Introduction to Micro Combined Heat & Power (mCHP) Technology and Marketability (i.e. does it have a future?)

Wisconsin Distributed Resources Collaborative
WIDRC
Madison, WI

January 16, 2015

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Discussion Points

- Background and Definitions
- Parameters to affect success.
- Technologies
- Manufacturers
- The marketplace: What is it, and where is it going?
- Case Studies
- Future (is there one?)

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How is Power Generated?

- Central generating plant – fueled by Coal, Nuclear, or now Natural Gas. Typically **35% efficient** from generation to usage. Size is 100MW+
- Secondarily are "**peaker**" plants used for high use needs. Also, for "**campus**" type applications. These are more prevalent now as less costly to build. 50-75MW.
- Renewables – Wind and Solar…known as ***Distri-buted Generation (DG).***

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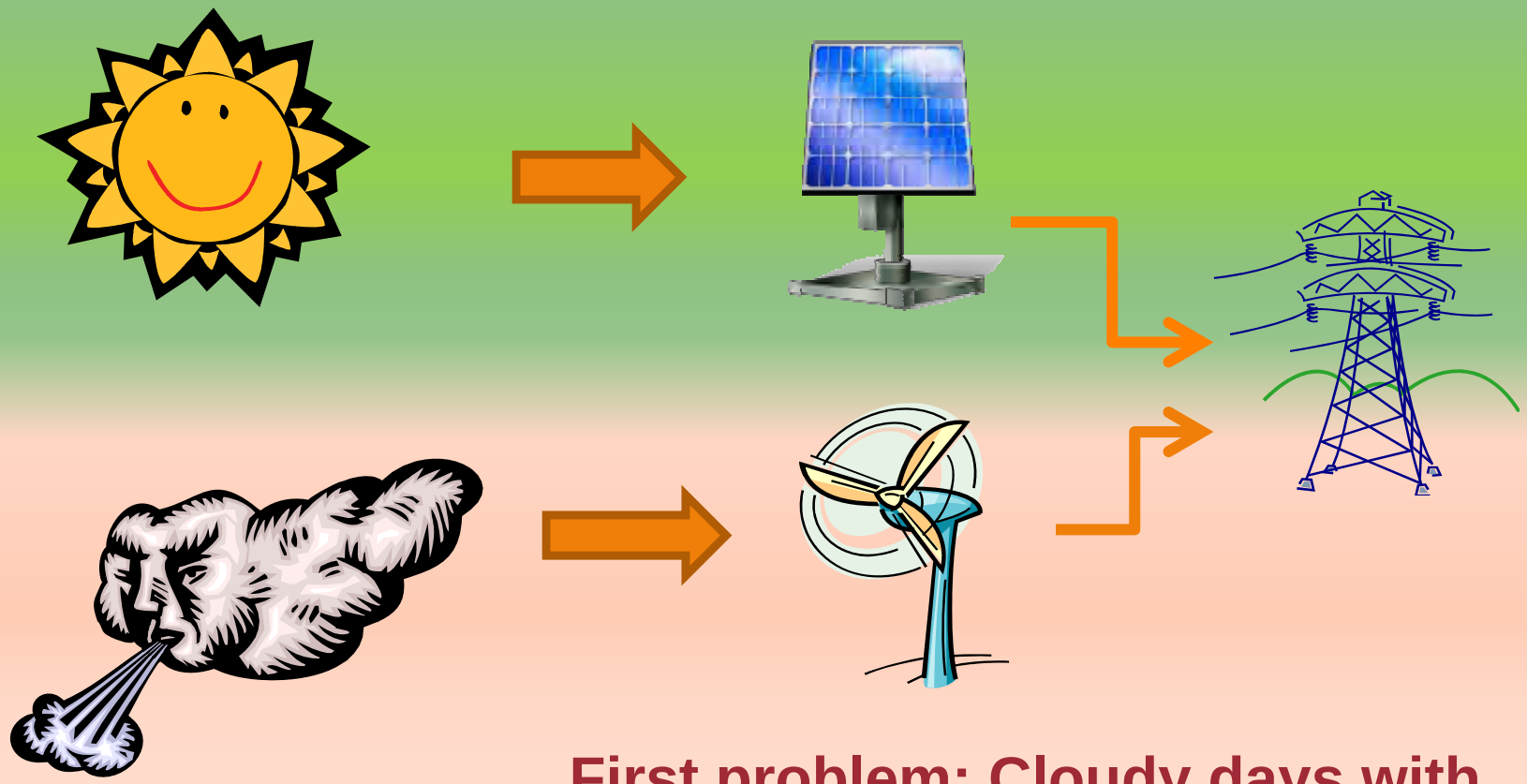
Great idea, but <u>two</u> problems:



<u>First problem</u>: Cloudy days with no wind, therefore <u>intermittent</u> generation of power.

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Second problem:

Electricity 101: Power generated must equal power consumed.

Why? Because there's no:

If you can't store it …. why not generate your own power... that's not intermittent?

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Another Idea for Distributed Generation

Why is Olaf smiling?

Because he's generating his own power (and heat)—and saving all kinds of Euros (€) and <u>doesn't care about wind and sun.</u>

Press Release: September 9, 2009, Germany

- **Volkswagen** and energy supplier **LichtBlick** form an exclusive energy partnership. Volkswagen is to produce the high efficiency "EcoBlue" Combined Heat & Power **appliances** and LichtBlick will be marketing these as **HOME POWER PLANTS**
- **100,000 units at 20kWe each = 2,000 megawatts and <u>60% reduction in CO_2 with High efficiency (>85%)</u>**

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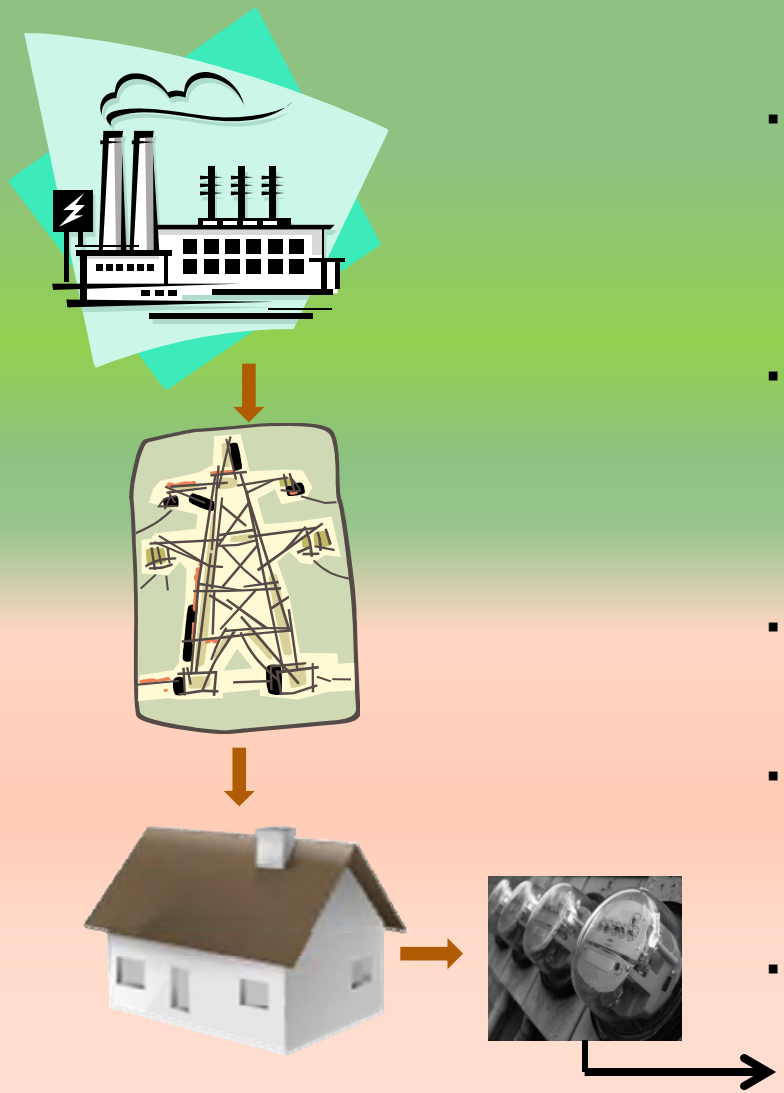
The Current Electric Grid



- Most technology and much of the infrastructure relating to generation and distribution of power (The Grid) is over **50-75 years old…. And in many cases even older.**
- Every day over **one-half million Americans are without power…at a cost of $150 billion/yr.** The **2003 blackout** in the Northeast resulted in **a $6 billion** economic loss to the region.
- The **efficiency** of the grid system is roughly **35%** from the central generation plant to the end user.
- By **2020 there will be 10 million** plug-in hybrid vehicles (PHEV) that will need to be supported with charging of batteries. (EPRI statistic.)
- Dealing with an industry that **collected data twelve times per year**.

