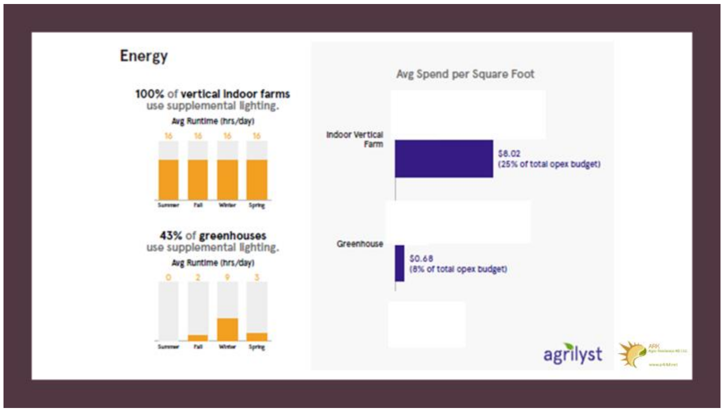
Chapter Seven – No Alternative To Efficiency – From Building Envelop to Cogeneration… Quadgeneration and Beyond!

I submit comparing between two building extremes will be highly illustrative of options we have and should exercise in the crucial need for energy efficiency. Could it be that selecting between a greenhouse translucent R1 insulated membrane versus an opaque R30 high value insulation building deserve careful consideration when thinking about energy efficiency? This is a important practical comparison for indoor controlled environment agriculture growers and here is the results of a study by Agrilyst on the subject:



This second graphic looks at thermal requirements and costs, which of course, are hugely dependent on where in the world one is locating a plant factory. Many would not expect the counter-intuitive fact that, to a point, colder climates have better economics for low insulation value translucent membranes due to the thermal gain and natural light enjoyed for approximately 1600 or so hours per year. As one gets closer to the equator and cooling becomes the hugely predominant thermal requirement, then historically greenhouses could not be affordably cooled enough to be conducive to growing but the ARK passive cooling system is a game changer in this regard, so our model will need to factor in heavily the cost of electricity. Tropical places like the Caribbean Islands where electricity comes mostly from diesel generators and therefore is about $0.50/kWh versus much of North America where electricity is about $0.12/kWh makes a huge difference in best selecting a blackhouse VS a greenhouse.

https://www.greentechmedia.com/articles/read/cannabis-growers-eye-microgrids-to-cut-energy-bills#gs.JkVNVWU

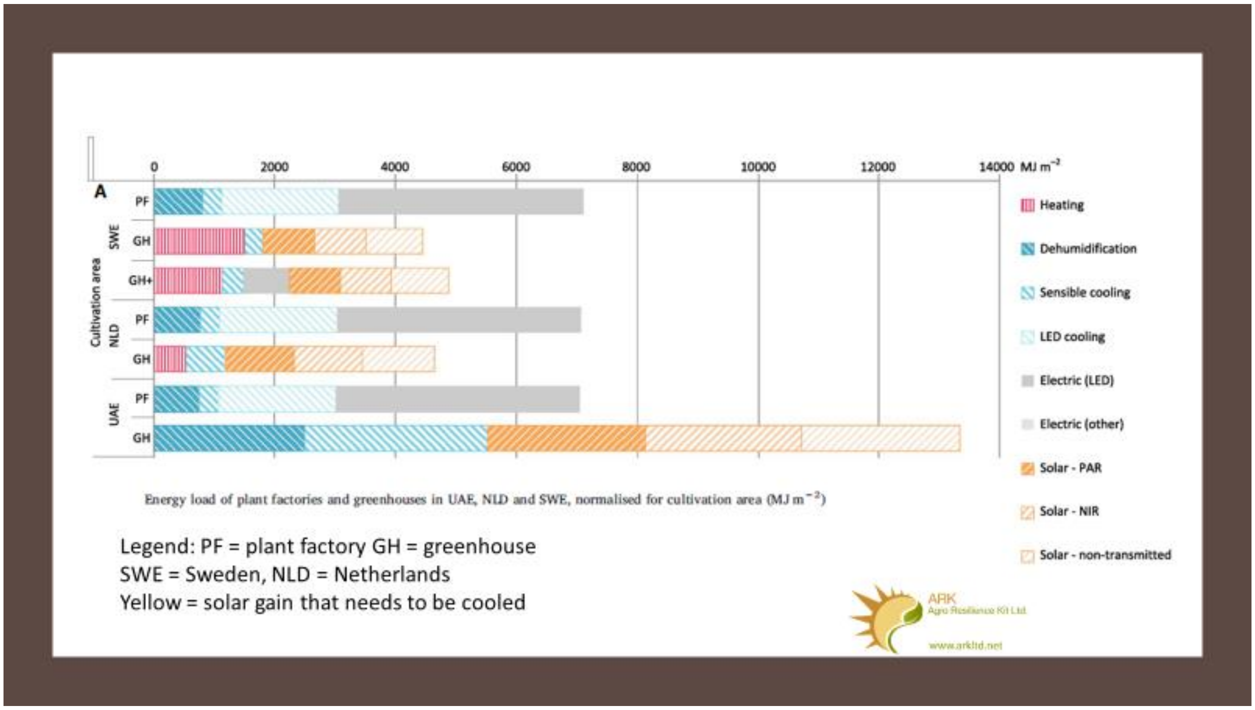
Economics of greenhouses and solar energy

Conventional glasshouses are solar collectors – some (PAR and near infra-red NIR) is trapped as heat. Too much can cause issues for plant growth, so ventilation is used to control temperature. A closed system needs to use fans and air conditioning to remediate this and in fact have proven impractical for almost all applications. Different parts of the globe require different glasshouses depending on solar levels.

It’s often assumed that in warmer climates closer to the equator growers would have an advantage due to higher solar radiation. The figures do not back this up. Work carried out by the Dutch shows that production costs, whilst being cheaper in Spain, also result in a shorter growing season with lower value crop in comparison to a Dutch tomato grower. Working with PhD student Esteban Baeza Romero who compared the costs of both systems, they demonstrated a better cost: benefit ratio due to the higher yield in the Dutch greenhouse. This combined with a higher sale price means it is more profitable to grow in a Northern climate than in a Mediterranean climate.

It’s cheaper to add energy than it is to take it out because of the massive temperature gain of a greenhouse. Therefore, the UK and other northern hemisphere climates have a competitive advantage on sub-tropical regions with glasshouse production. Fig 27, World Isolation Map, shows the amount of solar energy in hours, received each on an optimally tilted surface during the worst month of the year. https://agfstorage.blob.core.windows.net/misc/HD_com/2018/10/22/nuffield.pdf

One choice does not best suit all and www.ARKltd.net can assist with modelling and careful consideration to get to the best long-term answer.



Energy load of plant factories and greenhouses in UAE, NLD and SWE, normalised for cultivation area (MJ m^{-2})

Legend: PF = plant factory GH = greenhouse
SWE = Sweden, NLD = Netherlands
Yellow = solar gain that needs to be cooled

Source: “Plant factories VS greenhouses: Comparison of resource use efficiency Graamans et al Elsevier

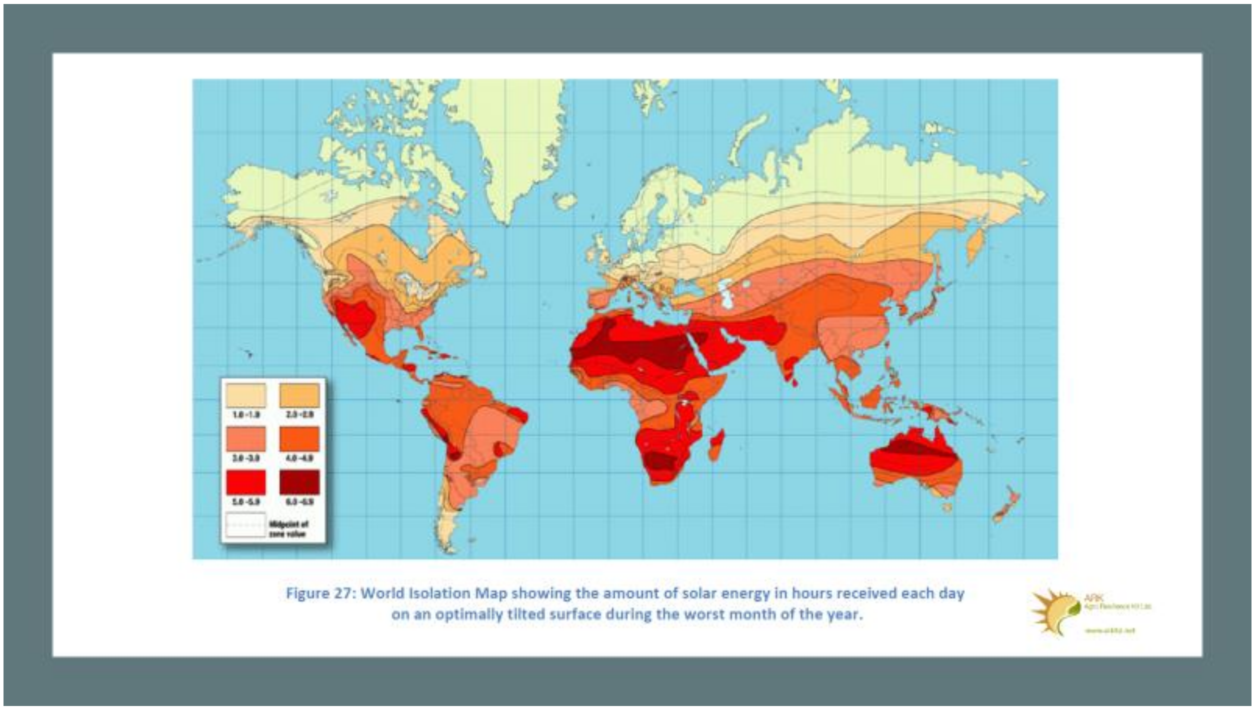


Figure 27: World Isolation Map showing the amount of solar energy in hours received each day on an optimally tilted surface during the worst month of the year.

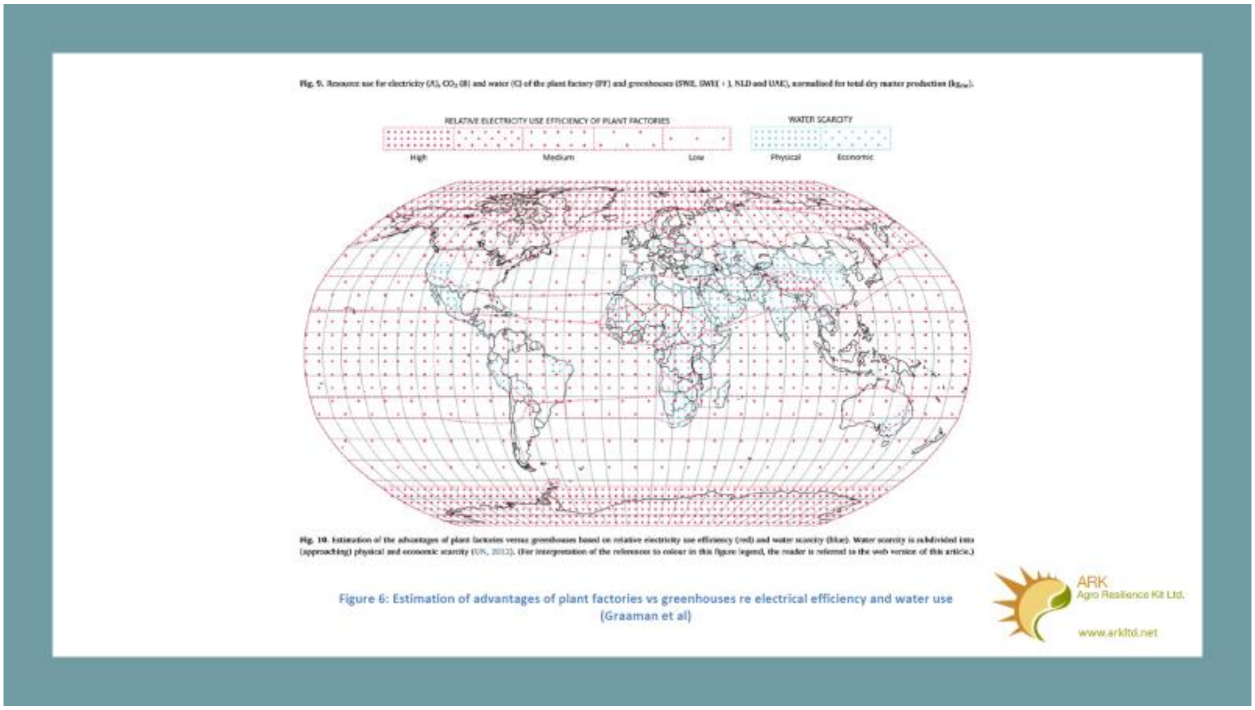


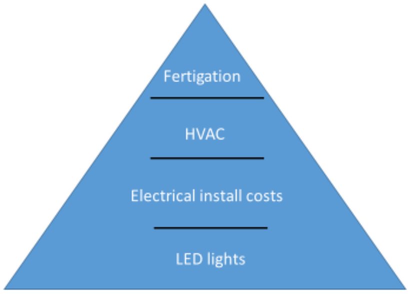
Fig. 9. Resource use for electricity (A), CO_2 (B) and water (C) of the plant factory (PF) and greenhouses (SWE, SWE+, NLD and UAE), normalized for total dry matter production (kg_{DM}).

