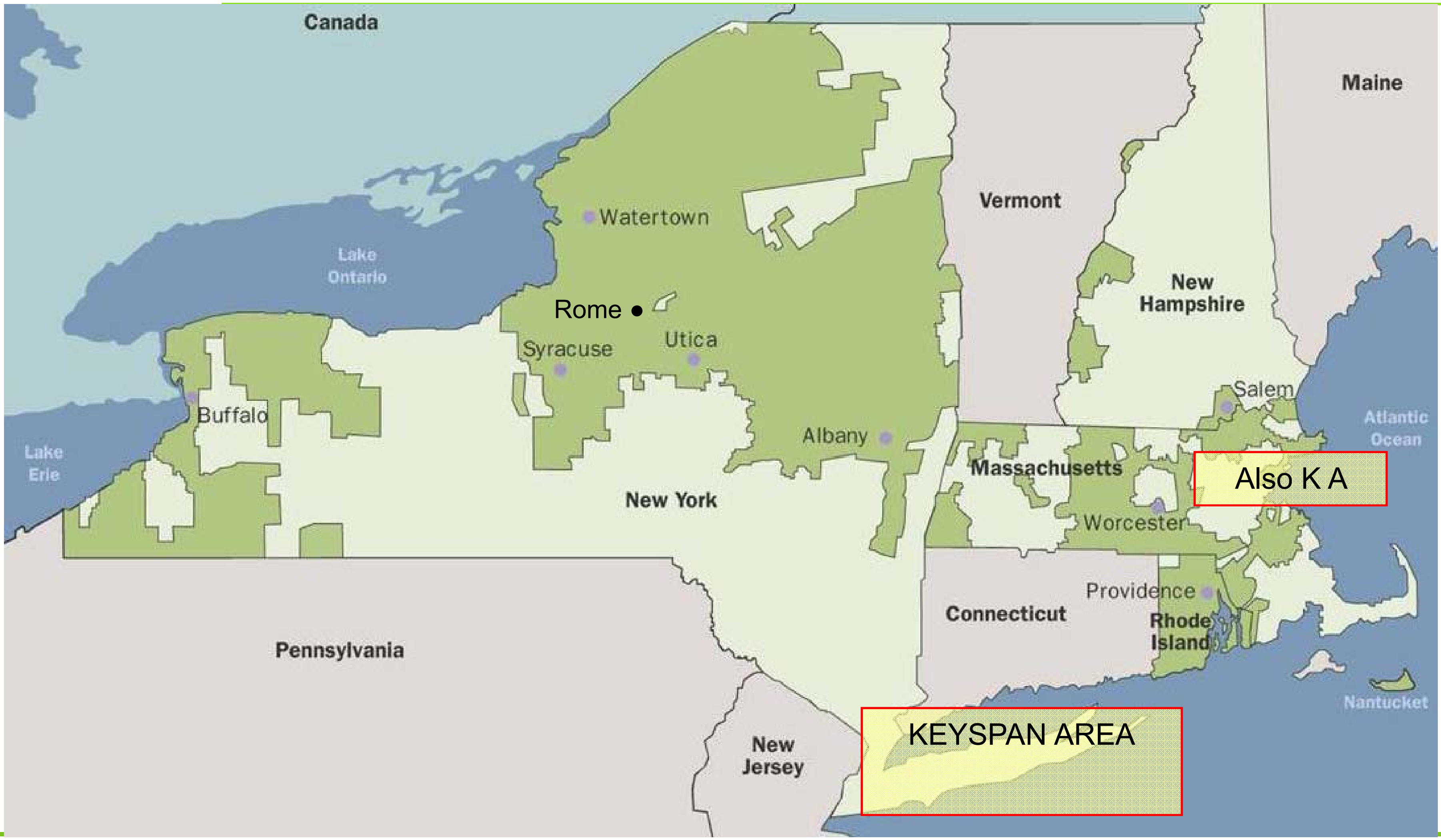
NATIONAL GRID'S U.S. SERVICE TERRITORY, Showing Former Keyspan Areas Roughly



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Presentation Outline

1. TYPES OF TECHNOLOGIES EMPLOYED FOR RES. CHP
2. CURRENT INTERNATIONAL TRENDS
3. EXAMPLES OF CURRENT CHP PRODUCTS
4. SIMPLE PAYBACK ANALYSIS OF A CHP SYSTEM
5. PRESENT-WORTH ECONOMIC ANALYSIS OF A CHP SYSTEM
6. CONCLUDING COMMENTS

PRIMARY ENERGY CONVERSION DEVICES USED FOR RESIDENTIAL CHP

- Conventional piston engine using natural gas as fuel
- Stirling engine using common fuels
- Solid-oxide Fuel Cell (SOFC)
- Proton Exchange Membrane (PEM) fuel cell
- Thermophotovoltaic (TPV) system
- Solar Concentrator and Stirling engine