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But…Changes are Occurring and Causing a BIG Problem.

- In 1950 the average monthly energy consumption of a home was **138 Kwh.**
- in 2010 the average monthly home consumption of energy was **1,000 Kwh.**

Therefore energy use is going up, but consider….

- A 60W i**ncandescent** light bulb = 525 kWh/yr, **CFL** = 131kWh/yr. and an **LED** = 70 kWh/yr.
- In 2005 average refrigerator used **840kWh/**yr, in 2010 it was **453kWh/yr**.

And for the first time in history…

- **Since 2009 power consumption has been flat (recession related) ..but in 2013 it was the first year on record of rising GDP and flat to decreasing power consumption.**
- **Where's the problem?**

Olaf's power plant

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Quote of the year, perhaps the decade... (that is, if you're in the gas business.)

"*The grid is ripe for the plucking by distributive innovation... It is our view that the grid... Is about to be disrupted by --of all things,* ***the unheralded natural gas distribution system ... (when it's) connected with an appliance (mCHP) that will convert natural gas into electricity in your home. There are 34 million homes served by both the electricity and natural gas distribution systems.... (wouldn't it be logical)*** *to pick the one that is reliably below ground verses the one above?"*

Think...Sandy for the answer*.*

David Crane, CEO of NRG Energy

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Small Scale Cogeneration – (mCHP) a Proven technology

- World wide, there are currently over 50 products identified as Small Scale cogen appliances from over 30 manufacturers (Generally <50kWe)
- Currently, there are only four micro-CHP appliances commercially available in North America. Growth opportunity?
- Numerous products from Europe and Japan/Korea are in, or will be in the process of certification for NA.
- Power Sources for mCHP appliances: internal combustion engines, Stirling engines, fuel cells, microturbines.

Total Sales: Worldwide* -- 292,000

- Japan ---234,000 units (134K ICE, 100K FC)
- Europe--- 45,000 units
- Rest of the World --- 12,000
- US ~ 700 units

* Source: Delta-ee, Advanced Cogen Ctr Japan

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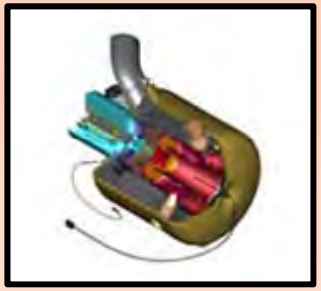
Yanmar


FreeWatt


EC Power


Capstone

Current MicroCHP Manufacturers Marketing in the US (<50kWe)

- **Marathon Engine Systems. manufactures and marketed the ecopower 4.4 kW(e) ICE**
- **Yanmar– Two products in the market – a 10kWe ICE unit and now a 5kWe .**
- **Capstone Turbine- a family of six units 30kWe to 1000kW. Not an mCHP.**
- **EC Power– Danish ICE based system. Four sizes: 6, 9, 15, 20kWe. In Canada now, and just started a US office in New Jersey-- maybe.**
- **ClearEdge– Fuel Cell (5kWe-PAFC) and is on hold----- bankruptcy. Sales in California. Doosan FC purchased assets.**
- **Climate Energy/ Freewatt– Marketed by ECR but *now in a reorganization*. Most applications in the Northeast with 300 + installs. 1.2 kWe ICE (Honda)**

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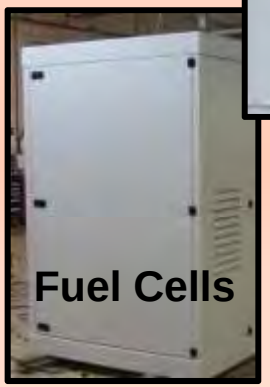
New Entrants in the Market

Qnergy

M-Cogen

Microgen



Fuel Cells

NRG / DEKA

- **Qnergy** – an Israeli company has developed a 7.5kWe Stirling engine 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.
- **NRG Energy and DEKA** are set to market a 10-15kWe Stirling. 20 units in test? *Marketed by NRG Energy*
- **M-Cogen---** Houston based company that has developed a **Trigen** system using an ICE and a **VC cooling system**. Heat, power and cooling. 6kW(e) and 5 tons of cooling.
- **Thermal Acoustic/Electric Generators** are in development and could enter in the next two years.
- **Fuel Cells–** a number of small fuel cell product manufacturers (1-3kWe) are *looking seriously* at the NA residential market. Very expensive/ subsidies.

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Three Key Parameters to affect success for mCHP:

Spark, Net, and Interconnect

In order to evaluate an application that could be suitable for micro-CHP, these parameters are key: (NOTE: These are "State sensitive").

1. **Spark spread**– Electricity price/ fuel cost in. (Above 3 is good.)

2. **Net metering**– Excess Electricity sent to grid. (Market price, avoided cost, feed-in-tariff)
3. **Interconnection standards**– Requirements to connect to the grid. (UL 1741 Std).

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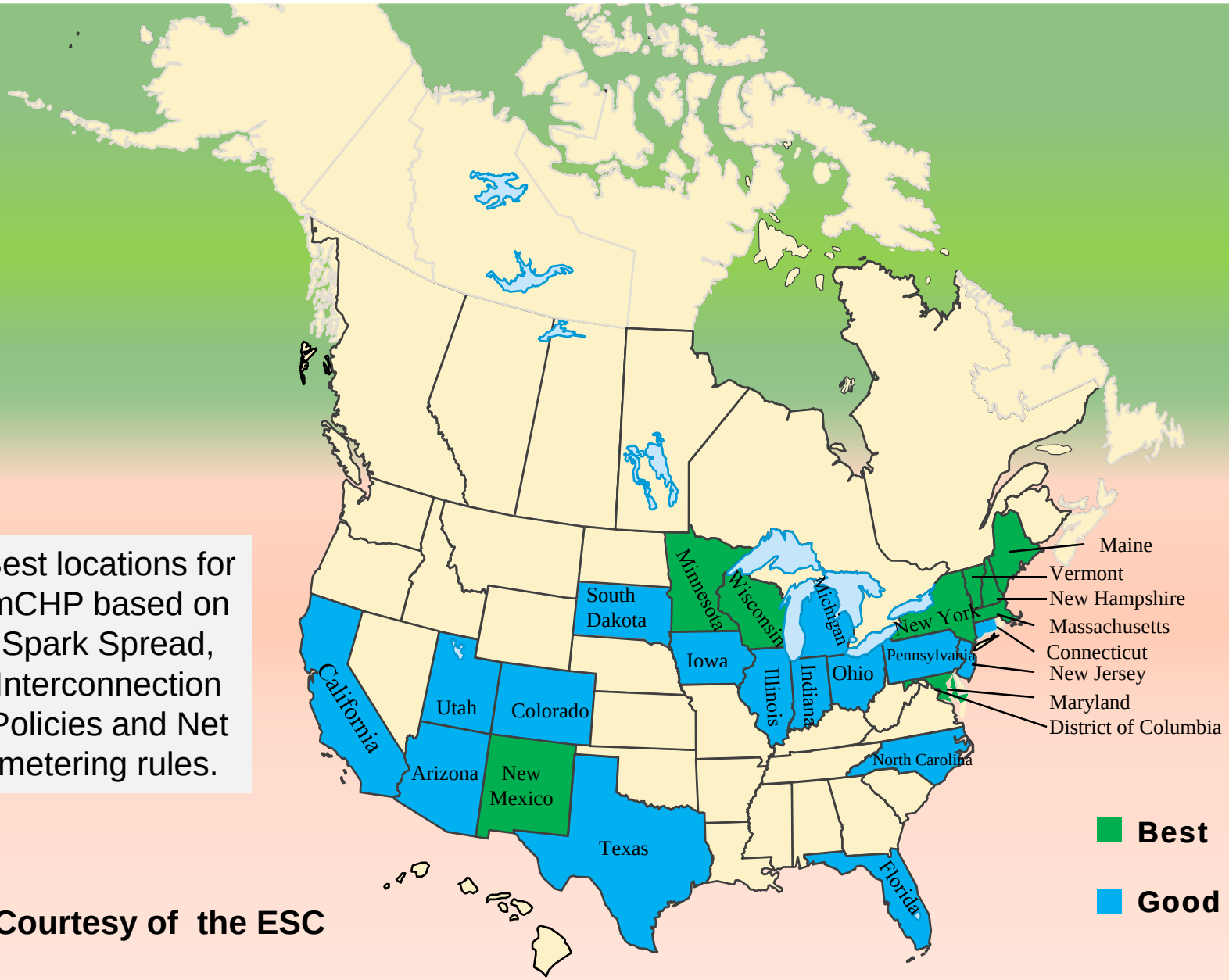
Refer to backup slides for more information on states