Fig. 10. Estimation of the advantages of plant factories versus greenhouses based on relative electricity use efficiency (red) and water scarcity (blue). Water scarcity is subdivided into (approaching) physical and economic scarcity (UN, 2012). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

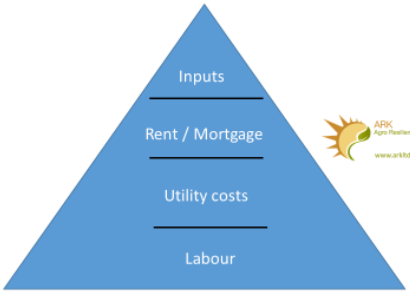
Figure 6: Estimation of advantages of plant factories vs greenhouses re electrical efficiency and water use (Graaman et al)

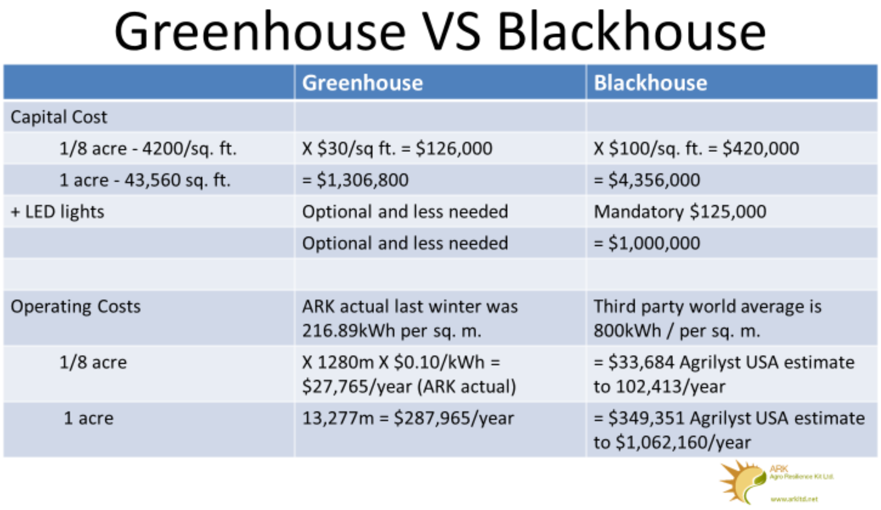
Greenhouse Compared With Opaque Insulated Plant Factory

Capital Expenditure (CAPEX)



Operational Expenditure (OPEX)





Greenhouse VS Blackhouse

	Greenhouse	Blackhouse
Capital Cost		
1/8 acre - 4200/sq. ft.	X $30/sq ft. = $126,000	X $100/sq. ft. = $420,000
1 acre - 43,560 sq. ft.	= $1,306,800	= $4,356,000
+ LED lights	Optional and less needed	Mandatory $125,000
	Optional and less needed	= $1,000,000
Operating Costs	ARK actual last winter was 216.89kWh per sq. m.	Third party world average is 800kWh / per sq. m.
1/8 acre	X 1280m X $0.10/kWh = $27,765/year (ARK actual)	= $33,684 Agrilyst USA estimate to 102,413/year
1 acre	13,277m = $287,965/year	= $349,351 Agrilyst USA estimate to $1,062,160/year

ARK
Agro Resilience Kit Ltd.
www.arkltd.net

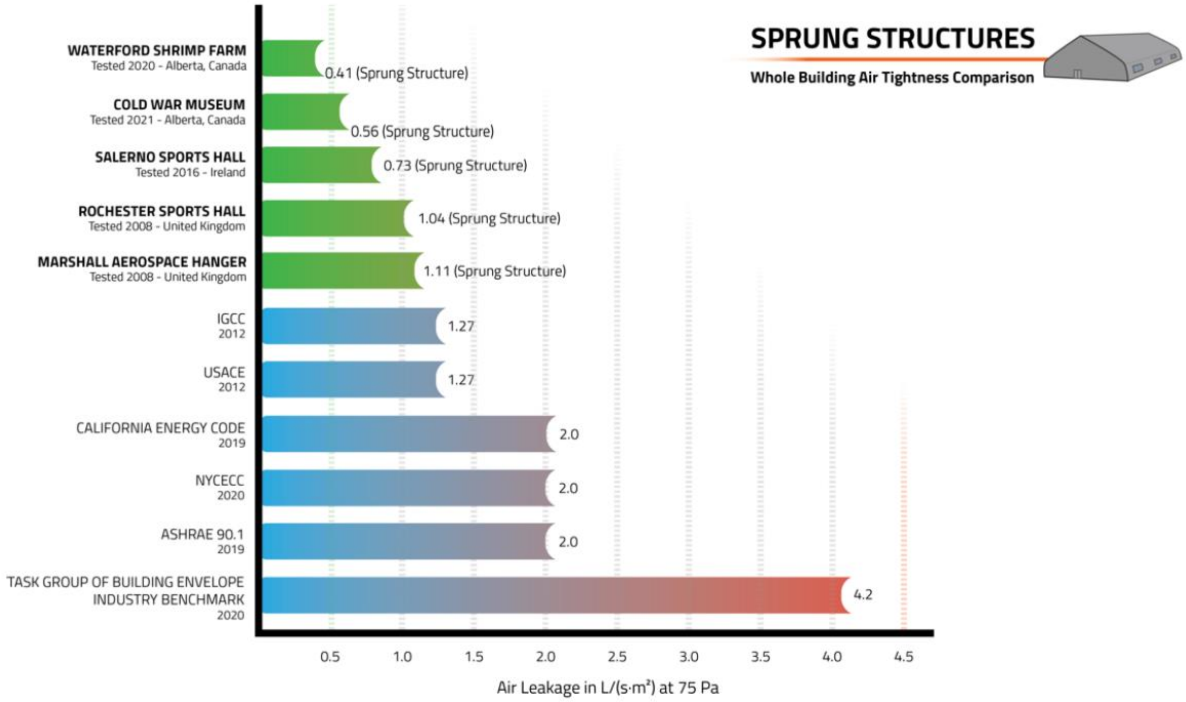
Sprung Structures experience and success with greenhouses extends back into the 1970’s see https://www.youtube.com/watch?v=vIJ5mHjRHRQ A confluence of extraneous events saw the company cease operating greenhouses but the technology advantages remained and have been resurrected in a business alliance with the offerings of the Agro Resilience Kit (ARK). Patented tensioned membrane structures have unyielding provided an advantage to Sprung Structures the world over for many decades.

The translucence of the Sprung/ARK membrane options is well proven with all plants tested to date to compete well against glass, polycarbonate or others greenhouse options. The job of a greenhouse is to provide a structure for growing plants that is translucent to sunlight, yet sufficiently enclosed to reduce convective heat loss (the exchange of air between the inside and outside). Sprung Structures and membranes have been analyzed many times by accredited third parties who have measured and concluded that the air tightness of the Sprung Structure is unparalleled in its thermal energy efficiency. This advantage means the membrane dramatically reduces the costs associated with heating or cooling which generally is the second highest cost of greenhouse operations behind labour costs. In the U.S., nationally, heating costs constitute 65-85 percent of annual energy cost for a year-round commercial greenhouse (Runkle and Both 2011).

Sprung Structures have options that include R30 walls if desired. Sprung Structures manufacturers systems off the manufacturing floor that achieve LEED Silver and BREEAM designations. BREEAM is a European standard that is a certification similar to LEED but said to be more stringent. For BREEAM air permeability is measured as air permeability is so very influential regarding ultimate energy efficiency and therefore heating and cooling costs of a building/greenhouse. The huge importance of air permeability is especially true with greenhouses as having appropriately transparent materials means either single ply materials with an R-value of about 1 and perhaps 2-3 with a double ply.

Audited Measured Results In Non-Greenhouse Buildings

The Wates Company, one of the largest private contractors in Europe undertook testing so a Sprung building could obtain BREEAM Certification. In the final result, Wates and HMPS couldn't quite believe how good the test results were and ran them a second time. In Wates test Sprung Structures achieved an air leakage rate of 2.01m3/(h.m2) and less as the below chart shows. For comparison purposes, a 100% airtight rating would be “1” which is simply not achievable. The Lowest acceptable rating for a commercial building is a 10, anything beyond this is a fail and cannot be permitted for construction. An aircraft hanger is typically a 10 and historically much worse. A good quality metal building typically achieves a rating of 6 to 7. With Sprung buildings air tightness and R30+ insulation in place, despite a low R factor natural daylighting ceiling, what is the ultimate energy usage results as compared to conventional construction? The following two independent studies attest to Sprungs results:



Please note: Codes referenced specify maximum whole building air leakage in L/(s*m2) at 75 Pa. The NECB and IECC have been omitted as they require air tightness of individual assemblies rather than whole-building. Other jurisdictions which use Air Changes per Hour (ACH) have been omitted as they are not comparable to this unit of measurement. The benchmark of 4.2 L/(s*m2) was identified by the research group Task Group of Building Envelope, where an average was found after testing a range of existing buildings.

Created March 2021

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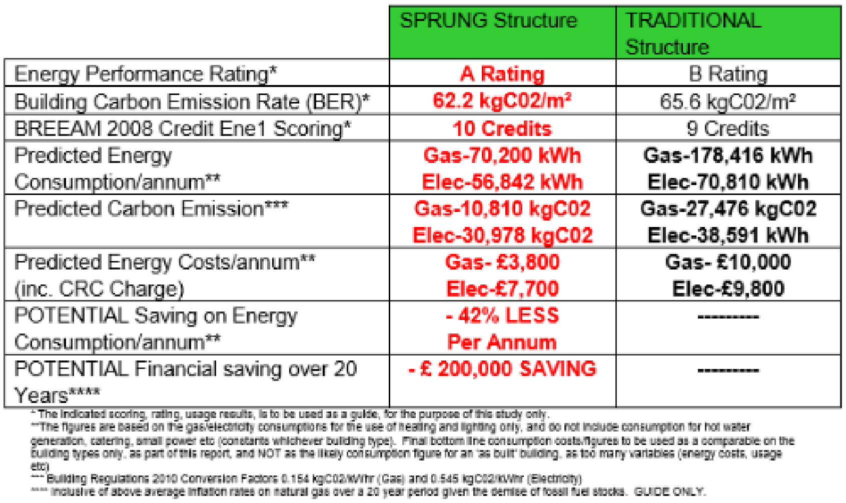


	SPRUNG Structure	TRADITIONAL Structure
Energy Performance Rating*	**A Rating**	B Rating
Building Carbon Emission Rate (BER)*	**62.2 kgC02/m²**	65.6 kgC02/m²
BREEAM 2008 Credit Ene1 Scoring*	**10 Credits**	9 Credits
Predicted Energy Consumption/annum**	**Gas-70,200 kWh** **Elec-56,842 kWh**	**Gas-178,416 kWh** **Elec-70,810 kWh**
Predicted Carbon Emission***	**Gas-10,810 kgC02** **Elec-30,978 kgC02**	**Gas-27,476 kgC02** **Elec-38,591 kWh**
Predicted Energy Costs/annum** (inc. CRC Charge)	**Gas- £3,800** **Elec-£7,700**	**Gas- £10,000** **Elec-£9,800**
POTENTIAL Saving on Energy Consumption/annum**	**- 42% LESS Per Annum**	**----------**
POTENTIAL Financial saving over 20 Years****	**- £ 200,000 SAVING**	**----------**

* The indicated scoring, rating, usage results, is to be used as a guide, for the purpose of this study only.

**The figures are based on the gas/electricity consumptions for the use of heating and lighting only, and do not include consumption for hot water generation, catering, small power etc (constants whichever building type). Final bottom line consumption costs/figures to be used as a comparable on the building types only, as part of this report, and NOT as the likely consumption figure for an 'as built' building, as too many variables (energy costs, usage etc)

*** Building Regulations 2010 Conversion Factors 0.154 kgC02/kWhr (Gas) and 0.545 kgC02/kWhr (Electricity)

**** Inclusive of above average inflation rates on natural gas over a 20 year period given the demise of fossil fuel stocks. GUIDE ONLY.

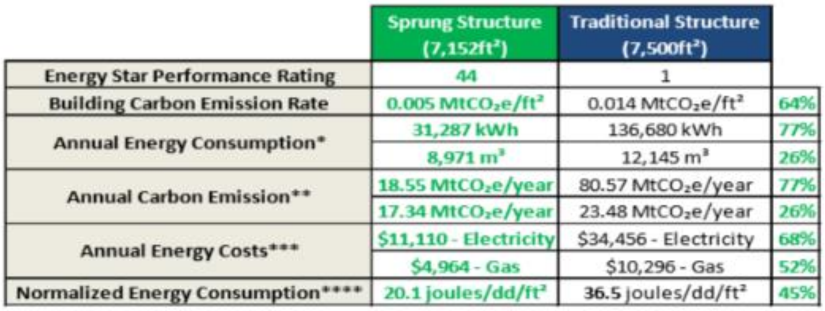
RePower Canada Inc. has conducted a comparison study between two different construction methods to determine overall building performance based on similar size and building function.

