ENERGY SOLUTIONS CENTER

Track: Residential Natural Gas

Unit #7: Natural Gas Options for Generating Power

An overview of Power Generation for Residential Customers

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Presentation Outline

- Statistics
- Residential Options
- Equipment Types
- Operation
- Maintenance / Service Contracts
- Economics – Back-Up Power
- Micro-CHP

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Why Consider Natural Gas Fueled Standby Power Generation

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US Power Outages

- A major outage is an event that affects a minimum of 50,000 customers (homes or businesses)

OR

- Interrupts service of 300 MW or more

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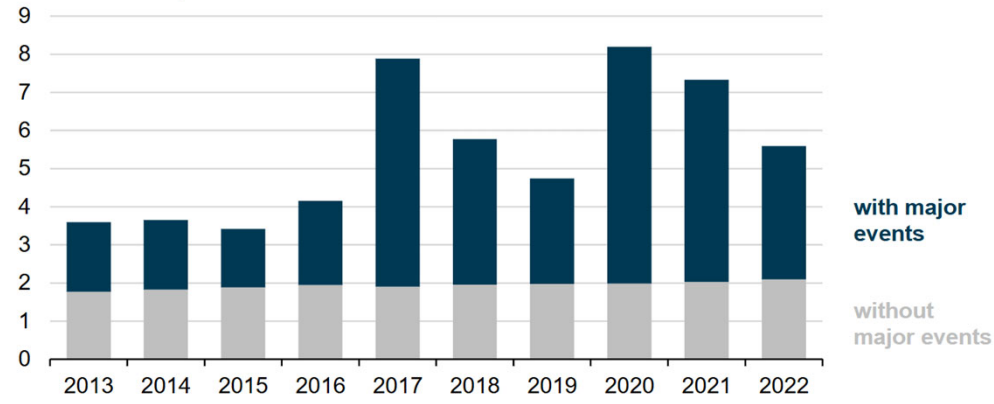
Since 2013, the Duration of Power Interruptions Has Remained Consistent, Barring Major Events

Average annual total of electric power interruptions (2013–2022)
number of hours per customer



Data source: U.S. Energy Information Administration, *Annual Electric Power Industry Report*

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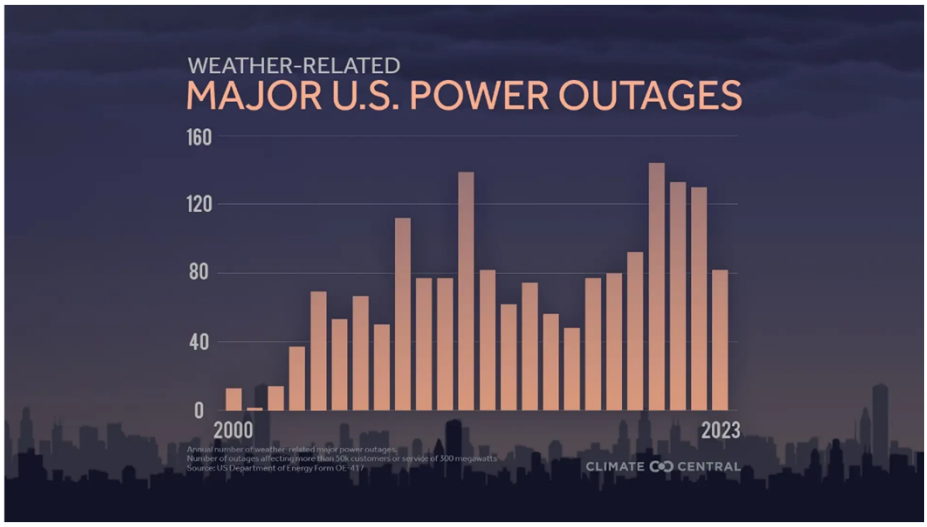
Weather – Related Power Outages are on the Rise