Best Current Locations for Micro CHP

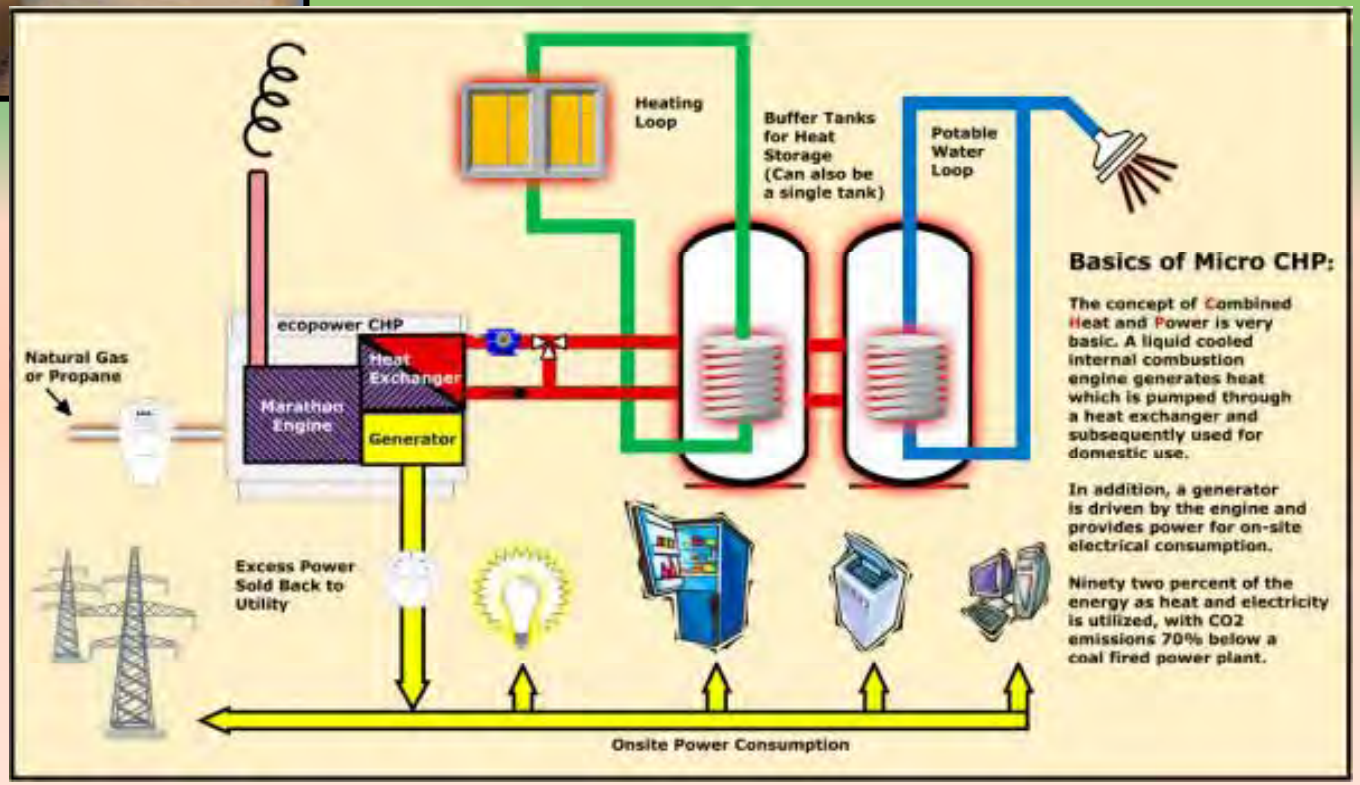
Best locations for mCHP based on Spark Spread, Interconnection Policies and Net metering rules.



Courtesy of the ESC

"It's all about making hot water."

The concept of small scale (<50kWe) cogeneration for residential and small commercial applications.



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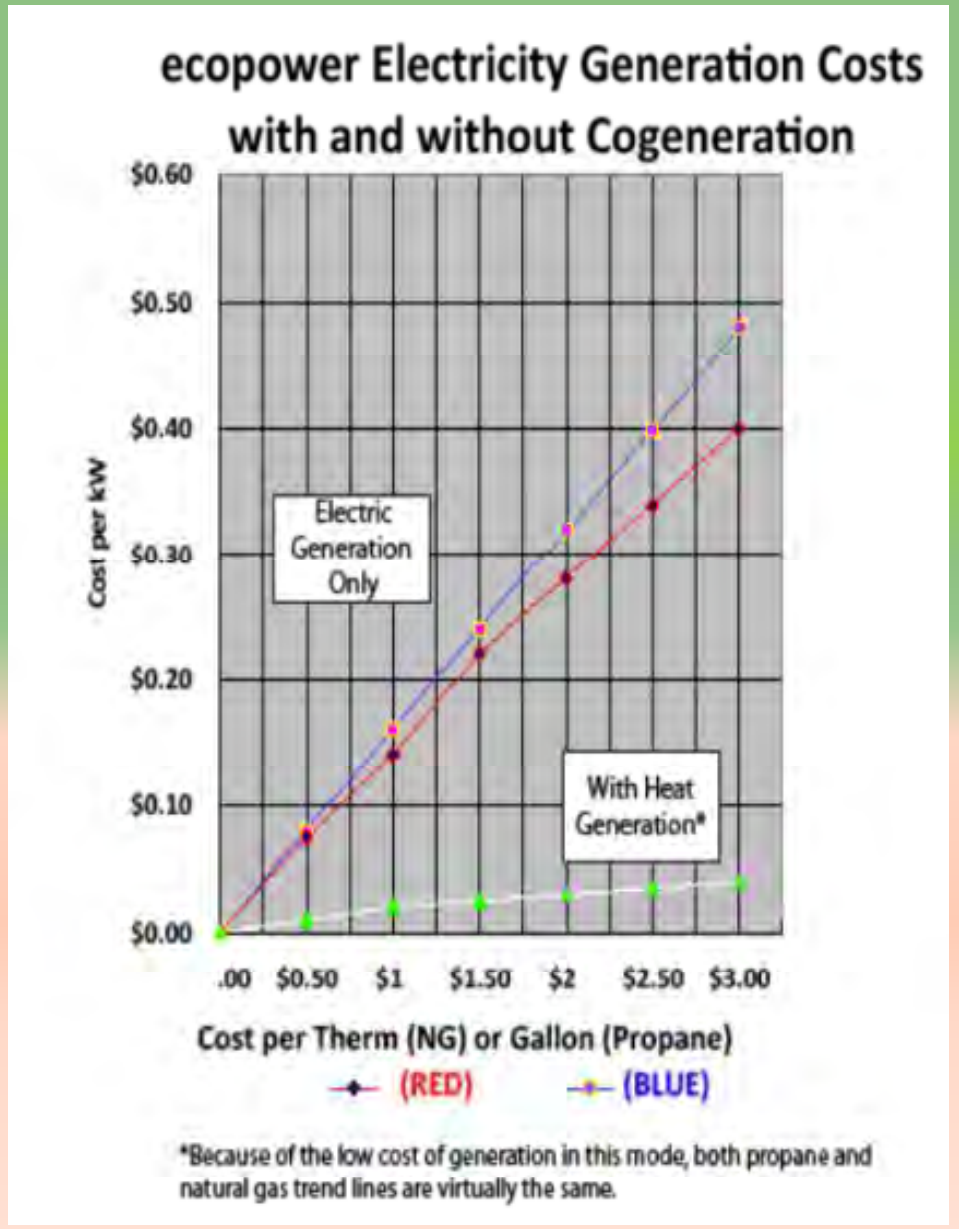
Cost of Generation