Selected for comparison is a traditional method of construction (TMC) consisting of concrete block, wood frame, and metal deck roof, and a modern method of construction (MMC) consisting of individual architectural membrane panels tensioned between a series of aluminum arched ribs.

RePower Canada Inc.

Each building's characteristics are as follows:

	Traditional Structure	Sprung Structure
Gross Floor Area:	7,500ft²	7,100ft²
Space Type:	House of Worship	House of Worship
Fuel Source:	Electricity Natural gas	Electricity Natural Gas
Heating:	Packaged Outdoor Unit (80% Efficient)	Packaged Outdoor Unit (81% Efficient)
Lighting:	Fluorescent T8	Fluorescent (Linear and Compact)
Ventilation:	Dedicated Vent Fans	Packaged Outdoor Unit (81% Efficient)
Air Conditioning:	Packaged Outdoor Unit (80% Efficient)	Packaged Outdoor Unit (81% Efficient)
Controls:	Digital Programmable	Digital Programmable



	Sprung Structure (7,152ft²)	Traditional Structure (7,500ft²)	
Energy Star Performance Rating	44	1	
Building Carbon Emission Rate	0.005 $MtCO_2e/ft^2$	0.014 $MtCO_2e/ft^2$	64%
Annual Energy Consumption*	31,287 kWh	136,680 kWh	77%
	8,971 m^3	12,145 m^3	26%
Annual Carbon Emission**	18.55 $MtCO_2e$/year	80.57 $MtCO_2e$/year	77%
	17.34 $MtCO_2e$/year	23.48 $MtCO_2e$/year	26%
Annual Energy Costs***	$11,110 - Electricity	$34,456 - Electricity	68%
	$4,964 - Gas	$10,296 - Gas	52%
Normalized Energy Consumption****	20.1 joules/dd/ft²	36.5 joules/dd/ft²	45%

* February 2011 - January 2012

** Based on emission factors from Portfolio Manager

*** February 2011 - January 2012

**** Based on weather data from Barrie & London, Ontario weather stations

The conclusion of RePower Canada Inc from the results of this study was that the Sprung Structure using its modern method of construction is more efficient when compared with a traditional construction method. Both buildings are of similar function and size. The Sprung advantages are due to:

1) Use of translucent membrane panels along the roof greatly reduces heat loss associated with glass and roof fenestration.
2) More daylight entering the facility compared to the traditional structure. The result is lower lighting demand which reduces energy consumption from artificial lighting and reduced cooling load (in summer from lamp heat).
3) Higher R-Values for the roof assembly reduces heat loss, decreasing consumption.
4) Higher R-Values for the roof fenestration reduces heat loss, decreasing consumption.

Overall the Sprung structure is considerably more efficient when compared to traditional methods.

- Consumes 45% less energy than a facility of similar size and function using the traditional construction method
- Operating costs are 62% less than a facility of similar size and function using the traditional construction method

Produces 65% less greenhouse gas emissions than a facility of similar size and function

The secret to this air tightness is the Sprung membrane and how all membrane panels are heat sealed together, absolutely minimizing air gaps, which is hugely detrimental to heat and cooling losses in conventional greenhouses. This airtight membrane also maximizes passive solar energy gain when the sun is shining, and such heat gain is desired.

The more airtight the greenhouse, the less heat loss impact of wind. Conventional greenhouse structures typically see their heating requirement double as wind speed goes from 0 to 15 miles per hour. Sprung Structures have been proven by third party measurement to be extremely airtight. Negawatts or energy one operator doesn't need to purchase, whereas his competition does, has always been a source of improved margins and advantage. The above culminate in impressive negawatts for greenhouses largest need, which is thermal.

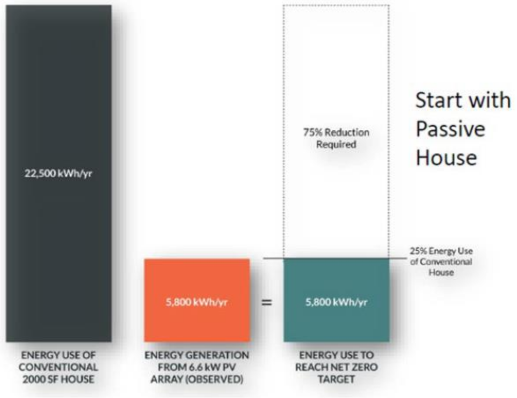


Figure 1 Net Zero Energy reduction requirements from conventional buildings with renewable energy generation. Source: hammerandhand.com

Sources include Bellows 2008 Greenhouses ATTRA National Sustainable Agriculture Information Service

Material	R value per inch
Pink fiberglass insulation	3.9
Expanded polystyrene	3.85
Phenolic foam	8.3
Sprayed polyurethane foam	6.88
Air per 24"	1

Peak Estimated Heat Requirements in BTU/Square Foot of Surface Area

*Zone	A -40°F	B -30°F	C -20°F	D -10°F	E 0°F	F 15°F	G 30°F
R20 insulated north wall or lean-to greenhouse							
Single glazing	370	330	290	250	210	175	140
Double glazing	250	220	190	160	130	100	70

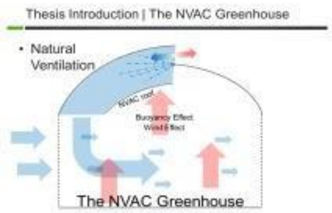
Freestanding Greenhouse							
Single glazing	400	360	320	280	240	180	120
Double glazing	250	225	200	175	150	110	85

*Zone – The tables assumes a 60°F inside night temperature and minimum temperatures for your given area; individual locations may have temperatures lower than this. In borderline locations, select the colder zone. Source: Adapted from Greenhouses (NRAES-137)

Shading, Cooling and Thermal Control

Forced air natural gas space heating is typical for many greenhouses. The greenhouse industry average for northern climates is a 30 BTU per square foot when averaged over a year (Note: most greenhouses are built in mild climates) (Source: Greenhouse Canada / Statistics Canada 2017). Peak load is about 400 BTU per sq. ft. of greenhouse or 1 million BTU for the 4200 sq. ft. ARK greenhouse.

ARK studies found that three 6 horsepower fan motors operating from about 9am until 6pm daily was not enough cooling to avoid the greenhouse from often hitting temperatures that actually damages plants and badly slows productivity. ARK began working with a prestigious university to deploy a patented system (described below) which has proven to cool the ARK greenhouse by as much as 5-20°C depending on ambient humidity. essentially without the use of electricity. Operating the fans required about 9,000 kWh over 3 months, which is all but eliminated with the ARK membrane cooling system.



ARK (NVAC) COOLING SYSTEM (FOR NATURAL LIGHT GREENHOUSES)

The NVAC Cooling System is an evaporative cooling technology developed specifically by ARK for the Sprung Structure. This patented solution has proven to cool the interior of the greenhouse during summer months between 6°C and 15°C (3.4 °F -22°F) cooler than external temperatures

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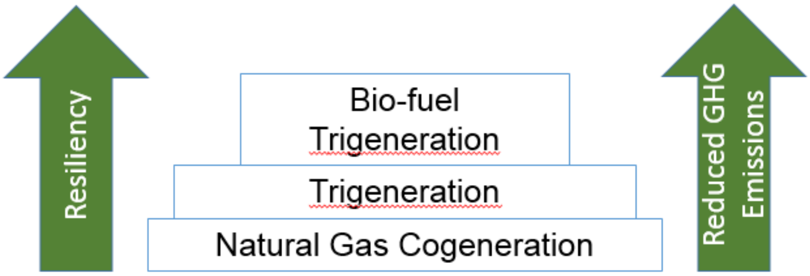
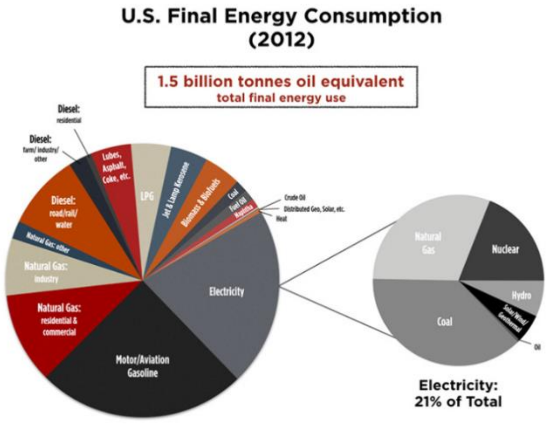
The ARK Cooling System uses approximately 5% (only 0.27kWh when operating) relative to that of an electric Swamp Cooler that at (4.9kWh) in the same sized greenhouse. Source McGill NVAC thesis

Hierarchy of Resiliency & GHG Footprint



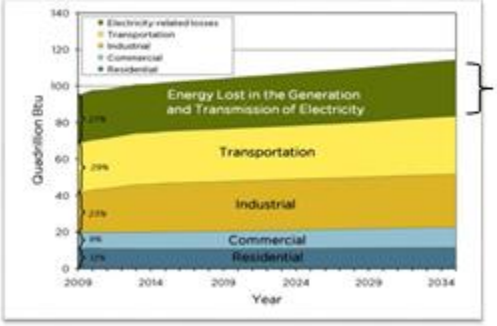
If every kWh of electricity ever generated on the planet was added up, we'd quickly discover that spinners/turbines or thumpers/reciprocating engines have generated the vast majority of those kW's from the beginning until today. The reasons such equipment has been so dominate mostly go back to energy density discussions as highlighted by this link http://www.computerworld.com/article/3053882/sustainable-it/solar-on-all-us-roofs-would-supply-39-of-power.html

Of course, even if we can absorb the massive investment needed to put solar on all roof tops, and if we suppose that all rooftops are well suited for solar panels (which isn't the case), and further we have found a cost effective way to store solar power – then we still have to reconcile with the fact that electricity is only about 21% of energy use. Thermal energy use is the largest energy use and as the graphic to the right shows, if we capture the energy currently lost in electricity generation, for use in current thermal requirements – *we can take a quantum leap forward*. As people understand the thermal dynamics of cogeneration it becomes readily apparent why this is so.

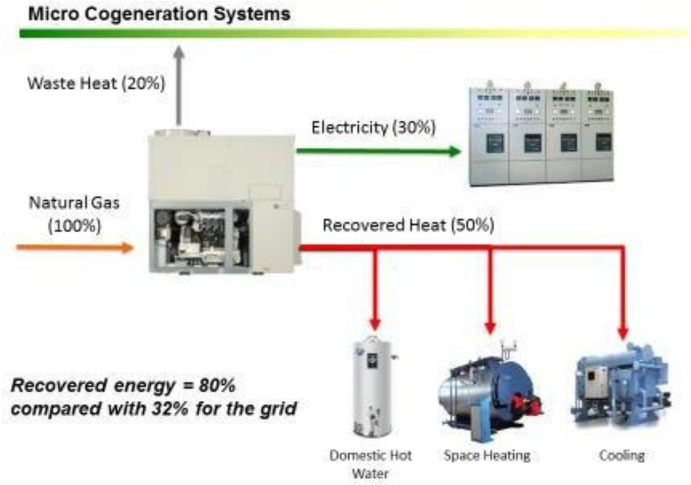


sources: IEA Energy Balances; U.S. EIA

. Energy lost in the Electric Power Generation Sector Compared to other Sectors of Society



A Huge Waste of Energy
Waste Heat from
Thermal Power Plants
equals all the energy used
for transportation or by
industry in North America



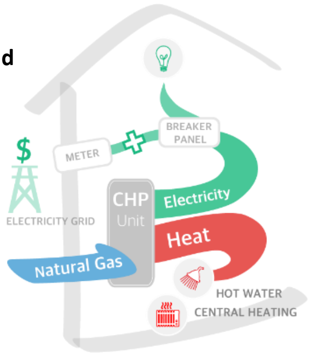
Cogeneration (also referred to as **combined heat and power**, **CHP**) is the use of a heat engine to simultaneously generate both electricity and useful heat.

All thermal power plants emit a certain amount of heat during electricity generation (in fact, on average, 68% of energy into a central electricity plant is lost as waste heat). This gets released into the natural environment through cooling towers, flue gas, or by other means whether it's from coal, natural gas, oil or even nuclear plants (which operate at 33% efficiency). By contrast, CHP captures almost all of the by-product heat for heating purposes (space heating or domestic hot water) and is therefore able to operate at least at 80% efficiency – most often at 90%.

The body of knowledge highlighting the superior economics as well as energy efficiency and CO² reduction advantages of CHP is extensive.