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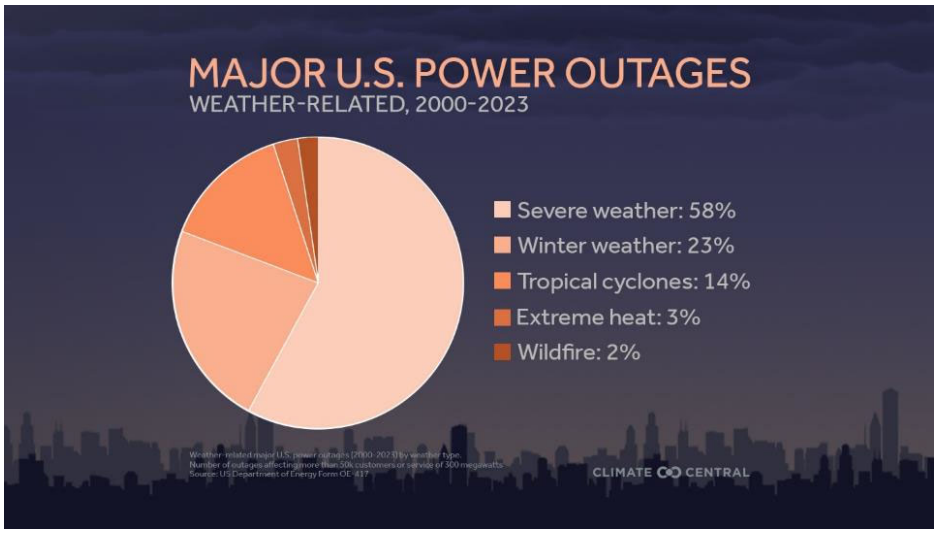
Power Outages by Type of Weather



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Weather and Power

- 80% of US power outages from 2000 – 2023 were due to weather
- The US experienced twice as many weather – related power outages from 2014 – 2023 than from 2000 – 2009
- The nation's electric grid, which transmits and distributes much of the power above ground, is severely impacted by adverse weather

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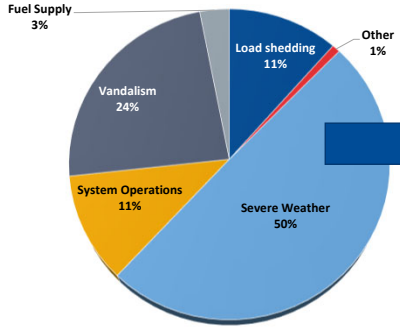
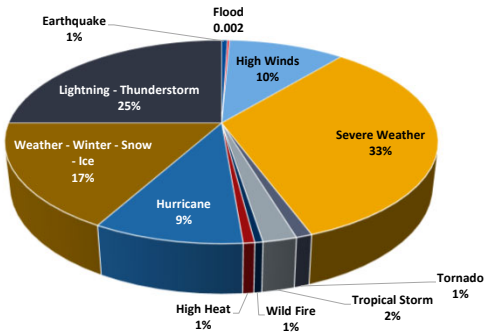
Electric Disturbance Breakout

Electric Disturbance Event Breakout 2002-2016



% of Weather Related Disturbances (2002-2016)



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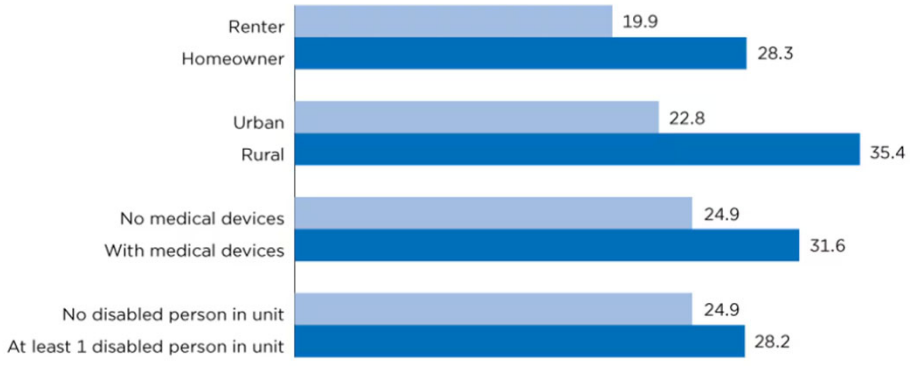
Who is Affected by Power Outages

Housing Units Ever Completely Without Power in the Last 12 Months
(In percent)



Source: U.S. Census Bureau, American Housing Survey, 2023 (sponsored by the U.S. Department of Housing and Urban Development).