Ecopower: 2.0kWe to 4.4kWe and 13,000 to 47,000Btu/hr heat output



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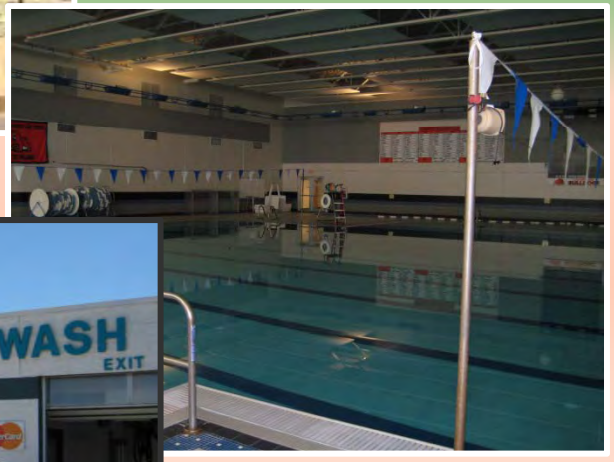
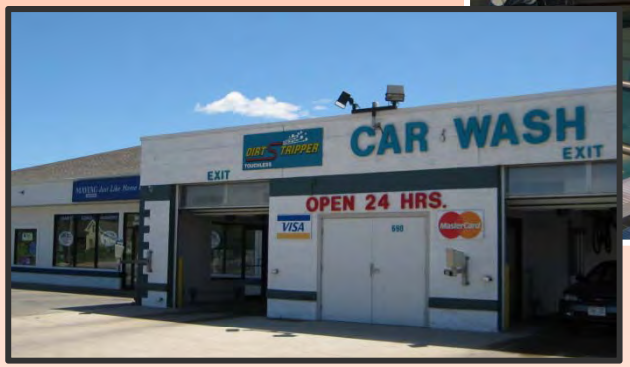
Markets for mCHP





Commercial Market is stronger and shows promise

- **Multifamily apartments**
- **Nursing Homes/ Assist. Living**
- **Health Clubs**
- **School District Pools**
- Restaurants/ Truck Stops
- Medium Size motel
- Hydroponic farms
- Greenhouses
- Laundries
- Car Washes
- Large Building Reheat
- **Larger Homes w/ pools**.

Bottom Line: Any application that uses hot water– the more the better.

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Case Studies / Success Stories

Yeah! microCHP

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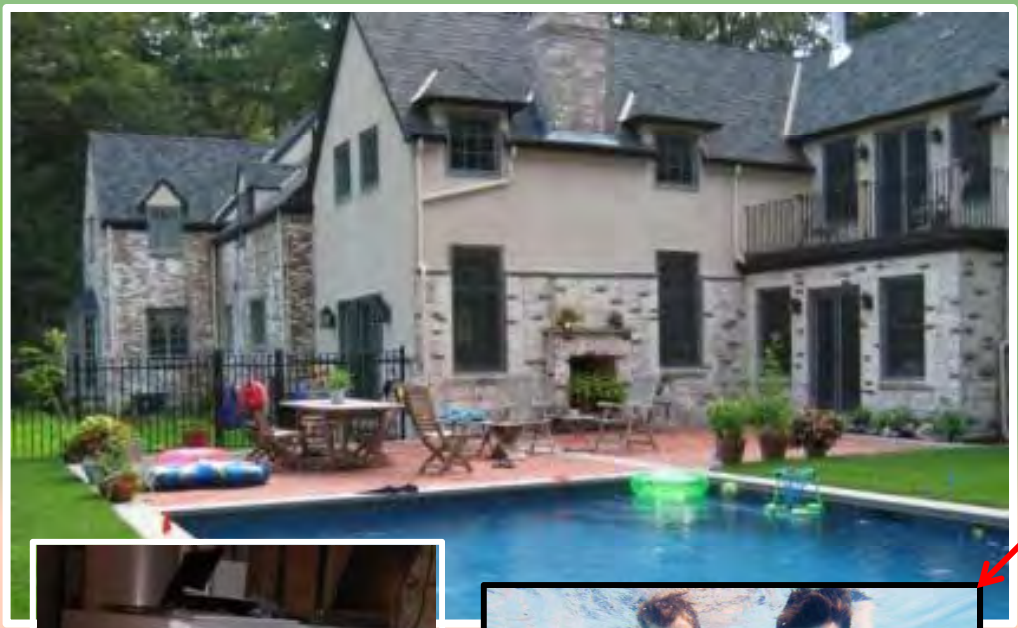
Residential Application-Massachusetts



- 9,000 sq.ft.
- Full in-floor radiant heating system in the house. **Sept to 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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Large Residential Application: Greenwich, CT

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

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Commercial Application

Apartment Building **GAME CHANGER**

Domestic hot water for a 56 Unit, LEED Platinum apartment building, Bronx, NY

- NYSERDA funded for emerging technology.
- Installed August 2009
- Operational October 2009
- **Domestic hot water for year around application.**
- Can generate: 6 Mwh/mo
- Current electric rate is $0.25/kwh
- In the first 15 months – 92 Mwh.
- **Savings of $17,000** + per year in electrical costs to the owner.

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Commercial Application - Fresh & Easy

Fresh & Easy Neighborhood Market-
San Francisco, CA

- Located on 32nd and Clement in the Outer Richmond neighborhood
- **5 ClearEdge fuel cell systems (25 kW)**
- Part of the DOE program
- 2.9 year expected payback
- Fuel cells supply heat and power to 22,000 square foot facility

Financial model, projected spending and savings reflected in this case study are based on customer's engineering estimate of gas and electricity usage as well as third party energy assessment.

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Commercial
Hot Water Applications

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

- **YMCA swimming pool** complex in Wisconsin
- New install – awaiting data.

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System Costs*

Residential System – 1500- 2000 ft^2 house. primary function is domestic hot water, base load power offset. 1-3kW. Installed costs now: $15,000. Target: < $10,000 Maintenance costs: $4-$600/yr based on 4,000 hrs and technology used.(*Note, no systems currently selling in NA*).

Large Residential (> 7,000 ft^2), light commercial- heat is primary focus with electrical generation maximized for off-set of electric costs. 3- 10kW. Installed costs now: $35-$45,000, Tgt: < $20-$25,000 Maintenance costs: $6-$800/yr.

Light Commercial-- Primary focus is maximum heat production, with offset of power costs. 12- 30kW. Installed costs now: $3- $4,000/kW. Target is: $2,000/kW. Maintenance: $8-$1K/yr

Refer to backup slides for more information on heat/power led.

*** Estimates based on geography, new or retrofit install, complexity of the system, and technology used.**

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Barriers

- **No large player in the market**-- Only small companies. Not a cohesive market. No unified focus.
- **Utility Reluctance** – Very slow to change, however the solar impact is changing attitudes.
- **Large Capital cost for install**– High costs because of being an emerging technology. Can be $3k-$8,000/kW

- **Sales Channel**-- can be difficult because of understanding new technology. Small companies have it hard to keep dealers.
- **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– states are fractured. No Federal energy policy.
- **Heat Driven --**therefore limiting to colder climates, partial use during the year --- difficult ROI.
- **Cooling technology** – some exist but are expensive and not practical.
- **Backup Power** --- not consistent and more costly.

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Drivers and Opportunities

Drivers:

- Energy Costs- NG prices are down and Electricity prices are up.
- System Costs- Market will drive prices down.
- Aging Grid – Concern generates changes– Electric utilities impacted by solar DG.
- Energy Awareness- GDP is up and Electric generation is down. First time in history.
- New Entrants and Competition

Opportunities

- Large Market– 68M homes --NG
- Proven & positive track record for mCHP technology
- Spark Spread is very favorable with 34 states >3.0.
- Clean – significantly less CO_2 NOx.
- Good Applications– Hot water.
- High Efficiency- most >85%
- Leasing is becoming viable
- Backup power can be an option.
- Smart Grid / Demand Response
- Multiplexed for larger needs.

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What's Missing?