"The cost-effectiveness and near-term viability of CHP development establishes this exciting technology as a leader among other clean energy technologies such as wind, solar, clean coal and nuclear power." (Source: Oak Ridge National Laboratory (ORNL) "Effective Energy Solutions for a Sustainable Future").

Financial Post. Key quote: "We can double the efficiency of our current electrical system with a technology that's practical, proven, readily available, inexpensive and technologically simple."



The benefits are many and well documented, as exemplified by the Oak Ridge National Laboratory (ORNL) as they answered the question - What would happen if 20% of the generating capacity of the U.S. came from CHP within commercial buildings?:

1. A 60% reduction in projected increase of carbon dioxide emissions. Both fuel use avoided and using rather than wasting heat from central fired electricity plants means that the greenhouse gas emissions avoided with the use of cogeneration systems is large and material.
2. Fuel conservation of 5.3 quadrillion British thermal units (BTU) annually, the equivalent of nearly half the total energy currently consumed by U.S. households
3. **<u>Put another way the wide spread adoption of cogeneration has the potential to reduce overall energy demand in the U.S. by 23%.</u>**
4. Being a completely closed loop system and utilizing heat outputs means that when compared to central fired electricity plants, cogeneration also conserves a great deal of water!

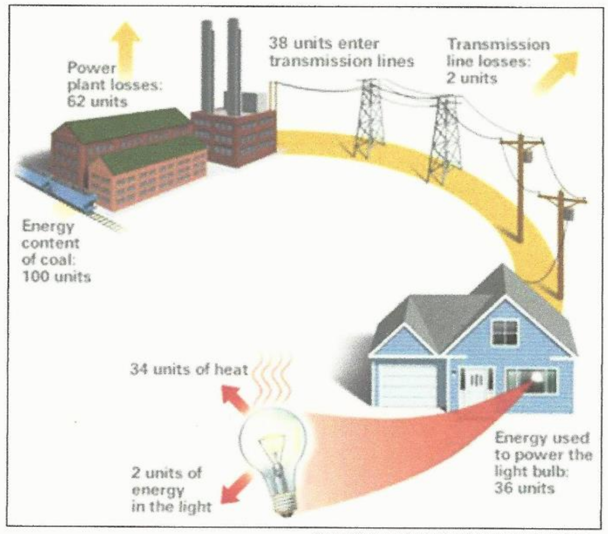
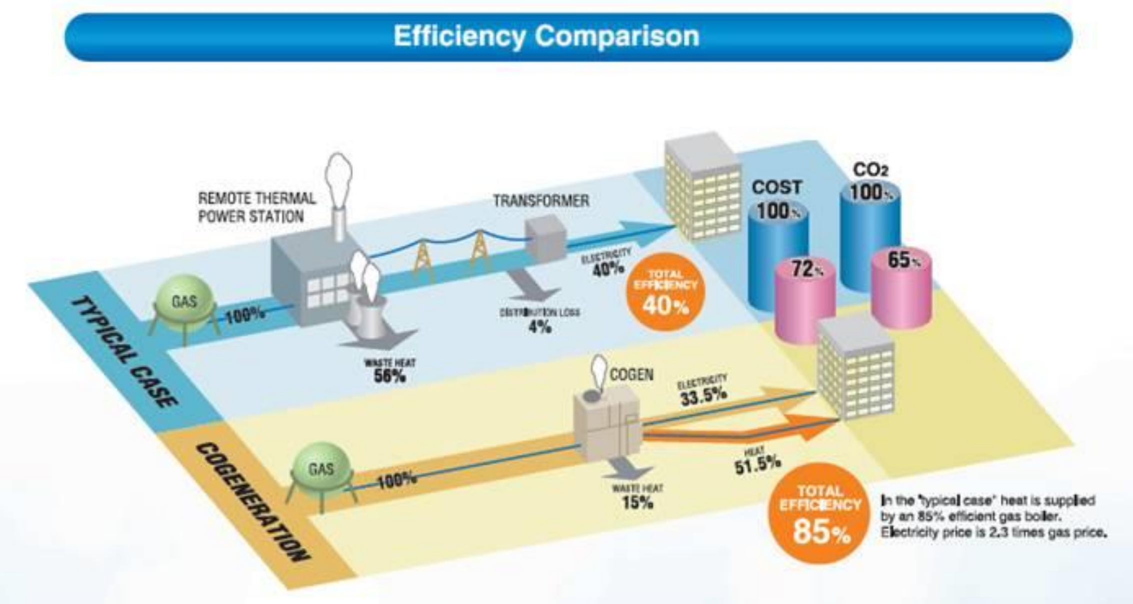


Image Source: The National Academy of Science



The mechanical principals of cogeneration are not all that different than your car. The engine is very different because your car engine is designed to be as light as possible for miliage fuel efficiency and unfortunately planned obsolesce. The engines specified for cogeneration are heavy, industrial strength engines with compression ratios of 12:1 plus and designed to run 7 X 24, 90% of the hours of the year, for on average 15+ years. Anything less, is an underperforming cogen system. Like your car, fuel is burned to drive reciprocating pistons which turns the drive shaft and gears to cause propulsion. Unfortunately while that occurs, most of the fuel energy going into a car is being dissipated as waste heat; through the radiator for the fluid cooled engine and out the exhaust pipe.

In the case of cogeneration, while our industrial strength engine is turning a generator at 1200 to 1800 RPM's, we use heat exchangers to capture the heat off the engine jacket as well as the exhaust pipe. We then put this heat to good use either heating domestic hot water, space heating and even for cooling (as described below). It is quite amazing to see a system, for example, generating 150kW of electricity while simultaneously heating 120,000 square foot building in Edmonton most months of the year, or an entire swimming pool and recreation center or chilling a diary cooler. In other words, a lot of energy is conserved and/or put to very good use!

Some salient points:

1. Fossil fuels quickly became the dominant supply of energy for electrical and thermal needs because it's much higher energy density than that of solar, wind, biomass, etc. Our ancestors had energy wisdom and recognized this. Such high energy density literally enabled the industrial revolution.
2. Industrial processes and commercial buildings are two of the top four consumers of energy in the world with transportation being number one. Surprisingly, **waste** heat from central fossil fuel fired electricity generation plants is the second largest user of energy in the world – but much of this is unnecessary waste that can be avoided.
    a. By leveraging co- and trigeneration, we enable a decentralized approach to generate electricity on site, while capturing what otherwise would be waste heat and put it to productive use in space heating for buildings or industrial processes that can leverage the heat to create chilling, drying and desalination. Fuel sources to fire reciprocating engines can include natural gas, petro-diesel, bio-diesel or bio-methane's as available supply, economics and other drivers might dictate. Natural gas is far and away most readily available today, provides the best economics, while still dramatically reducing GHG emissions, particularly for urban commercial buildings today and likely for quite some time.
3. When it comes to attempting to go back to the future by using less fossil fuels in favor of clean, sun based energy such as wind, for some reason, electricity generation has garnered far and away more attention than thermal requirements. However it is very often the case, in many locations such as Canada, that thermal energy requirements are in fact, larger than electrical requirements.
    a. For commercial buildings north of the 49th parallel, heating degree days far exceeds cooling degree days. Most buildings significantly rely on natural gas for space heating needs and therefore cogeneration can reduce these buildings operating costs by 20-40%. The Canadian averages are as follows according to Natural Resources Canada:

FIGURE 5

Commercial Building Energy Consumption by End Use[21]

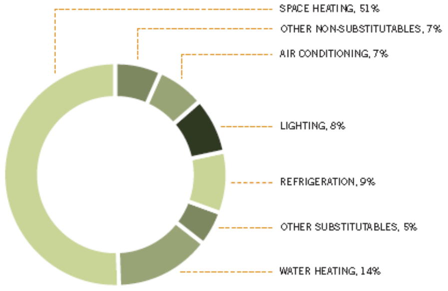
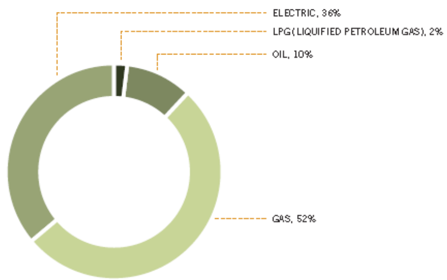


FIGURE 6

Commercial Building Energy Consumption by Fuel Type[22]

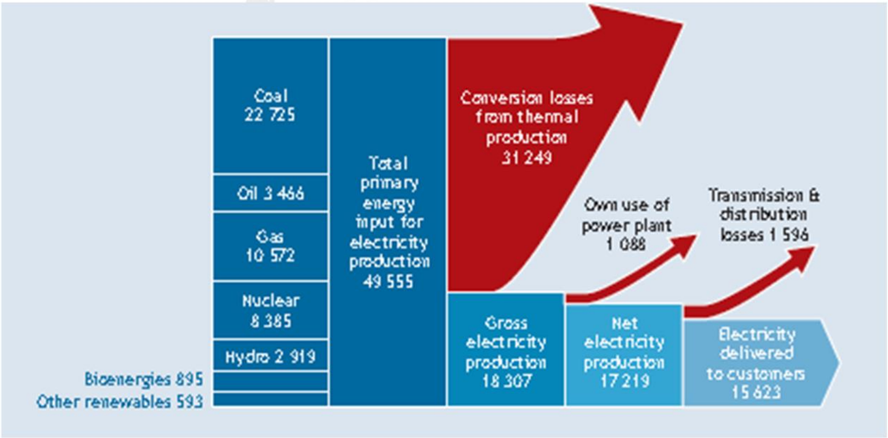


This Holmes on Homes video shows the technologies use in Edmonton http://www.youtube.com/watch?v=67o9aNFxxIl

Proven technology provides secure, clean, non-interruptible combined heat and power source at lower cost:

- Cogeneration is a well-proven technology with tens of thousands of installations worldwide, and is recognized as a more efficient and therefore cleaner and less costly alternative to conventional and other clean energy technologies. Government incentives to install the technology are offered in many jurisdictions.
- In countries such as Norway, Denmark, Finland and Russia, cogeneration accounts for over 30% of electrical generation. According to the International Energy Agency's "Combined Heat and Power – Evaluating the benefits of greater global investment", CHP accounted for 9% of global power production in 2010.
- CHP systems produce electricity and heat from a reciprocating engine resulting in an overall efficiency of 80+% compared to conventional electricity grid and boiler energy consumption which results in an approximately 50% efficiency and 20-40% higher utility costs. Trigeneration or including chilling in many geographies results in even better economics and the Binary Fluid Ejector (more on that below) increases the efficiency many fold.

Energy Flows in the Global Electricity System (TWh)

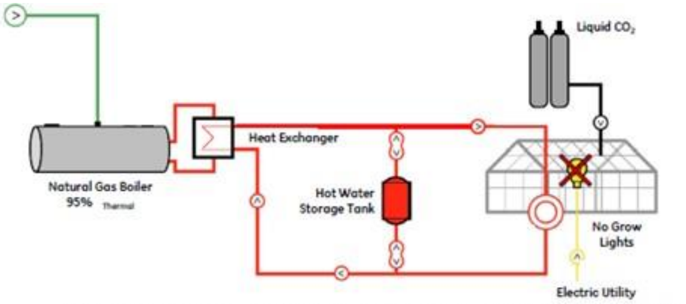


Source: IEA

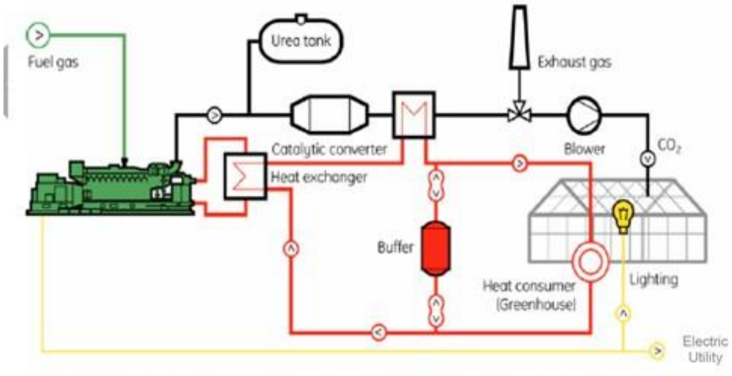
- In addition to reducing reliance on external power sources by providing consistent, dependable and cost effective on-site electrical and heat supply, cogeneration also reduces greenhouse gas ("GHG") emissions which can be monetized, relieves grid congestion and peaks and improves overall energy efficiency.

This is a picture of a reciprocating engine based CHP (the most efficient option), shown within its noise attenuated, anti-vibration enclosure surrounding it. Source: Ener-G

Correct system sizing is critical to maximizing CHP system efficiency and ROI, since CHP systems are most efficient when there is a good match between electricity and heat produced by the unit, and the electrical and heating needs of the building. CHP systems are typically employed in larger commercial buildings or multi-residential facilities, where there is a significant heat demand. CHP installations that I have been involved with provide electricity and heat to hotels, apartment complexes, office buildings, seniors' residential homes, sports and recreation centres, greenhouses and other commercial building types. CHP systems are particularly well suited to provide heat and electricity to greenhouses, resulting in meaningful energy and financial savings.