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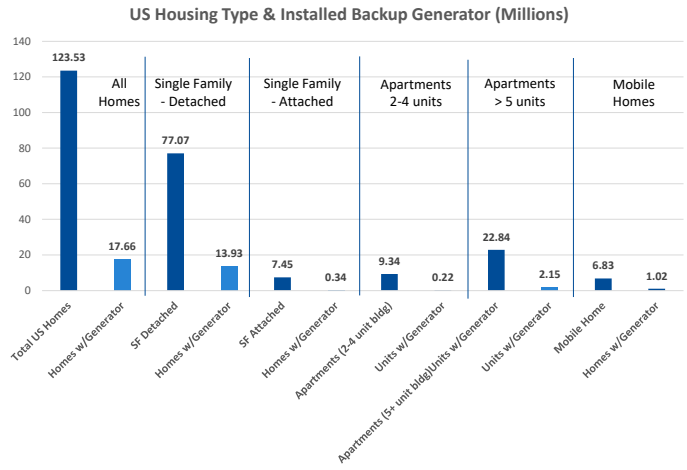
Homes that Own Back-up Generators



14% of all US homes have a generator
18% of SF detached homes have a generator
15% of mobile homes have a generator

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EIA's 2020 Residential Energy Consumption Survey; Table HC2.1 Structural and geographic characteristics of U.S. homes by housing unit type

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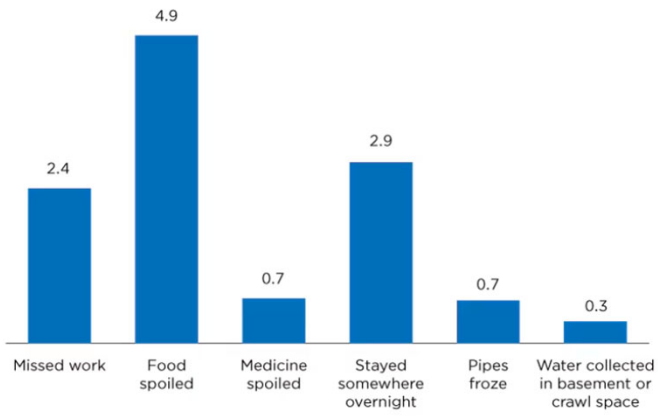
Difficulties Encountered Power Outages

Difficulties Encountered by Housing Units That Reported Being Ever Completely Without Power in the Last 12 Months
(In millions)



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Source: U.S. Census Bureau, American Housing Survey, 2023 (sponsored by the U.S. Department of Housing and Urban Development).

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Residential Options

- Common reasons people want back-up power
  - Prevent Food from Spoiling
  - Lighting
  - Heating and Cooling
  - Cook and Prepare Food
  - News and Weather Reports
  - Maintain Computer and Internet connection
  - *Function as before with minimal interruption*

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Residential Options

- Size of Generator
  - Evaluate Critical Loads
  - Evaluate *Need* vs. *Want*
  - Manufacturer web-based sizing programs
- Select generator to serve part of total load
  - Feed power only to certain circuits
  - Use Load Management controls
- Or serve entire home – Winter & Summer

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Residential Options

- Critical Loads
  - Medical Needs
  - Home Security & Protection from Damage
  - Communication
  - Heating or Cooling
  - Water Pump
  - Sump Pump for Basements

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Residential Options

- Installation
  - New Construction
    - Install during Construction
    - Install key components only - to facilitate easy future installation of generator
  - Retrofit during Remodeling
  - Retrofit Existing Home
    - Higher cost due to replacing some existing components

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Residential Options

- Other Factors
  - Is incoming Gas Service adequate?
    - Pressure
    - Volume
    - Meter Size
  - Unit Placement and Noise Constraints
    - Local zoning or Home Owners Association restrictions