A Major Company* into the Market

- **Add Credibility**
  - Unknown technology
  - Costly product/system
  - Path to market is difficult
    - Dealer retention & training
    - Service and Maintenance
  - Education of all involved
- **Become a market driver**
  - Lower costs – buying power.
  - Help with legislation
  - Impact/Soften utilities

  - ***Examples only, not for speculation**

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Utilities Need to Accept DG

(and figure out how to embrace it)

- **Abandon Silos– Employ out of the box thinking.**
- **Accept solar and learn from it.**
- **Gas Utilities–learn ways to take advantage of a strong position.**
- **Energy Service providers are more flexible.**
- **Microgrids, *Smart Grid*, and Climate change- are coming. Learn to market these.**

- **...the energy regulatory system in the U.S… "is a relic of 1860 or something; it has fundamentally no basis in the modern world**
  Jeffrey Immelt, CEO of GE
- **The decoupling (ie. decrease) of the demand for electricity verses the increase of GDP has occurred for the first time in history."**
  Jim Rogers, former CEO Duke Energy
- **"We're a superpower with a third world energy grid."**
  Former Energy Sec. Bill Richardson
- "Regulators need to go further and develop a system where utilities get compensated for the quality of service they provide as a "system integrator". We have to have a regulatory model built to accelerate our role as a battery, an optimizer."
  Jim Rogers
- **"There are 50 million buildings in America that are suitable for rooftop solar installations..." David Crane,**

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What Does the Future Look like ?

“ I hate making predictions–
especially if it’s about the future “

Lawrence Peter Berra

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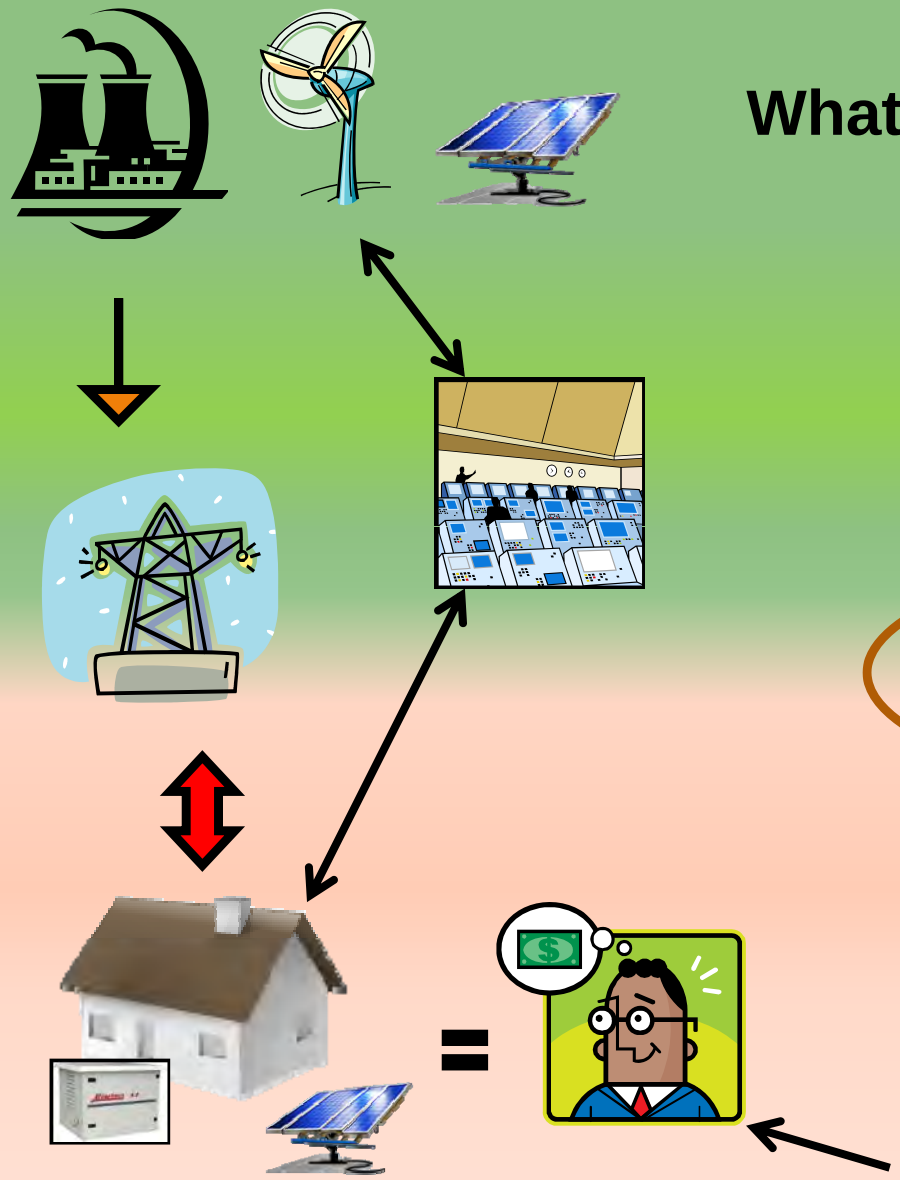
Smart Grid
What it is… and when is it coming ?



The Smart Grid will have the following attributes*:

- **Self healing** – Grid monitors and controls will anticipate and respond to problems and interruptions.
- **Secure –** Deployment of new technology will allow better identification and response to disruptions.
- ***Distributed generation*– Standardized power and communication interfaces will allow customers to interconnect distributed generation technologies on a plug and play basis.**
- **Better control** of appliances and equipment– Grid will interconnect with energy management systems to allow customers to ***manage energy use and reduce their energy costs.***

*Smart Grid Working Group convened by the Energy Future Coalition.

Joe, Olaf's American cousin

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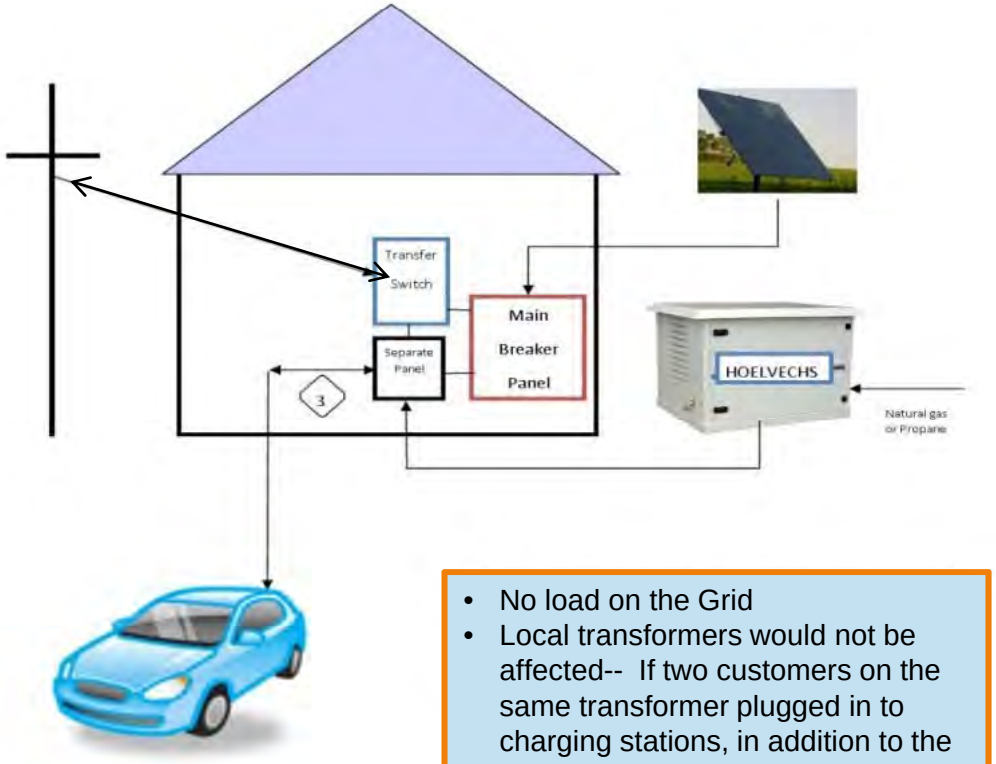
HOELVECHS* Concept Schematic



- **Long life** 5kw engine generator
- Capable of running **4,000 hours** between maintenance needs.
- Natural gas, biogas fueled.
- **Therefore, no strain on the grid.**
- **Electric vehicle charging capable**.
- **Backup power capable** for grid outages. May have a battery complement. (Optional)
- As it 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**

HOELVECH Advantages

- No load on the Grid
- Local transformers would not be affected-- If two customers on the same transformer plugged in to charging stations, in addition to the existing load, it may exceed the emergency rating of about 40% of today's distribution transformers.
- Significantly less polluting than a coal fired plant generated electricity.
- Smart Grid will have the ability to monitor the charging stations and give GHG credits

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Final Thoughts/References

"The benefits of highly increased levels of CHP deployment are too great to ignore. It is imperative that we dramatically accelerate the level of CHP project development...As ratepayers are being asked around the country to pay higher and higher rates, it is unfair to all that some of the most cost-effective energy infrastructure available today is rarely being deployed."