Existing greenhouse infrastructure with natural gas boiler and liquid CO_2 (Modak, 2011)



Heat, electricity and CO_2 supply to greenhouse by cogeneration (Kramp and Hesener, 2011)

WHY CO_2 FOR GREENHOUSES FROM COGENERATION?

Photosynthesis

Sunlight
+
CO_2
+
Water

Glucose
+
O_2

- **CO_2 is an essential ingredient for the photosynthesis process of plants**
- **Ambient concentration of CO_2 is about 340 ppm by volume**
- **Concentration to the level of 1,000 ppm or higher increases photosynthesis proportionally**
- **Higher concentrations increase yields by 30%**

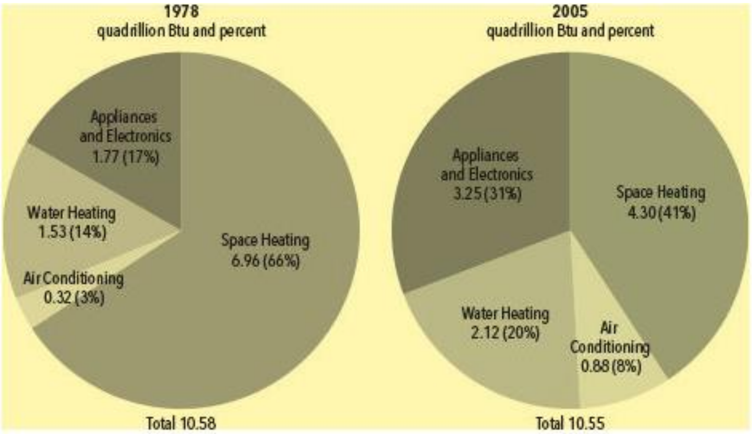
Quad-generation

CO_2 for Greenhouses

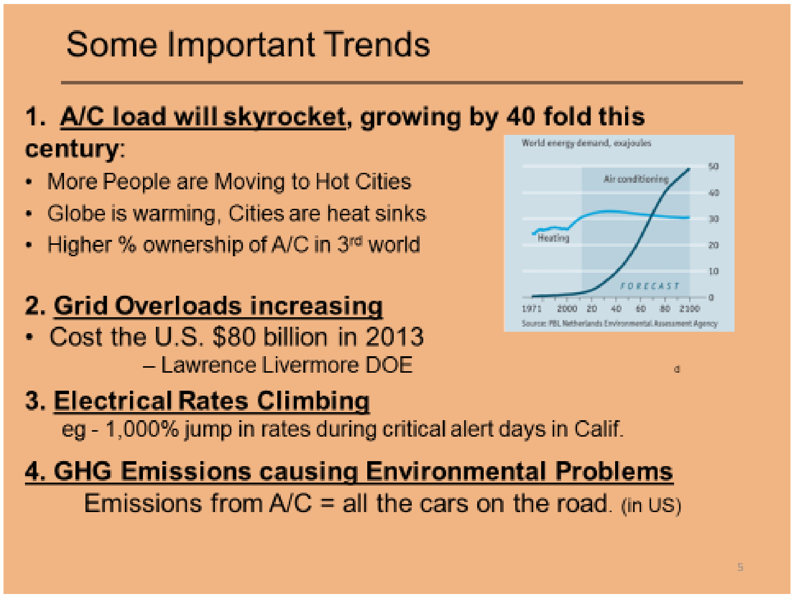
Carbon Dioxide is essential ingredient for the photosynthesis process of plants. Ambient concentration of CO_2 is about 340 ppm by volume which enables all plants grow well but by increasing the concentration to the level of 1,000 ppm or higher photosynthesis increases proportionally resulting in higher yields. CO_2 is therefore regarded as a nutrient, usually transport in pressurized vessels and supplied to the greenhouses.

Deriving Cooling From Heat - Trigeneration

Energy data analysis shows a couple of notable trends. First, although household occupants have shrunk since 1940— back then the average house held 3.7 people, against 2.5 in 2012— the size of new houses has bloated from 1,100 square feet then to 2,300 today. Each American has triple the room today that her predecessors had in 1940. Although Americans are using less energy for space heating than they were in 1978 as a percentage of expenditure, they are using much more for everything else: hot water, air conditioning, appliances and electronics. In spite of efficiency increases (or perhaps because of them), total energy consumption has not decreased since 1978. Source: US Energy Information Administration, http://www.eia.gov/consumption/residential/reports/2009/electronics.cfm. The other trend is that heating and cooling are a much smaller share of our energy use today, but— no surprise here— we're using twice as much electricity for home electronics and appliances. In 1978 we spent 69 percent of home energy use on heating and cooling and 17 percent on powering appliances. In 2009 those numbers were 48 percent and 34 percent, respectively. Because houses are better insulated today and furnaces more efficient, they use less of our total home energy budget than they did, but we've made up for this by doubling the proportion of juice drawn by our plug-in gear. We've gotten more efficient, but we own far more toys. This is living proof of Pareto's law, which says that increases in efficiency won't result in less consumption but in more use of these efficient devices. All we've done is juggle where we use energy, and the result is that total household energy use is about the same as it was in 1978.



What the below graphic highlights is, in a relatively short period, air conditioning / cooling went from 3% to 8% of household energy use. Several resulting trends present themselves:



Some Important Trends

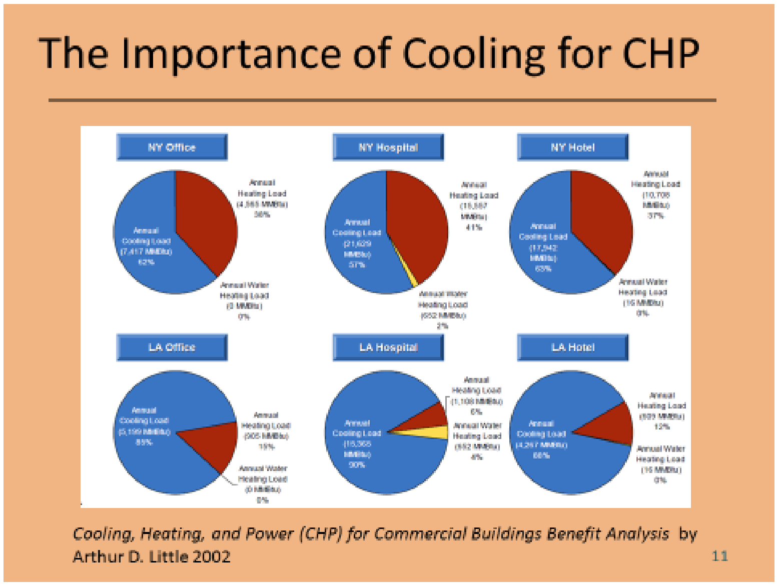
1. **A/C load will skyrocket, growing by 40 fold this century**:
- More People are Moving to Hot Citiees
- Globe is warming, Cities are heat sinks
- Higher % ownership of A/C in 3rd world

2. **Grid Overloads increasing**
- Cost the U.S. $80 billion in 2013
  – Lawrence Livermore DOE

3. **Electrical Rates Climbing**
   eg - 1,000% jump in rates during critical alert days in Calif.

4. **GHG Emissions causing Environmental Problems**
   Emissions from A/C = all the cars on the road. (in US)

5



The Importance of Cooling for CHP

Cooling, Heating, and Power (CHP) for Commercial Buildings Benefit Analysis by Arthur D. Little 2002

11

Today as we have congregated in cities, we find a very large desire for chilling in a warm climate such as Los Angeles but still a surprisingly large cooling demand even in the relatively cold climate of New York. Chilling is essential in many industrial processes such as throughout our food supply chain and in how we work and live (a significant number of hours).

A **chiller** is a machine that removes heat from a liquid via vapor-compression or absorption refrigeration cycle. This liquid can then be circulated through a heat exchanger to cool air or equipment as required. A typical chiller for air conditioning applications is rated between 15 and 1500 tons (180,000 to 18,000,000 BTU/h or 53 to 5,300 kW) in cooling capacity. One ton of cooling is the amount of heat absorbed by one ton of ice melting in one day, which is equivalent to 12,000 Btu per hour (h), or 3.516 kilowatts (thermal).

In a typical commercial building, chillers consume more electricity than any other single energy-consuming device (except for an occasional extremely large fan). Thus, inefficient chillers can waste significant amounts of electricity, and even modest improvements in efficiency may yield substantial energy savings and attractive paybacks as measured by **Coefficient of performance (COP):** The ratio of the cooling capacity output power to the total power input at any given set of rating conditions, expressed as watts of output per watts of input.

Electromechanical and centrifugal compressors, were adopted when the narrative of the time, deluded people to believe “electricity prices of the future would be such that electricity would be too cheap to meter”. No utility companies today are offering any such program, but shockingly not so dissimilar meme’s related to natural gas, fusion, solar, etc. still persist many decades later. With the prevailing assumption that electricity prices would remain inconsequential, then less efficient modes of chilling associated with electromechanical and centrifugal chilling became the vast market share winner, but by no means is it the most energy efficient means of chilling known to human kind over the past hundred years. Two types of chilling capable of leveraging low or high grade heat from various sources including from a cogeneration system are known. The first is absorption chilling and the second dates back to the days of Pullman rail cars and is known as ejection chilling. These two technologies are known as trigeneration. Trigeneration can continuously produce low temperature (cool water) of 7 to 15℃ by taking advantage of low temperature waste heat (low temperature heat generation), hot water from cogeneration. This contributes to drastic energy savings and CO_2 emission reduction.

When to use Trigeneration

1. If you are operating chillers for more than 4 months per year
2. Consider using trigeneration when your electricity costs are high, but your fuel costs are low. This differential usually needs to be pretty large, as we’ll show in our example at the end.
3. Consider using trigeneration when you have adequate low grade waste hot water available—especially during the cooling season. The key word here is “waste” heat. If you’re producing more heat than you would otherwise use just for the purpose of supplying the chiller, it’s not waste heat. You’re paying for the fuel to make it. Note that we have seen people fool themselves or be bamboozled by vendors because they did not understand this very key difference.
4. Consider using trigeneration if you have adequate capacity on your low pressure heating systems to produce excess heat during the cooling season. Make sure that items 2 or 3 also apply. This where a cogen system can make it all economical.

Advantages

1. The process can use either low grade hot water heat to drive the trigeneration process.
2. Absorption chillers have minimal moving parts. This means that they make less noise and have fewer vibrations than mechanical chillers.
3. Absorption chillers typically only use 2 – 9% of the electricity that is usually required for mechanical chillers. This means that facilities can avoid peak demand charges and high time-of-use electricity rates (if they are on that type of electric rate schedule).

Disadvantages

1. Absorption chillers have low efficiencies compared to mechanical chillers.
2. It can be difficult to cost effectively install new equipment, depending on the existing utility rates and estimated energy savings.
3. Most facility staff and local equipment servicers are not as familiar with the maintenance for absorption chillers as they are with mechanical chillers. We've heard more than one facility manager gripe about how they just "couldn't get the thing to run right" and eventually gave up and started running the old mechanical chillers again. You may need to rely on a maintenance contract with a chiller distributor to regularly maintain your equipment.

Moving Forward

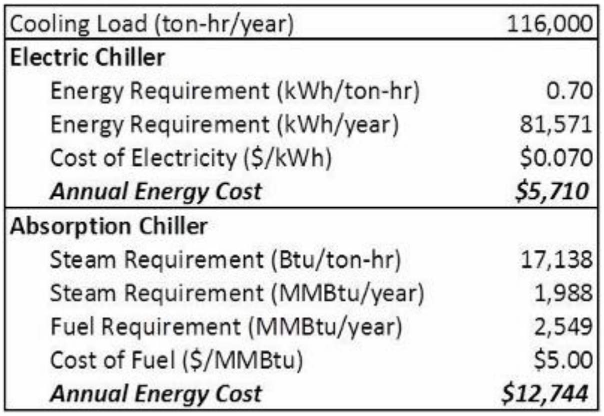
Unfortunately, it's not enough to check off the ground rules above when you're trying to decide whether an absorber is right for you. Fuel and electricity costs change over time, so it's critical to figure out just how much it's going to cost you to produce a ton of cooling with each type of chiller over a range of energy costs. Here's our theoretical choice between installing a new mechanical chiller or a new absorption chiller

Option 1: Install a 100 ton water-cooled centrifugal mechanical chiller. The unit's COP is approximately 5.0, meaning that it takes 0.70 kWh to produce one ton of cooling for one hour (or one ton-hour of cooling).

Option 2: Install a 100 ton single-effect absorption chiller. The unit's COP is approximately 0.7, meaning that it takes 17,140 Btu of steam or hot water to produce one ton-hour of cooling. Low-pressure steam in this scenario was supplied by a 78% efficient boiler plant. Trigeneration dramatically improves this scenario.