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Equipment Selection

- Engine Speed
  - High Speed (3600 RPM)
    - Costs less to install due to smaller size
    - Shorter Life if operated a lot
  - Low Speed (1800 RPM)
    - Costs more to install due to larger size and more equipment in package
    - Longer Life
    - Quieter than high speed
    - Require less maintenance

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Equipment Selection

- Cooling Systems
  - Air Cooled - Typical on High-Speed Units
    - Usually not as efficient as Water Cooled
    - Less suited to hot climates
    - Tends to be smaller and weighs less
  - Water Cooled - Typical on Low-Speed Units
    - More equipment & systems to maintain
    - Better suited to warmer climates
    - More suitable for critical situations that must operate during a power outage

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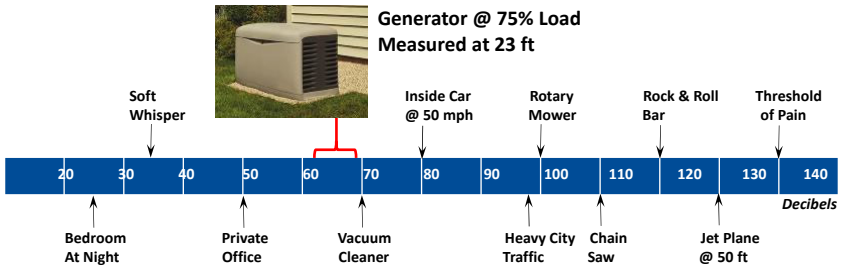
Equipment Selection

- Sound Levels – Muffler and Sound Enclosure
  - Determine local requirements
  - Proximity to neighbors



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Equipment Selection

- Higher Elevations & Warmer Regions of US
  - High Altitude and Temperatures routinely over 80°F (26.6°C) can reduce the power output of engine driven generators
  - Check with your dealer for details on your specific location

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Equipment Selection

- Enclosure Features
  - Sound Dampening
  - Protection of unit
  - Aesthetics of appearance
  - Judge ease of access for maintenance

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Operation of Standby Generators

- Control Systems
- Testing
- Monitoring
- Maintenance

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Operation

- Automatic Start
  - On loss of power, control system starts generator
  - Automatic Transfer Switch (ATS) shifts to generator
  - If equipped with automatic control system, it monitors load and manages which circuits are served – including starting of AC units
  - When utility power is restored, the control system turns off generator and returns home to utility power

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Operation

- Periodic Testing
  - Typically run Weekly for 12-20 minutes – no load
  - Exercises the engine and system to keep it in good condition and keep oil seals lubricated
  - If fault occurs during testing – owner can get it repaired so unit is ready to run when outage occurs – reducing chance of failure when needed

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Operation

- Remote Monitoring by Cellular Connection
  - Notification of successful weekly test
  - Maintenance reminders
  - Change in status (AUTO START/MANUAL START/OFF)
  - Fault notifications
  - Designate up to four different parties to receive email and/or text notifications – personal as well as service company

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Operation

- ***There's an APP for That***
  - View status and upcoming maintenance
  - Set generator's exercise schedule
  - Review run time and maintenance
  - Receive notifications of changes in status

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Maintenance / Service Requirements

- Normal Maintenance
  - Service Contract with local Contractor
  - Annual Check or Every 100 hours of operation
- Basic Check includes
  - Engine oil & filter change
  - Air cleaner filter change
  - Sparkplugs
  - Radiator flush & fill (Liquid cooled)
  - Electrical, electronic & fuel system inspection

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Economics
What is it worth to you to have reliable standby power?

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Economics

- Installed Cost
- Operating Cost
  - Annual Gas Consumption – Testing Only
- Maintenance/Service Contract Cost
- Frequency & Duration of Power Outages
- "Need to Have" vs. "Nice to Have"
  - Medical Needs
  - Home Protection – Security & Damage Prevention

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Economics

- Installed Cost - Rough Estimate = Twice Purchase Price

Note
Average Home sizes for those considering generators is in the 2,000 sq ft range – for which a 20-25 kW generator will usually be adequate.