ACEEE Paper *on* ***Utilities and the CHP Value Proposition***, July 2013, Anna Chittum, Kate Farley.

- ACEEE Paper on ***How Natural Gas Utilities Can Find Value in CHP***, Ibid.
- ACEEEE Paper on ***How Electric Utilities Can Find Value in CHP***, Ibid.
- EPRI, ***The Integrated Grid, Realizing the Full Value of Central and Distributed Energy Resources***, 2014.
- ICF International, for the AGA, ***The Opportunities for CHP in the United States***, May, 2013, Bruce Hedman, et.al.
- **http://www.gastechnology.org/news/Documents/Natural_Gas_in_a_Smart_Energy_Future_02-22-2011_FINAL.pdf**

"When faced with steamrolling technology, you either become part of the technology or part of the road."

Lowell Bryan (Business Consultant)

Department of Energy and AO Smith

Innovation has a name.

The DOE and AO Smith are collaborating on a three year project to:

- Apply **a 20kWe mCHP** at eight sites to be chosen within the next year -- - **East coast, Midwest, and California**.
- Test sites will chosen from those submitted by gas/electric utilities or other interested parties. Typical sites would be **restaurants, health care/club facilities, mid-sized motels, and multi-family apartments with high hot water use 3-6,000gal/day.**
- **Install and maintenance will be covered** by AOS/partner company and the sites will be monitored for two years by ORNL (Oak Ridge).
- At the end of the term, **units will be left in or replaced with a new system** like the original that was in-place.
- Costs– Right now **an upfront fee of $20,000 is required**, however this should be off-set by yearly **savings of $13-$15,000** . Life of the system is **8-10 years so overall savings > $100,000**. A **three year payback** is anticipated including the install costs.
- Contact microcogen99@gmail.com or 262.353.6263 if you wish to be added to the “interest” list. (Mike Cocking)

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Questions?

Mike Cocking
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microcogen99@gmail.com
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Thanks for your time

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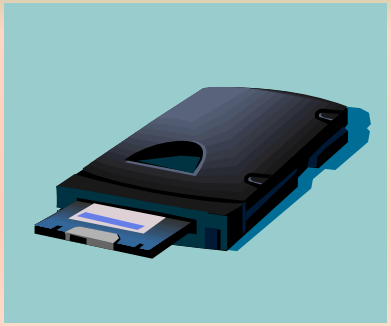
Support & Backup Information



Spark Spread

- Spark spread is the relative difference between the price of fuel and the price of electricity.
- **For a CHP system, the spark spread is the ratio between the cost of purchased grid power divided by the cost of fuel to produce power (and heat) on site.**
- As the primary fuel for most applications is natural gas, the **lower that cost becomes (denominator)** the larger the Spark Spread– also compounded by an **increase in electrical costs.**
- **Generally a 3 or higher on a scale of 1-5 is considered a good spark spread.**

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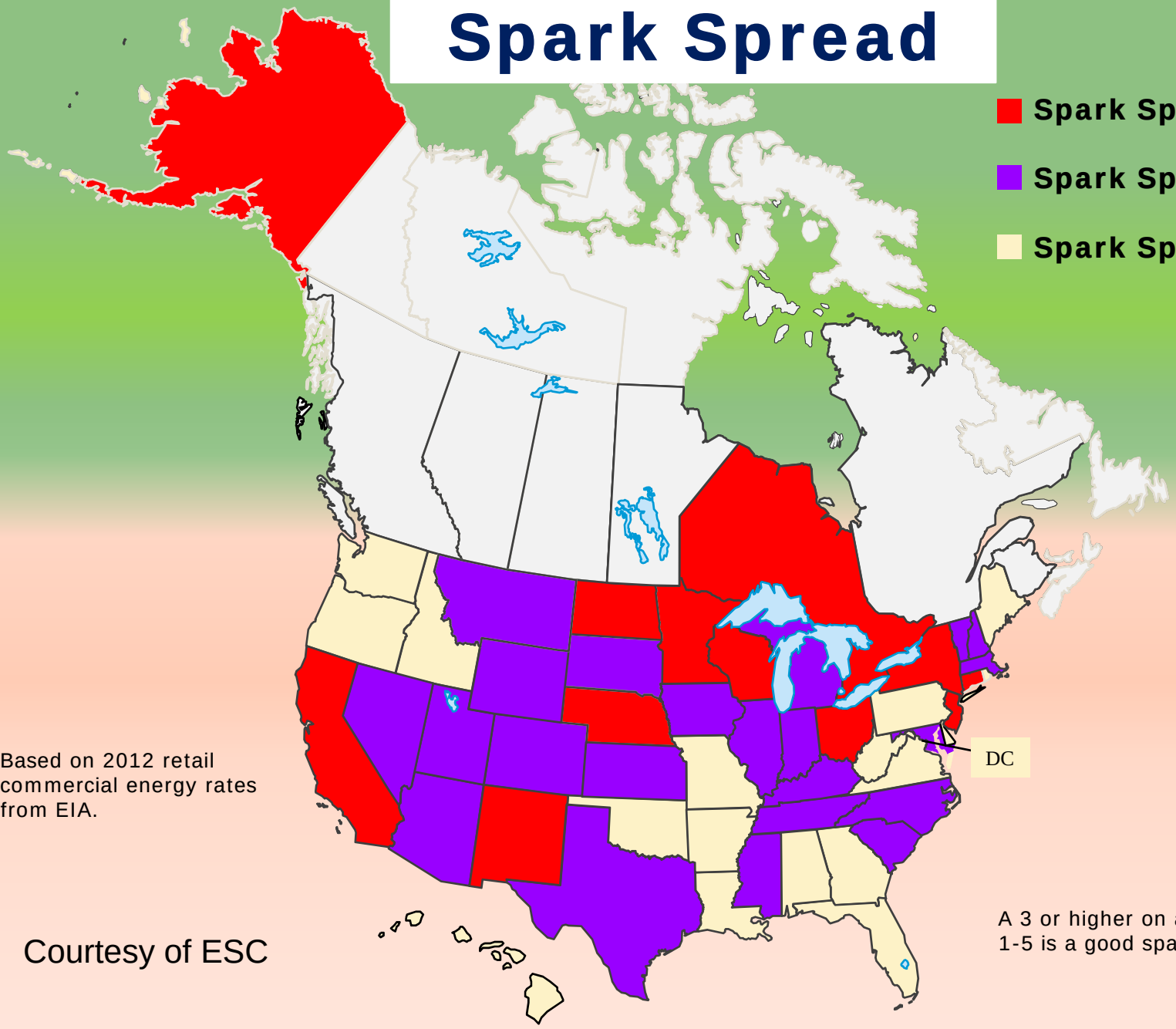
Spark Spread



Based on 2012 retail commercial energy rates from EIA.

Courtesy of ESC

A 3 or higher on a scale from 1-5 is a good spark spread.

Net Metering

- When a micro-CHP is used primarily for heating, often times **more electricity is being produced** than is being consumed by the home or business.
- Net metering allows the consumer to **spin the meter backwards and put power back on the grid** at times 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**. However, the local utility determines what the "**payback"** rate will be.
  - **Avoided cost is the minimum paid** which is the cost the utility uses their cost that is offset by local generation. Usually $0.02-$0.04/kWh.
  - **Feed- In tariff is a premium paid** for local generation. Enacted to promote distributed generation.