Option 3: The future with Propulsion Chilling or a Binary Fluid Injector (BFE)

Assuming a north location and a cooling load typical of an institutional campus, the site requires approximately 116,000 ton-hours of cooling a year from the new chiller. The site's incremental electricity cost is currently $0.07 per kWh (very low…most of North America today is over $0.11/kWh delivered), while its incremental natural gas cost is currently $5.00 per GJ. Multiplying the total ton-hours of cooling required by the energy input requirement of each chiller and then by the appropriate energy cost, you can estimate the energy input cost for each chiller.

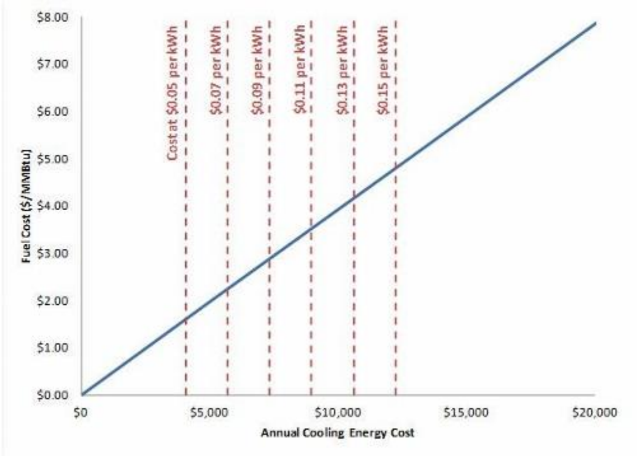


Cooling Load (ton-hr/year)	116,000
Electric Chiller	
Energy Requirement (kWh/ton-hr)	0.70
Energy Requirement (kWh/year)	81,571
Cost of Electricity ($/kWh)	$0.070
Annual Energy Cost	***$5,710***
Absorption Chiller	
Steam Requirement (Btu/ton-hr)	17,138
Steam Requirement (MMBtu/year)	1,988
Fuel Requirement (MMBtu/year)	2,549
Cost of Fuel ($/MMBtu)	$5.00
Annual Energy Cost	***$12,744***

At that fuel cost, the absorption unit is going to cost you over twice as much to run as the electric chiller. **This simple analysis doesn't take into account differences in maintenance or capital costs (which are higher for absorption chillers), so the true lifecycle cost disadvantage will be even worse.**

So when *would* it make sense to use an absorption chiller?

Using the same chiller load and assumptions used above, you can calculate the annual energy input cost for your absorption chiller at a range of fuel costs. (See the blue line in the chart below.) These can then be compared to what electricity rate would be required for the absorption chiller to cost the same or less to run than the electric unit on an energy input basis. (See the dotted red lines in the chart below.)

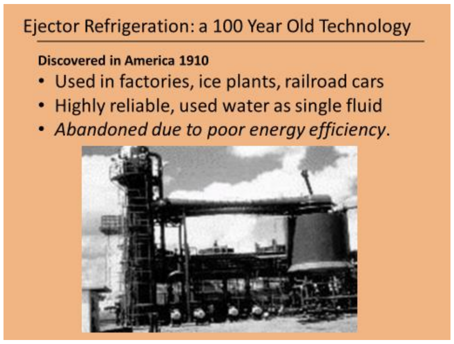


For example, if you're paying $0.15 per kWh for electricity, your fuel costs have to be less than $5.00 per MMBtu before you can save on chiller input energy costs by using an absorption chiller and far and away more than that with a BFE. If you're paying a more modest $0.11 per kWh, you can only save money if your fuel costs are $3.50 or less per MMBtu. Natural gas may be cheap these days, but it's probably overly optimistic to say you can obtain $3.50/MMBtu fuel for the whole lifetime of the chiller.

Now for the "waste heat" effect. Heat that would otherwise be discarded costs you no additional fuel. Examples of this would be if you have a cogeneration engine where all of the heat being recovered off the generator isn't being fully utilized, or if you have a manufacturing process that requires heat that is being vented to the atmosphere instead of being recaptured at the end of the process. If your facility's electricity cost is $0.11/kWh to operate an electric chiller and your absorption fuel energy cost is $0, in this scenario you would save almost $9,000 per year in chiller energy.

Bottom line: Just because you can produce hot water to fire an absorption chiller doesn't mean that you should! Your thermal energy needs to be very, very cheap before an absorption chiller can compete with an electric unit on an input energy cost basis. Before deciding to go with one type of chiller or the other, make sure you know what each type of chiller will cost you to purchase, maintain and operate at a range of fuel and electricity costs.

But absorption chilling isn't our only option nor our best option as we will discuss below. Interestingly the fax machine was invented very shortly after the telephone but saw very little market adoption for almost a century. Then along comes the smart phone and a convergence of technologies and the telephone that plugs in the wall, the fax machine, scanners and cameras all end up in one device…BFE technologies as we describe below is analogous to smart phones for HVAC technologies and overall energy efficiency.

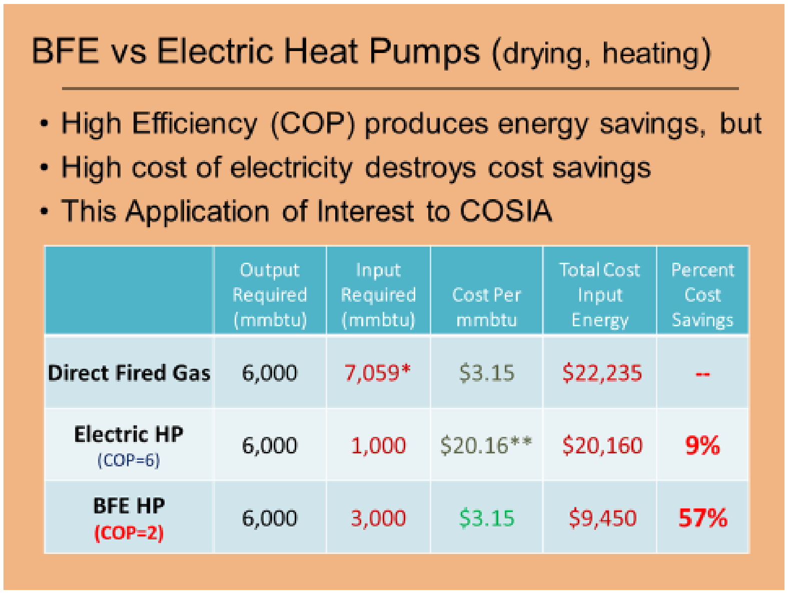


Ejector Refrigeration: a 100 Year Old Technology

Discovered in America 1910

- Used in factories, ice plants, railroad cars
- Highly reliable, used water as single fluid
- *Abandoned due to poor energy efficiency*.

Not unlike how the smart phone needed a number of digital technology layers to mature before they could converge into a single device, ejector refrigeration or Binary Fluid Ejection so too needed maturation in terms of technology development.

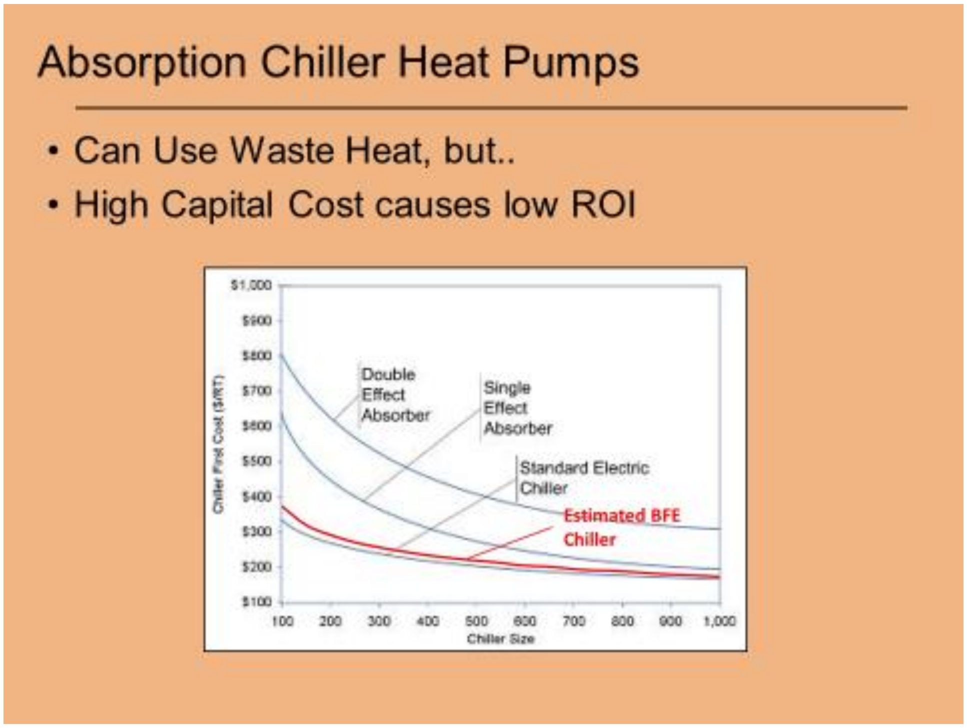


BFE vs Electric Heat Pumps (drying, heating)

- High Efficiency (COP) produces energy savings, but
- High cost of electricity destroys cost savings
- This Application of Interest to COSIA

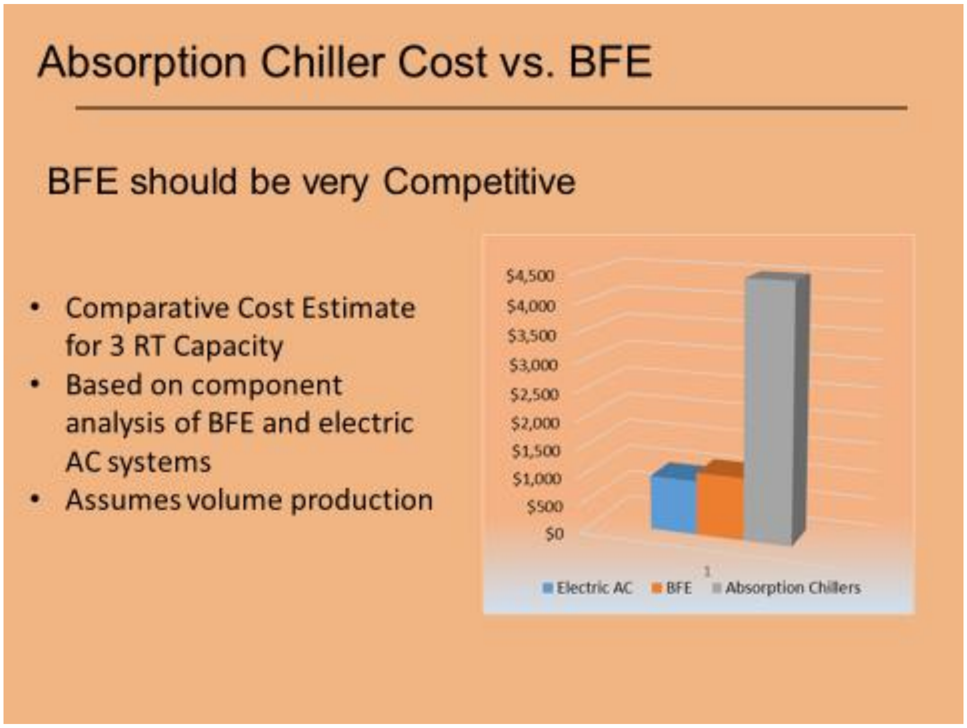
	Output Required (mmbtu)	Input Required (mmbtu)	Cost Per mmbtu	Total Cost Input Energy	Percent Cost Savings
Direct Fired Gas	6,000	7,059*	$3.15	$22,235	--
Electric HP (COP=6)	6,000	1,000	$20.16**	$20,160	**9%**
BFE HP **(COP=2)**	6,000	3,000	$3.15	$9,450	**57%**

The manufacturing process required for absorption chillers means that it can only compete with conventional chilling technologies with high percentage of hours of utilization whereas BFE technologies appear able to compete much more readiliy.