OVERVIEW OF INTERNATIONAL POLICIES SUPPORTING RESIDENTIAL CHP (RCHP)

- **Japan: subsidies have led to installation of 50,000+ units**
- **Europe: governments promoting multi-family building CHP units and RCHP; "export/feed-in" payments in Germany**
- **United States: the federal and some state governments encourage RCHP, but incentives are small**
- **Canada: policies vary by province, two supportive now**

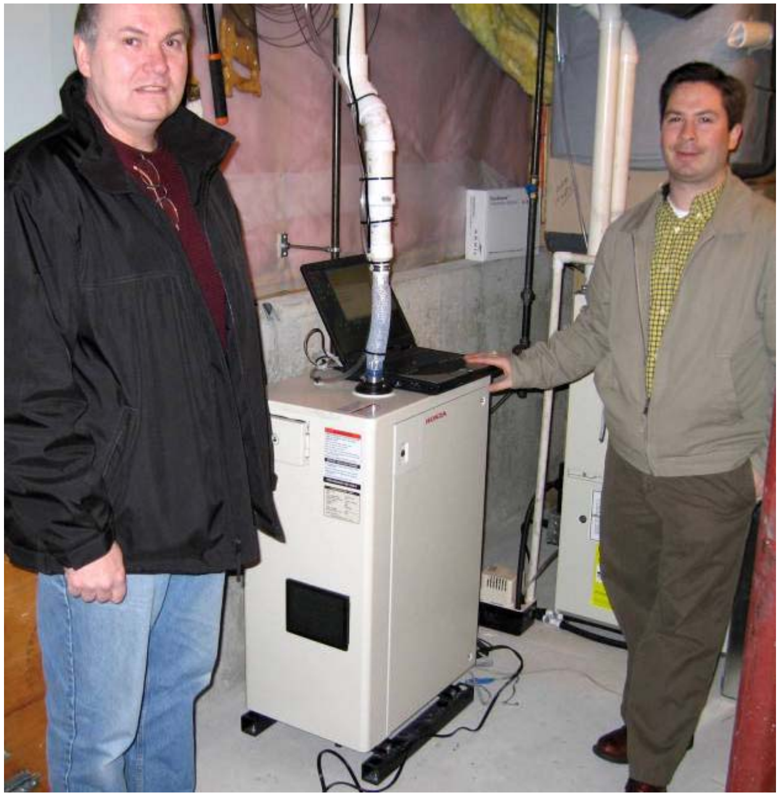
CHP Technology Types Employed

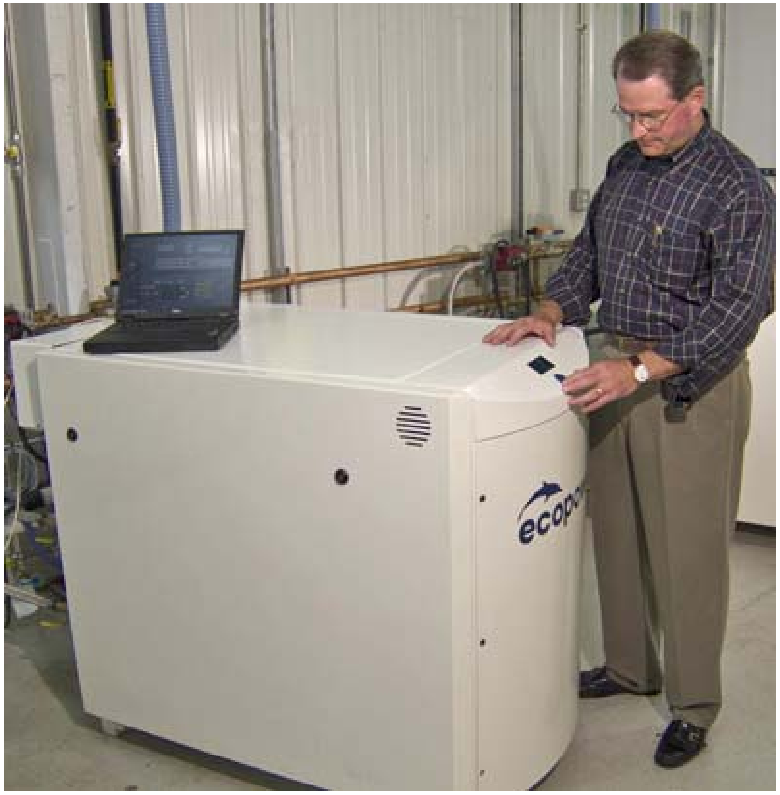
- Japan
  - Internal-combustion piston engines
  - Proton Exchange Membrane (PEM) fuel cells; several fuels
  - Solid-oxide Fuel Cell (in development)
- Europe
  - Stirling engines
  - Solid-oxide Fuel Cell
  - Internal-combustion piston engines
- United States
  - Internal-combustion piston engines (4- & 2-cycle)
  - Thermophotovoltaic (TPV) systems
- Canada
  - Solid-oxide Fuel Cell
  - TPV