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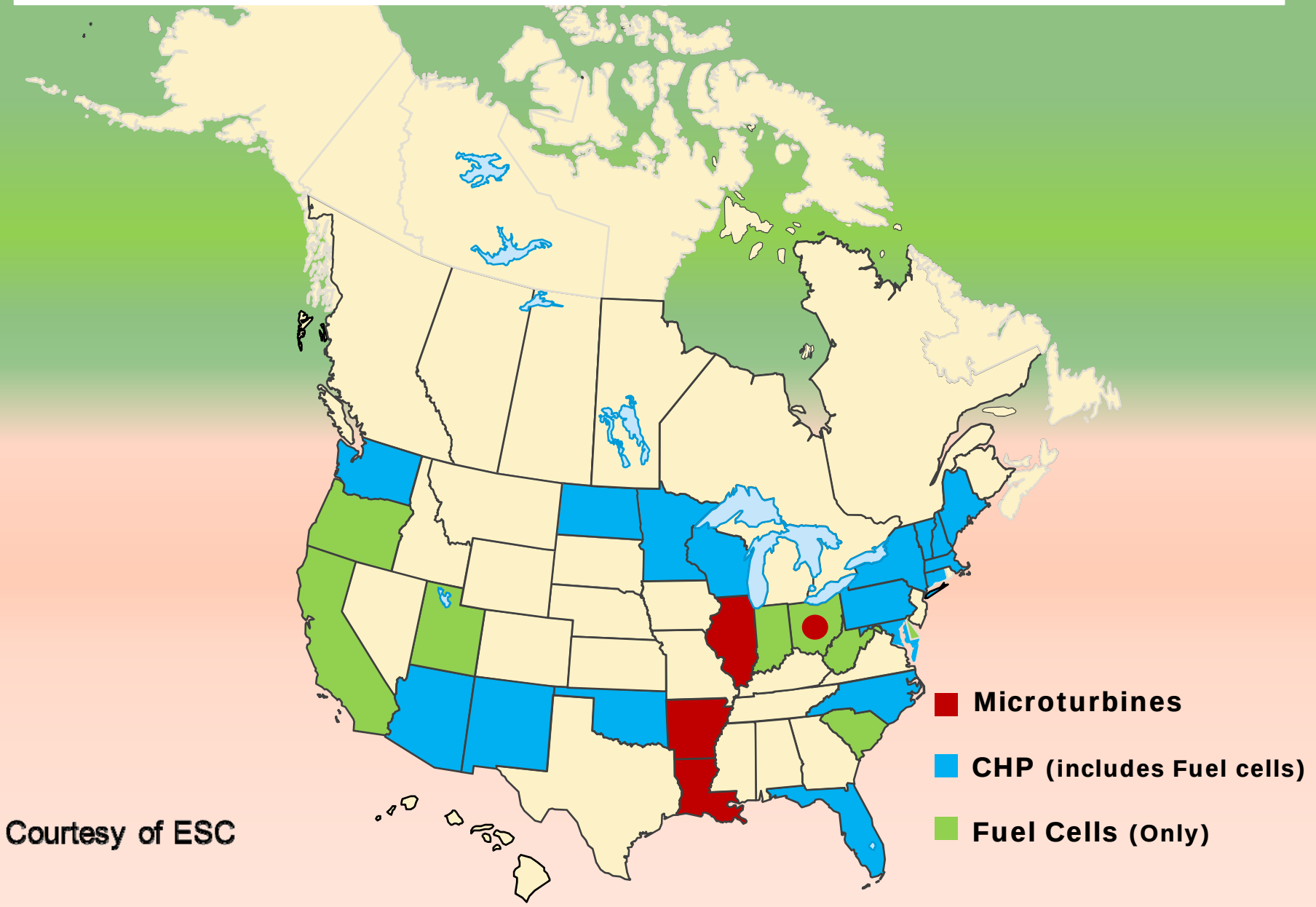
States Allowing Net Metering for mCHP



Courtesy of ESC

Interconnection

- Interconnection standards include the **technical requirements** and the legal procedures whereby a customer-sited generator interfaces with the electric grid.

- Generally, the electric distribution utility must review and **approve a proposed DG system** within a framework established by the state's public utilities commission.

- **Utilities traditionally** have determined which systems may connect to the grid and under what circumstances ---which can cause **significant barriers to customer-sited CHP**. For the most part, if the appliance meets **the UL 1741 standard**, it would have no problem being approved.

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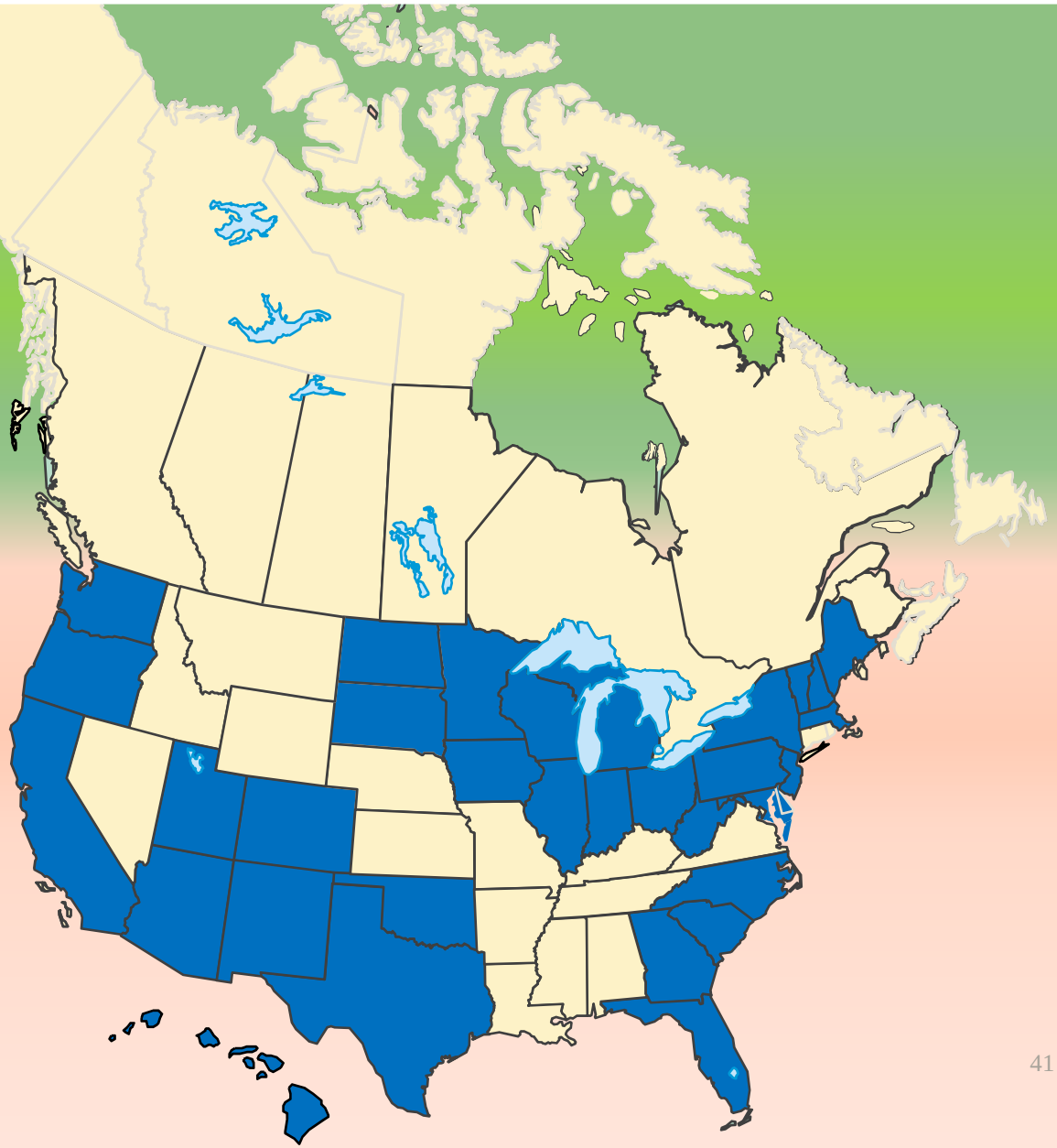
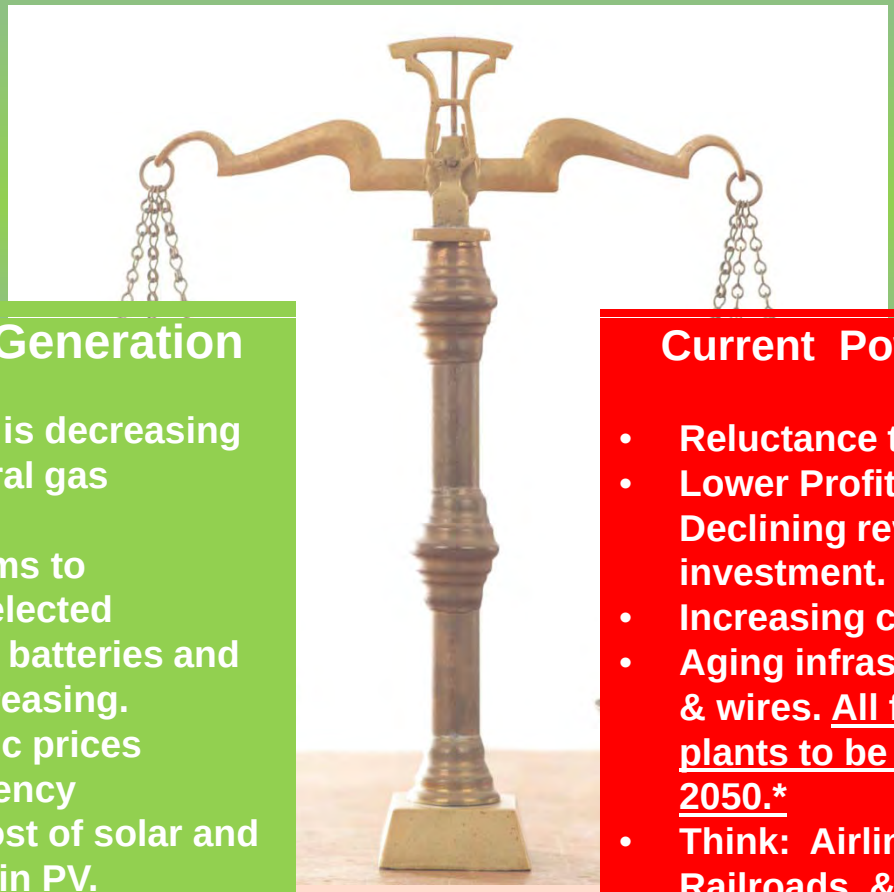
States with Interconnection Policies for CHP