Absorption Chiller Heat Pumps

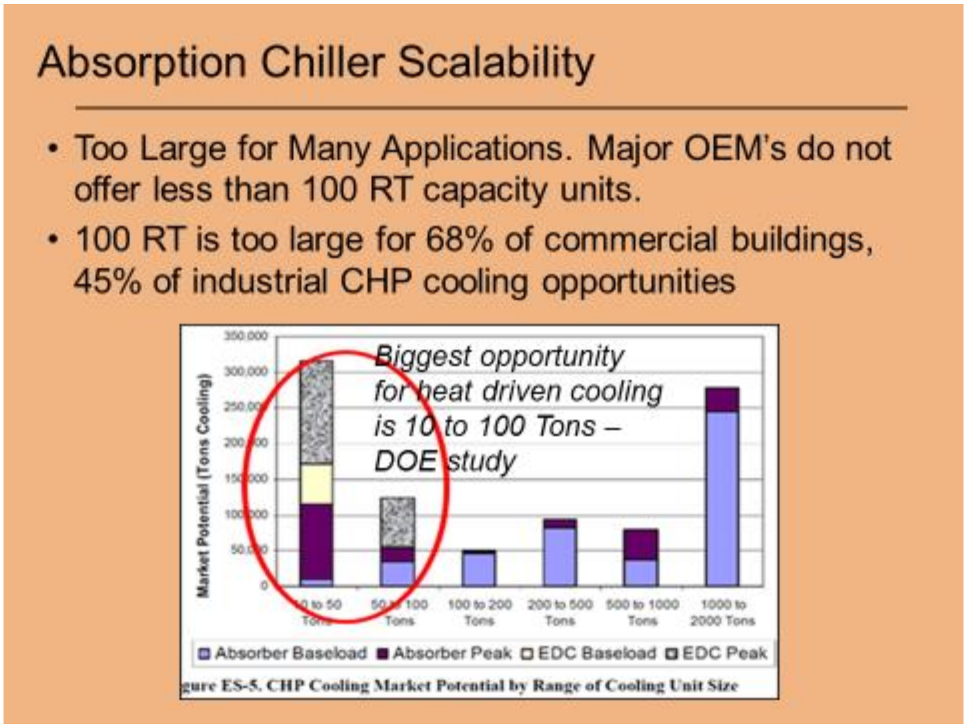
- Can Use Waste Heat, but..
- High Capital Cost causes low ROI



Absorption Chiller Cost vs. BFE

BFE should be very Competitive

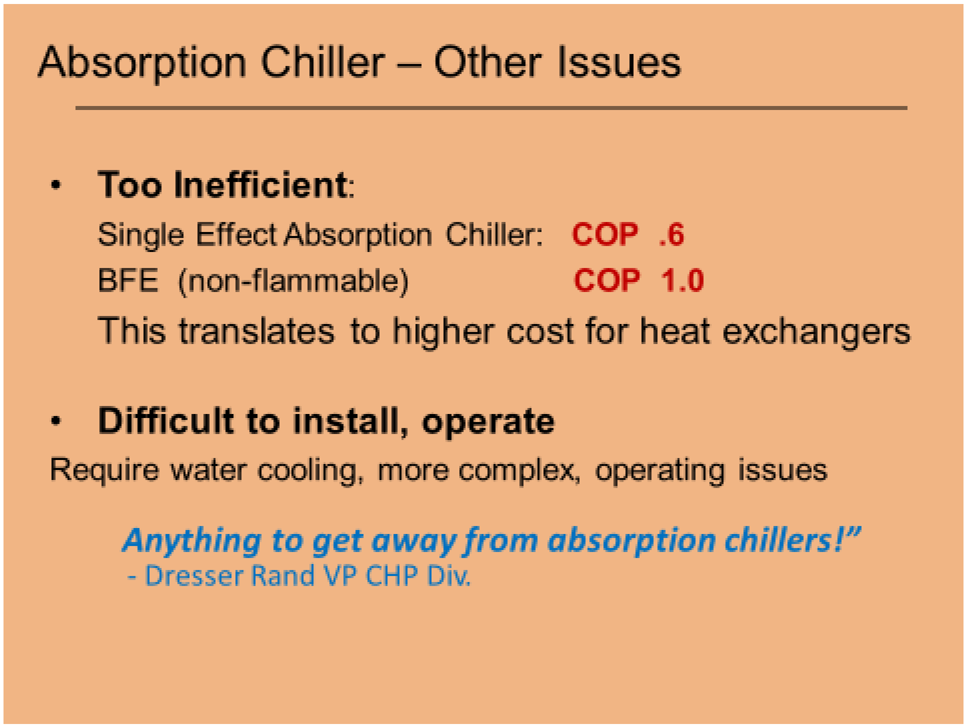
- Comparative Cost Estimate for 3 RT Capacity
- Based on component analysis of BFE and electric AC systems
- Assumes volume production



Absorption Chiller Scalability

- Too Large for Many Applications. Major OEM's do not offer less than 100 RT capacity units.
- 100 RT is too large for 68% of commercial buildings, 45% of industrial CHP cooling opportunities

gure ES-5. CHP Cooling Market Potential by Range of Cooling Unit Size



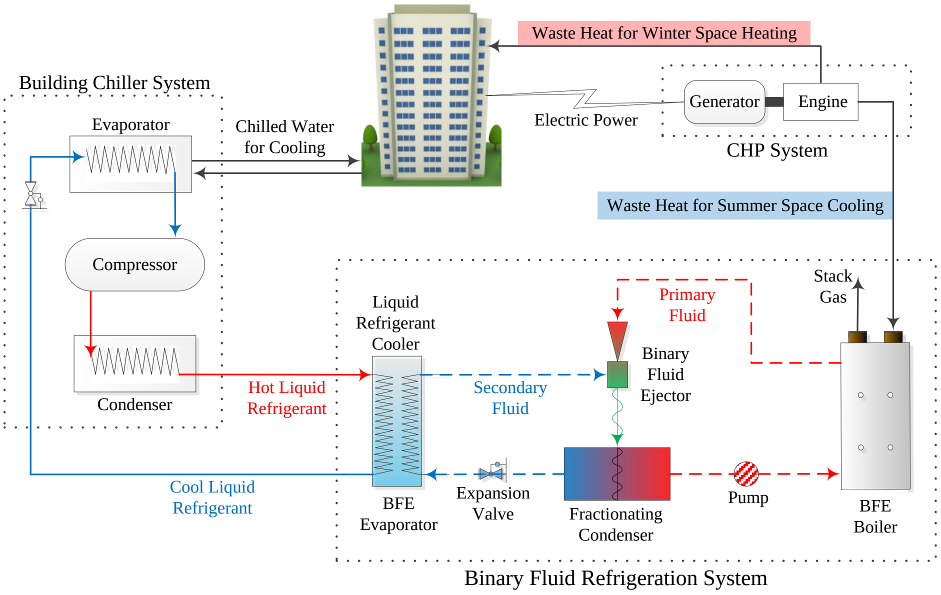
Absorption Chiller – Other Issues

- **Too Inefficient**:
  Single Effect Absorption Chiller: **COP .6**
  BFE (non-flammable) **COP 1.0**
  This translates to higher cost for heat exchangers

- **Difficult to install, operate**

Require water cooling, more complex, operating issues

Anything to get away from absorption chillers!”
- Dresser Rand VP CHP Div.



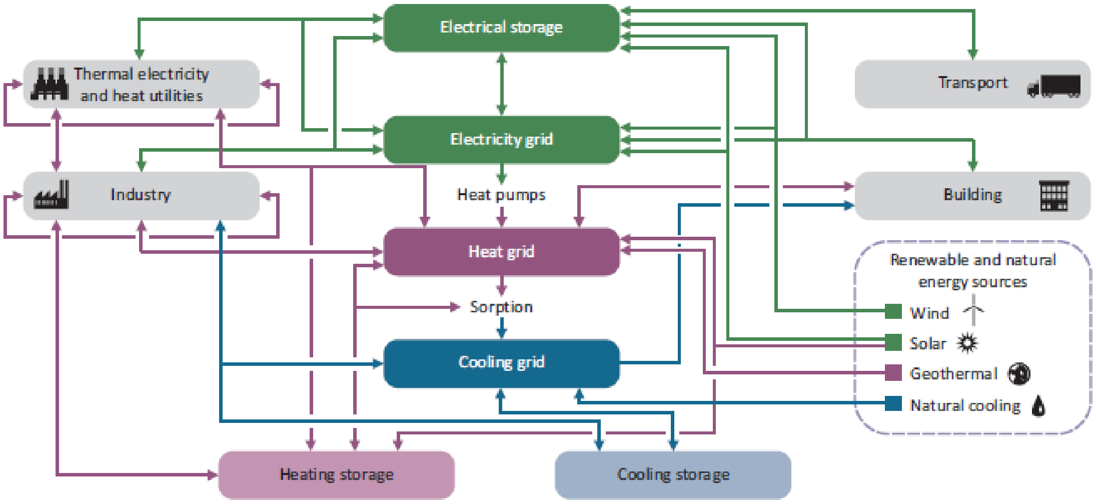
A BFE-LRC system integrated with a commercial building chiller and a CHP system.

Propulsion Chilling or Binary Fluid Ejector (BFE) Chiller

- A BFE is a thermally-driven fluidic compressor that replaces the electro-mechanical compressor in reverse-Rankine thermal cycles (refrigeration cycles).
- A BFE system essentially acts as a highly-efficient heat pump, and results in energy and economic savings.
- BFE units can be driven by many types of low-grade thermal energy, including: solar thermal, geothermal, waste heat, stack flue gas, engine exhaust, biogas, biomass or natural gas and other fossil fuels.

- BFE is a cross-cutting technology, applicable to a broad swath of applications in many economic sectors, including: air conditioning, space heating, water heating, refrigeration, industrial-scale desiccation, distillation and desalination, waste heat recovery and re-use, etc.

Figure 3 Interconnections of electricity and thermal energy in an integrated energy system



Key point • Electricity and thermal energy systems are complex and offer numerous opportunities for deep integration.

Creating Resiliency or Anti-Fragility With Cogeneration

https://www.yahoo.com/news/fridges-off-venezuela-power-rationing-hits-030240311.html

Fossil fuel energy enabled the industrial revolution. Peak fossil fuels does not mean that we will run out of fuels any time soon, it means that the cheap, easy to exploit resources are behind us and energy efficiency will gain in value rapidly. Such a massive change to what has seemed normal to us but in fact is but a 150 or so year old anomaly, means that the system will undergo radical change. Some aspects of the current system is already downright fragile and many others will experience fragility. The entire electric grid is one such system in early stages of the most severe change since its inception, due to the massive changes occurring across the entire energy industrial complex. A further layer of change on top of this for the electricity grid, is that climate disruption seems to be upon us, as the following two charts show. We highlight this because cogeneration has proven to be an excellent way to add resiliency to the mix.

Electricity line losses increase exponentially with flow so that each additional megawatt transmitted on a line results in an increasing loss rate. In particular, marginal losses as a function of power flow equals: Marginal Losses = 2 * Resistance * Flow/ Voltage2 or 2 * Average Losses. Therefore, we should observe that losses increase as more power is transmitted over longer distances and marginal losses are exactly twice average losses. Therefore, if the average losses at some point in time on the system is 5 percent and the quantity transmitted were increased slightly, 10 percent of the incremental flow would be lost. *Source: Dr. David Patton, Phd expert witness in transmission costs for NY PUD.*

220 kV towers for a 500 km line spaced 450 m apart uses in the order of 55 million lbs. of steel and 4.4 million lbs. of aluminum alloy; a single solar panel uses about 15 lbs. of steel. Both cost a lot but trade-offs must be carefully considered. Transmission, distribution and riders being 50% of per kWh charges for small commercial users, with the City of Calgary rider / tax being 11% alone. Rural customers pay considerably more. Such fees have increased between 34-82% in the last five years.

Reliable as the Canadian grid is currently, power outages cost businesses a great deal fast. According to Price Waterhouse research, after a power outage disrupts IT systems:

- 33+% of companies take more than a day to recover
- 10% of companies take more than a week
- It can take up to 48 hours to reconfigure a network
- It can take days or weeks to re-enter lost data

Financially, power outages can mean substantial losses for the company affected. According to the US Department of Energy, when a power failure disrupts IT systems:

- 33% of companies lose $20,000 – 500,000
- 20% lose $500,000 to 2 million
- 15% lose more than $2 million
- **Cogeneration shows worth in withstanding Sandy**
  More news is emerging of the part cogeneration technology played in keeping the power on in the US during Hurricane Sandy. **View Now**

Further Resilience With A Fuel Flexibility Future

If the prediction had been that growth would come at the expense of prosperity, then the prediction is holding up rather well. Where we lack prosperity we can anticipate discomfort and disruption. Equilibrium can only be regained if we have reasonably balanced energy supply and demand. As we have discussed, we can prolong things with fossil fuel energy conservation and trigeneration contributes nicely to that. Additionally, renewables such as solar and wind are and will continue to contribute to this intelligent response; but we remain with a significant short fall if we try to solely rely on these, one that can perhaps be partially made up with resiliency built up with fuel flexibility due to the ability to burn bio-gas or methane's as well as bio-diesel. I do not support using bio-fuels that causes a food versus fuel debate in a solution mix but multi-flex trigeneration systems fueled by a mix of biogas, biodiesel and fossil fuels as supply allows, is a very interesting and impactful part of the intelligent response / solution mix. As I will identify below, bio-gas can contribute affordably now if we adopt appropriate techniques to produce it, but 'contribute' is the operative word. Like solar and wind, it is only part of the solution mix but cannot contribute enough to solve all that we want/need. Biodiesel on the other hand, as I will show below, has potential to solve all we want and need, but at what price point remains an open question. Currently all sources of biodiesel struggle to be produced at price parity to petrodiesel. Currently diesel or natural gas fuel consumption in a cogeneration system is as follows:

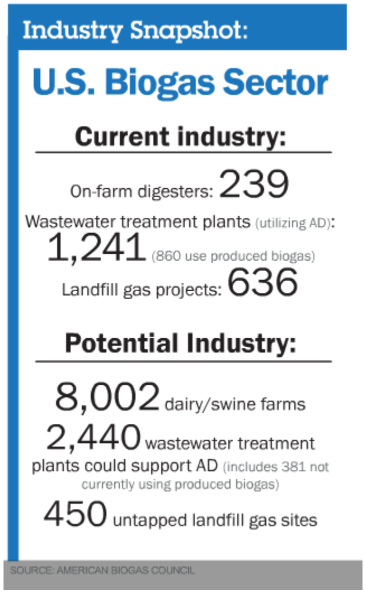
	Gallons per hour	Litres per hour	Diesel $/L as at Dec 2015	Fuel cost per hour	Natural gas consumption (GJ'S)	Nat gas would need to cost X/GJ to compare to diesel cost
150kW	10.9	41.26	0.779	$32.14	1.25	$25.71
250kW	18	68.14		$53.08	2.7	$19.65
400kW	28.6	108.26		$84.33	4.113	$20.50

What this indicates is that one would not purchase a solely bio-diesel cogen system until such time as the price of natural gas is consistently over $20/GJ. That said, another option exists and that is the ability to operate dual fuel or multi-flex fuel systems. We can operate a diesel compression system with as little as 15-50% diesel and aspirate natural gas/biogas. We start to get the best of all worlds with such a system including:

- Diesel engines come at less capital cost than natural gas engines, currently
- Higher compression and therefore electricity efficiency which maximizes savings is had from diesel engines.
- Diesel systems can take full electricity loads within 8 seconds
- We can alternate based on price or availability between diesel or up to 85% natural gas.