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Based on manufacturer's pricing for Residential units on their web sites Briggs & Stratton, Generac and Kohler.

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Economics

- Annual Natural Gas Consumption – Test Only
  - 20 min/Week at 25% load for 52 weeks

Size of Unit (kW)	CFH @ 100%	CFH @ 25%	CF / Year	Annual Cost of Natural Gas
10	195	**29**	**507**	**$ 5.07**
20	280	**42**	**728**	**$ 7.28**
30	430	**65**	**1,118**	**$ 11.18**
40	590	**89**	**1,534**	**$ 15.34**
50	750	**113**	**1,950**	**$ 19.50**

Assuming Natural Gas @ $ 1 per CCF

Note Testing Standards vary by Vendor. These are the high end.

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Economics

- Commercial and Industrial applications – can measure value of lost sales and production to enable calculation of Payback
  - $ to Install & Operate / Annual Losses = Payback
- Residential applications – harder to evaluate
  - Food Spoilage & Repair Cost of Potential Damage
  - Homeowners must use Personal Judgment to determine value to them

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Conversion of Portable Generators

NO POWER LOSS !

If it's a GOOD QUALITY ENGINE

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Conversion of Portable Generators

- Engine Conversion Kit

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Conversion of Portable Generators

- Install Motor Snorkel at Carburetor Inlet, reinstall Air Filter and mount Gas Regulator

- Generator will start on Gasoline and then run on Natural Gas

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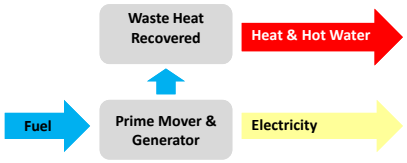
Micro-CHP (mCHP)

Combined Heat and Power (CHP) by definition is the generation of two forms of energy from one common source of fuel also known as Cogeneration.



Micro-CHP (mCHP) appliances are cogeneration systems less than or equal to 50kW in size, larger systems are CHP.

The difference between CHP and mCHP is that most large commercial & industrial CHP applications are Electricity-led where electricity is the main output and heat is a byproduct. Micro-CHP systems in residences or smaller commercial applications are more often Heat-led. Heat is the main output and electricity is the byproduct

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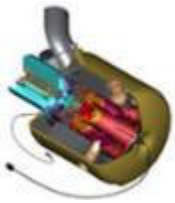
Micro-CHP

- Basic Features
  - Combined Heat & Power (CHP) – system producing both Heat and Electric Power
  - Micro-CHP – Generates less than 50 kW
  - Heat captured from the generator – that would otherwise be lost to the atmosphere
  - Many types of equipment can be used
    - Micro-Turbines
    - Internal Combustion Engines
    - Stirling Engines
    - Thermal Acoustic Converters
    - Fuel Cells



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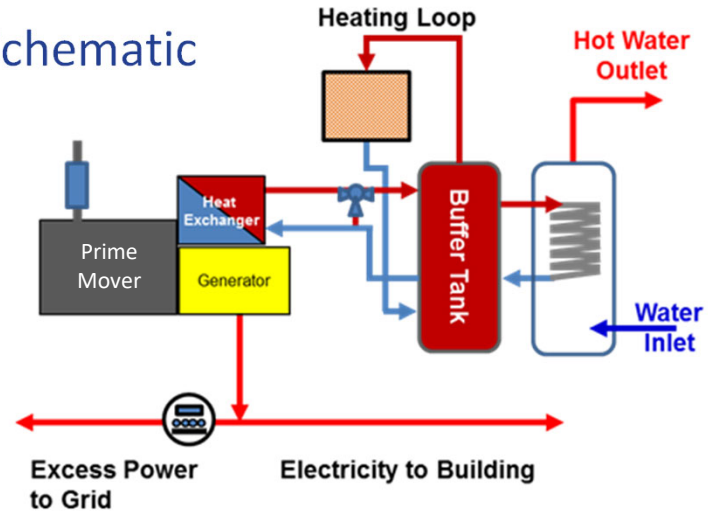
Micro-CHP

- Basic Schematic



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Micro-CHP

- Basic Sizing Options for Micro-CHP Systems
  - Size to provide all power for entire home
    - ✗ more heat than could be used in home
  - Size to provide year-round base-load power
    - ⇨ can be effective if able to use heat
  - Size to provide heat that can be used year-round can be
    - ⇨ homes with greater heat loads – pool heaters, hot tubs, etc.