Arizona	Maine	Oklahoma
California	Maryland	Oregon
Colorado	Massachusetts	Pennsylvania
Connecticut	Michigan	South Carolina
Delaware	Minnesota	South Dakota
D.C.	New Hampshire	Texas
Florida	New Jersey	Utah
Georgia	New Mexico	Vermont
Hawaii	New York	Washington
Illinois	North Carolina	West Virginia
Indiana	North Dakota	Wisconsin
Iowa	Ohio	



Courtesy of ESC

The Future of Generation?



Distributed Generation

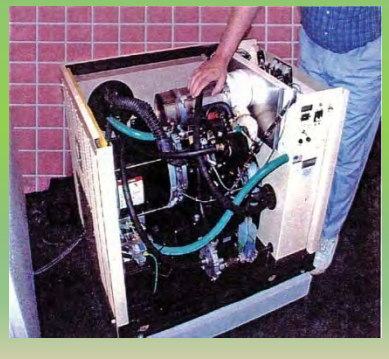
- Costs for DG is decreasing
- Price of natural gas decreasing
- Govt. programs to incentivize selected technology--- batteries and fuel cells increasing.
- Rising Electric prices
- Energy Efficiency
- Decreased cost of solar and increase use in PV.

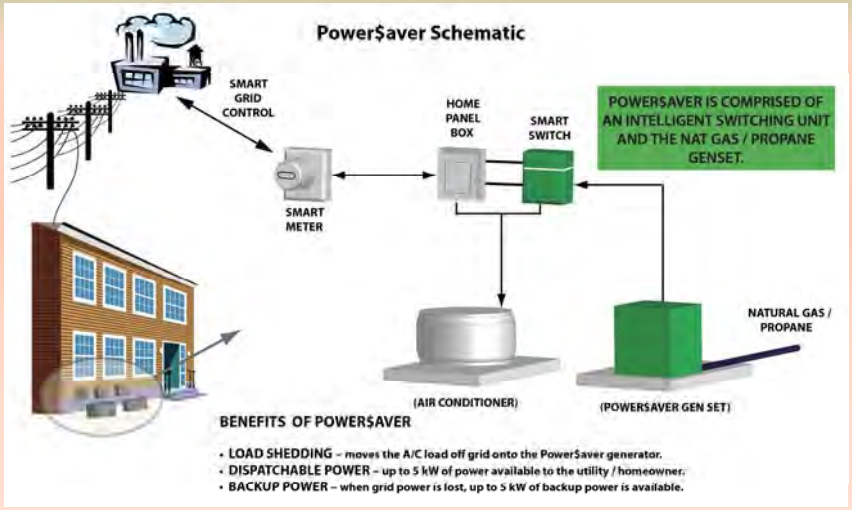
Current Power System

- Reluctance to change
- Lower Profitability – Declining revenues, less investment.
- Increasing costs
- Aging infrastructure- poles & wires. <u>All fossil fueled plants to be replaced by 2050.*</u>
- Think: Airlines, Telephone, Railroads, & Post Office.

* Jim Rogers quoted.

Power$aver – the *Almost* Perfect Smart Grid Application.





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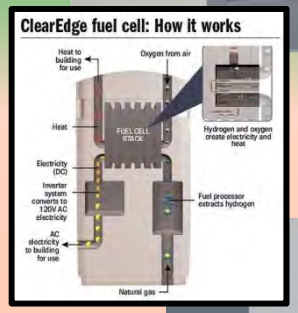
Power$aver

- Ability to **switch the A/C load from the grid to the genset --- seamlessly.**
- Has 5kW of **dispatchable power.**
- Totally **controllable** from a central utility.
- Offers 5Kw of **backup power** (more with battery compliment)
- No heat capture, therefore reasonably priced. **Installed for < $8,000**.
- The perfect **Smart Grid appliance.**

mCHP: Heat-led or Electric-led ?



When dealing with CHP technologies, a consideration must be made with regard to what is **the *primary energy* generated** and what's the byproduct? There is no clear-cut answer, but size of the unit and the power source must be taken into account**.**

- **General Considerations:**
  - **<u>Large systems (>50kWe)</u> would be industrial or large commercial applications are *usually* electrically led. Heat is secondary and used for space heat and air conditioning.**
  - **<u>Light Commercial applications</u> >3kWe and <50kWe). These are usually heat led, meaning they are in-place to supply hot water or space heat and electricity is the by-product.**
  - **<u>Residential and small applications</u> (<3kWe) are usually electric led so as to handle the base load of the residence. Heat is secondary. It should be noted that <u>larger homes (>6,000ft)</u> and with a pool or hot tub would be heat led because of the year around need for thermal energy.**

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Gas Load Opportunity- Future

- **A 1.5kW Fuel Cell mCHP can produce virtually all of the hot water needs of a residential home.**
  - **Gas use for DWH before mCHP = 25 MCF/Year**
  - **Gas usage for mCHP/DWH = 69 MCF/Yr**
  - **Incremental load = 44 MCF/year**
  - **1.5 kW Fuel Cell Equals about the equivalent of roughly 2 water heaters**
  - **And generates ~6,000 kWh/yr of Power.**
- Benefits
  - **Gas Load Growth**
  - **Revenue Generation- Oil/Electric Conversion**
  - **Revenue from Equipment Sales/Lease**
  - **Customer Retention & Customer Loyalty**
  - **Energy Efficiency = Good PR + Green thinking**
  - **mCHP is energy conservation that increases residential gas load: Typically 15%-30%**
    - **Typical gas use for heating = 100 MCF/yr (Cold Climate)**
    - **High Eff. Heating = ~ 80 MCF/yr**
    - **A 1kW microCHP = ~ 110 MCF/yr**

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The evolution of micro Combined Heat & Power (mCHP) from large scale systems.

- Large systems (>100kW+) have been around for many years. **Edison's plant in Manhattan was a Cogen plant.**
- Early innovators 1970-1980. **Germany and Japan started because of limited energy resources.** US allowed grid access from Qualified sources in 1978.
- Because of the development of this technology in Europe and Japan the **US can reap the benefits.**
- Single biggest challenge for the micro appliances was **a long-life power source that could run continuously** for at least 4000 hours (Six months).

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… or an Even a Smarter Grid ?

"The **North American natural gas** infrastructure is an interconnected system…serving over **75 million customers with a history of close to 100% reliability**… The integration of natural gas with electricity into a highly reliable energy delivery infrastructure would **provide an extraordinary combined level of reliability, especially when coupled with applications** interconnected with this integrated grid such as **backup electricity generation, microgrids, and loops of heated or chilled water managed as thermal grids."***

*Recent GTI Report

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