Conventional Piston-Engine CHP: Japan and United States

- **Most common unit (50K installed) made by Honda**
  - **One-piston, constant rpm (now)**
  - **Inverter output to grid, 1 kW (1.2 kW planned)**
- **Marathon CHP System**
  - **One-piston, variable speed**
  - **Inverter output to grid, 2.0 – 4.7 kW**
- **Other small firms working on products**

Honda (L) & Marathon* (R) Systems





* Image from Marathon web site, marathonengine.com

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CHP System Manufacturers Using Stirling Engine Technology

- **Infinia**, Kennewick, Washington, U.S.
  - Working with Rinnai (Japan) to supply Bosch (Germany +), Merloni (Italy +) and Rinnai itself
  - Sealed helium system, zero maintenance claimed
  - Third generation of commercial development
- **Whispertech** , Christchurch, New Zealand
  - Focused on European residential CHP market
  - Many orders placed; hard to find manufacturer
- **Sunpower** (MicroGen) – U.S. company (U.K. engine)

Simple Payback Analysis (*not* recommended)

- **Incremental capital cost of CHP over a conventional heating system = ICC**
- **Net annual value of electricity displaced minus annual maintenance cost = NAV**
- **ICC / NAV = SPP (Simple payback period)**
- **Typical ICC = $8K; -$2K (incentive) => $6K**
- **NAV = (2200 x $.2/kWh) - $150 = 290**
- **SPP = 21 years (under these assumptions)**

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Basic* Financial Analysis

SAMPLE CALCULATION: 1-kW IC Piston engine; some default values (DV) below.

B20	C20	D20	E20	F20
PROJECT CAPACITY (KW)	EQUIPMENT COST ($/ KW)	INSTALLATION COST ($/ KW)	INTEREST RATE, i (%)	PROJECT LIFE (YEARS)
1	$5,000.00	$1,000.00	6%	20
DV = 1,000	DV = $250/KW	DV = $50/KW	DV = 8%	DV = 5

B28	C28	D28	E28	F28
PROJECT CAP. FACTOR (%) & hrs below	FUEL COST (F. C.) ($/Million Btu)	EFFICIENCY (fuel > kWh, %)	WASTE HEAT VALUE (if any) ($/kWh)	NON-FUEL O&M ($/kWh)
25%	$21.00	100%	0.001	0.068
(Nov-April@50%) 2190 DV = 75%	DV = $12.00	DV = 34%	DV = .001	DV = .006 $150 / AkWh +F8 / C40

CAPITAL COST =	*B20 x (C20+D20)* = $6,000 = C. C.	
C. C. x CRF =	$523 = ANNUAL FIXED COST = AFC	PROJECT ELECTRICITY COST, c/kWh
ANNUAL KWH =	2,190 = *B20 x B28 x 8760* = AKWH	
$FUEL / YR = FY	= (KWH/eff.)x(3.412/1000)x(F. C.) = $157	
ELEC. COST =	((AFC+FY) / AKWH) + (N-F O&M) - WHV = ===============>	37.80
ELEC. VALUE =	$438 (AKWH x CEC)	DV = 9.67

* Time value of money, but no tax considerations

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WHAT MIGHT ADD TO THE VALUE OF HOME CHP SYSTEMS?

- **Stand-alone operation, in winter – heat & basic electricity**
- **Grid-connected operation – *<u>in summer</u>* (DR credits)**
- **Pre-heating or heating of water for domestic hot water or pools**
- **Coordinate CHP inverter use with a PV system inverter - ?**

SIMPLIFIED INTERCONNECTION APPLICATION

1. Is the Point of Common Coupling on a radial distribution system?

No → Go to Network Process

Yes ↓

2. Is the ***aggregate*** DG capacity on the circuit less than 7.5% of the circuit annual peak load? (See note 1)

Yes ↓

3. Does the facility use a Qualified Inverter (UL 1741) with a power rating of 10 kW or less (1Ø), or 25 kW or less (3Ø)?

Yes ↓

4. (***Almost always the case***) Is the DG connection such that the service transformer loading is balanced? (See note 5)

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Conclusions

- **Many technologies, from renewable to basic to advanced, are being explored to develop an economical CHP system.**

- **Well-known manufacturers and high-volume mass production are finally starting to be associated with residential CHP systems.**

- **High "feed-in" tariffs may not persist in countries with them now.**

- **As utilities move toward decoupling (less $/kWh, more $/kW) and offer credits for summer peak-load reduction, CHP appears more attractive.**

- **We are familiar with CHP applications and process them quickly.**