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Quick mCHP Sizing Math

- Install **.8kW mCHP system** at 70% total system efficiency
- 1kW = 3,412 BTU.
- Output = .8kW*3,412 BTU/KW = 2,730 BTU Electric.
- .8 KW output =~ 8,530 BTU/Hr input @ 32% electrical efficiency
- Assuming 70% total system efficiency: 8,530 BTU/Hr input*.7 = 5,971 BTU/Hr output
- 5,971 BTU/Hr – 2,730 BTU/Hr electrical = 3,241 BTU/hr available heat
- Assume that unit runs 90% of the hours in a year = 8,760*.90= 7,884 hours run per year
- 7,884 hours * 3,241 BTU/Hr = **25,552,000 BTUs** of usable hot water heat produced per year from mCHP.
  - A typical residential water heater uses approx. **23,000,000** BTU/Yr

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mCHP Technologies

Prime Movers:

- Engine Drives
  - Internal Combustion (IC)
  - Stirling
- Microturbines
- Fuel Cells

Most currently available mCHP systems are larger than the heat load of a typical home.

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Engine Drives

- Natural gas engines
  - Spark ignited
  - Water cooled
  - Air cooled – smaller packaged units only
  - Low speed

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Stirling Engine

Closed-cycle external combustion engine, the Stirling engine heat source is outside the engine, so the inside of the engine can be maintained at high pressure. Stirling engines have a regenerative heat exchanger that allows them to re-use their heat to some extent. This feature is what makes the Stirling cycle so efficient. Since an external burner drives the Stirling engine, it can operate using virtually any heat source (e.g., oil, gas, solar, wood, coal, natural waste).

Today's Free Piston Stirling Engines are based off a ~ 200 year old technology.

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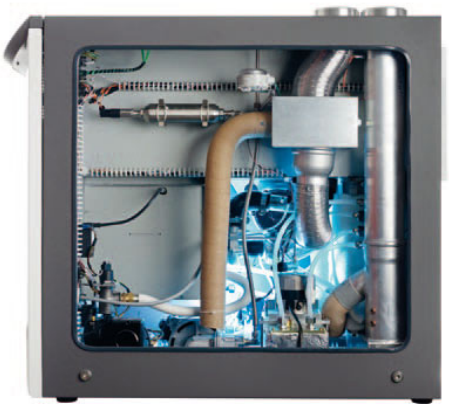
Microturbines

- Small, compact and lightweight packaged systems
- High grade heat available
- Known for installation flexibility
- Low emissions
- No cooling required
- Working to commercialize small residential sized micro-turbines



ENER TWIN heat & power

- 1-3 kW Microturbine
- System efficiency 87%

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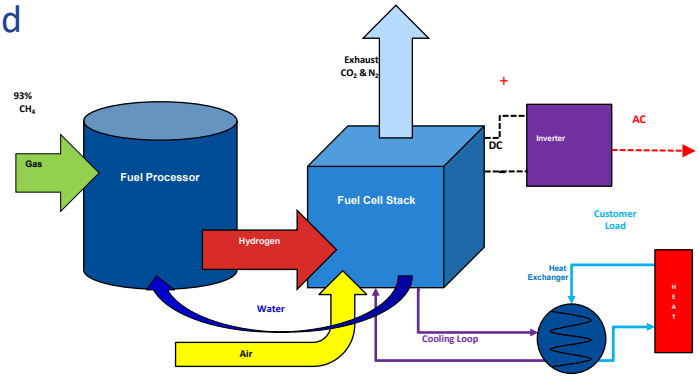
Fuel Cells

- Fuel cell stacks available and under development:
  - Can be fairly quiet
  - Produce no pollutants if run on hydrogen
  - Have few moving parts
  - Have potentially high system fuel efficiencies



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Current and Future mCHP Products

MARATHON ENGINE SYSTEMS

4.4 kW IC Engine

YANMAR

5, 10, & 35 kW IC Engine

ENGINUITY POWER SYSTEMS

6 kW IC Engine-Water Heater

WATT

1 kW Fuel Cell (U.S.)

Note that the mCHP market is in flux. There are multiple products working to enter the North American market and are under various stages of commercialization or development. The content on this slide and the next few slides are subject to change.

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Potential Future mCHP Products

BRASH EFFICIENT HEAT & POWER

1KW Rankine Steam cycle

Enviro Power, LLC

1.4-15KW steamturbine

SUNPOWER BETTER MACHINES FOR A BETTER WORLD

1 kW Stirling Engine

ENER TWIN heat & power

3 kW Micro Turbine

SOLID POWER

1.5 kW Solid Oxide Fuel Cell

remeha

Micro CHP Combi Boiler
(1kW Stirling - eVita)

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Other Innovative Products

iGEN TECHNOLOGIES i2

Residential furnace that is self powered and can export up to 1 kW back to the grid

ITC

Infinia Technology Corp
Water heater that produces 1KW of power

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Micro-CHP

- Uses of Heat from Micro-CHP
  - Water Heat for home
  - Space Heat – hydronic systems
  - Pool Heater
  - Hot Tub

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Net Metering

- When Micro-CHP is used primarily for heating, you will often find times when more electricity is being produced than is being demanded by the home
- Net metering allows the homeowner to spin the meter backwards and put power back on the grid when more power is being produced than consumed
- **This usually means excess power is being sold back to the electric utility at retail rates versus wholesale**
- This is important and really helps with the economics.
- Net metering policies are constantly changing. You will have to verify if your state/province has policies that support net metering

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Micro-CHP in Greenwich, Connecticut

- Large residence –13,000 sq ft.
- Goal - reduce the electric bill, heat the pool/tub, and **provide backup power**.
- 10 kW mCHP provides 85% of the power for the residence as well as the hot water for domestic use.
- The swimming pool (8 months/year) and hot tub (all year) are heated by the mCHP.
- Average operation time per month is 694 hours.
- Average power usage: 6.9 kW/mo.
- Annual energy savings: **$14,000 and offering a 3-year payback.**

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Micro-CHP in Greenwich, Connecticut

- 9,000 sq.ft.
- Full in-floor radiant heating system in the house. **Sept - May**
- 28,000 gallon pool @ 85°F (Grandkids) **May - Sept**
- Geothermal system as backup.
- **In 20 months of mCHP usage -- generated 40 Mwh of electricity @ $0.23/Kw savings of $9,000**

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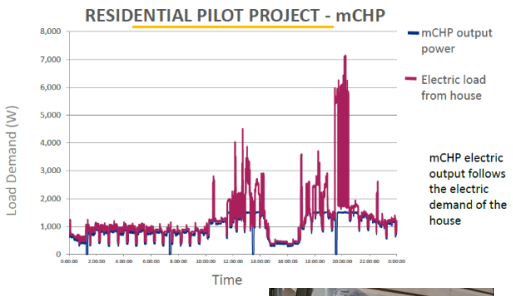
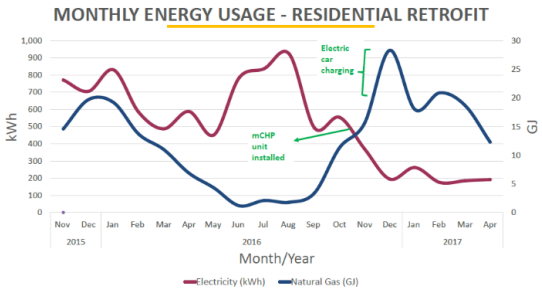
Micro-CHP in Alberta, CA



- Retrofit in existing home
- 1.5KW, 12,700 BTU/Hr



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