Methane production

Excerpts from Methane Production Guide - how to make biogas. (Richard Jemmett)



Industry Snapshot:

U.S. Biogas Sector

Current industry:

On-farm digesters: 239

Wastewater treatment plants (utilizing AD): 1,241 (860 use produced biogas)

Landfill gas projects: 636

Potential Industry:

8,002 dairy/swine farms

2,440 wastewater treatment plants could support AD (includes 381 not currently using produced biogas)

450 untapped landfill gas sites

SOURCE: AMERICAN BIOGAS COUNCIL

There is potential to provide renewable energy with an estimated 8,000 U.S. dairy, feedlots and swine operations that could support biogas recovery systems. Biogas recovery systems at these facilities have the potential to collectively generate more than 13 million megawatt-hours (MWh) per year of the 1.114 billion MWh's used annually. In addition, biogas recovery systems are also feasible at poultry operations. The total number of systems operating has grown steadily for more than a decade, with an average of 16 new digesters coming on line each year in the US.

2011 Trends - Almost half of the new projects that became operational in 2011 were complete mix designs, with mixed plug flow designs composing another 40 percent.

Depending on the digestion process, the methane content of biogas is generally between 55%-80%. The remaining composition is primarily carbon dioxide, with trace quantities (0-15,000 ppm) of corrosive hydrogen sulphide and water. The average expected energy content of pure methane is 33.4-39.8MJ/m3 (896-1069BTU/ft3); natural gas has an energy content about 10% higher because of added gas liquids like butane.

Anecdotal evidence indicates that biogas was used for heating bath water in Assyria during the10th century BC and in Persia during the 16th century. Jan Baptita Van Helmont first determined in 17th century that flammable gases could evolve from decaying organic matter. Count Alessandro Volta concluded in 1776 that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced. In 1808, Sir Humphry Davy determined that methane was present in the gases produced during the anaerobic digestion of cattle manure. The first digestion plant was built at a leper colony in Bombay, India in 1859. Anaerobic digestion reached England in 1895 when biogas was recovered from a 'carefully designed' sewage treatment facility and used to fuel street lamps in Exeter. The development of microbiology as a science led to research by Buswell and others in the 1930s to identify anaerobic bacteria and the conditions that promote methane production.

Gas made with a digester is commonly called biogas. Advantages: •Can make use of organic wastes and a fertilizer is produced at the end of the process. •Is a clean, easily controlled source of renewable energy. •Reduces pathogen (disease agent) levels in the waste. •Equipment can be simple to build and operate. •Low maintenance requirements. •Can be efficiently used to run cooking, heating, gas lighting and gas powered engines. Unlike solar PV and wind turbines, biogas is a good form of renewable energy for heating.

The optimum temperature which promotes activity of the micro-organisms and consequently produce more methane gas is between 30°C (85°F) and 35°C (95°F). In colder climates this is difficult to maintain but worthwhile trying to achieve. Below 60°F little gas is produced. Nexus has solutions to build cost effective digestors – which need limited heating even in cold climates.

Warm climates will commonly use lagoon based systems as they often cost about $1M to construct and will serve multiple revenue generating purposes, while stainless steel and boiler based systems cost on average over $1.6M to construct.

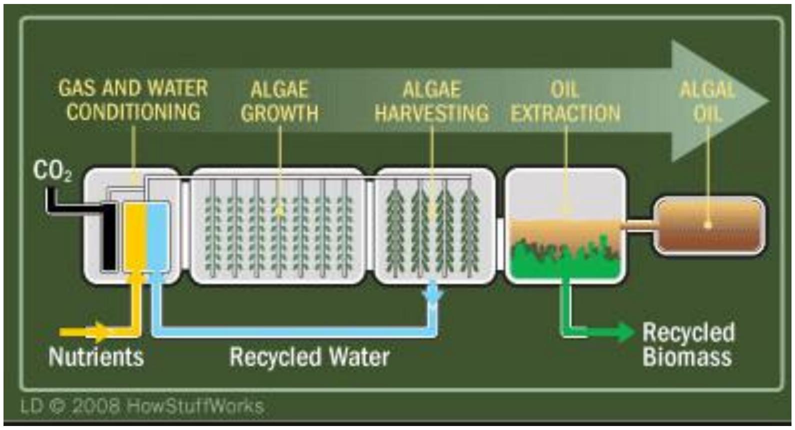
Covered Lagoon Digesters are used to treat and produce biogas from liquid manure with less than 3 percent solids. Generally, large lagoon volumes are required, preferably with depths greater than 12 feet. The typical volume of the required lagoon can be roughly estimated by multiplying the daily manure flush volume by 40 to 60 days. Covered lagoons for energy recovery are compatible with flush manure systems in warm climates. Covered lagoons may be used in cold climates for seasonal biogas recovery and odor control (gas flaring) unless they are housed in a Sprung greenhouse then there seems to be an option to economically operate year round. There are two types of covers, bank-to-bank and modular. A bank-to-bank cover is used in moderate to heavy rainfall regions. A modular cover is used for arid regions.

Given that an acre (43,560 sq. ft.) of basic greenhouse structure can be constructed for about $50/sq. ft. and that when passive solar techniques are well deployed we need to only artificially heat it about 30% of a year to keep it over 60°F, then we wonder if by combining passive solar greenhouses with lagoon based digestors we might be able to undertake small scale systems for say $1M as opposed to the average of $2.6M to great positive effect.

Why bio-diesel solves more:

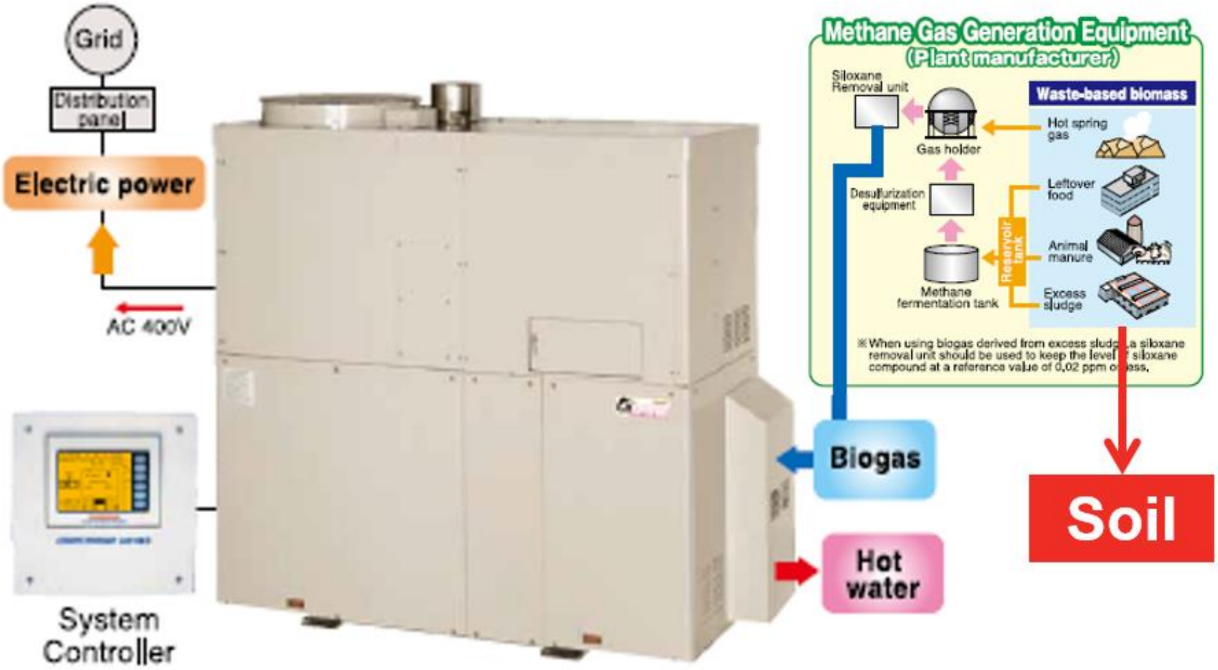
- 3:1 Energy In / Energy Out ratio similar to oil production today
- Leverages much of today's existing infrastructure
- Production is proven and available today with canola, camelina, mustard, soy, hemp, stink weed, algae, etc.
- Can avoid the fuel versus food issues
- Algae biodiesel seems to offer the greatest promise and albeit significant R&D dollars have gone into commercializing this – it certainly isn't ready for prime time yet.

Algae biodiesel has been recognized as the clear winner if we can solve the drying issues associated with it. The BFE and perhaps HEICO has a role to play here as well. Of course we could write a book unto itself on this subject matter, but we will leave that for another time. Research indicates that enough biodiesel can be produced from 7 million square acres (size of Hawaii) of algae biodiesel in salt water to produce enough biodiesel for all US transportation.



https://en.wikipedia.org/wiki/List_of_algal_fuel_producers

Biomass to energy / Waste to soil



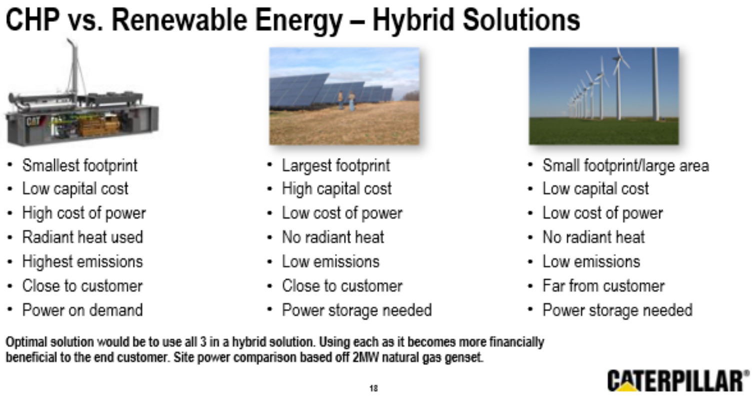
As this image shows growing algae, is going into greenhouses.

Multi-flex fuel

Readily available technologies enable a diesel engine to become a dual fuel engine capable of burning petrodiesel, biodiesel, natural gas and even biogas. Depending on a couple of variables this system will require at least 15% diesel, which with the dual fuel kit added, will enable the diesel in a diesel compression engine to serve essentially as the spark plug which will allow either natural gas or biogas to be aspirated in and burnt in the engine. Unfortunately, with diesel currently being about a 3 to 1 cost of natural gas, even with the higher electricity efficiency and lower capital cost of a diesel engine, the overall economics on a cogeneration system are hindered overall. The price of petrodiesel, natural gas, biogas and biodiesel prices have great propensity to fluctuate and we suspect over time…by a great deal. Today as an agricultural operator, I might have a lot of biogas available due to it being a high waste time but tomorrow I might have much less biogas, and not enough biodiesel so I would like my fuel mix to be able to go with the flow. Today, for all engine manufacturers, save one (that we know of), we would need a specialised power generation mechanic to tune our system to an exacting profile of the energy mix available, and we can't afford this engine mechanic to undertake this tuning very often in a year or own several systems. The one exception has developed an engine that monitors the fuel mix, and tunes itself to exacting specifications in real time as often as changes in the fuel mix requires.

Solar, Wind and Cogen Working Together

The knock on wind and solar, unrelentingly is their intermittent nature which cannot be denied. The sun is not available at night and the wind sometimes isn't blowing or in fact is too strong and turbines must be braked. Therefore power purchase agreements (PPA's) are often discounted to account for this intermittency. Some analysis has been completed over the years, to show that in some cases co-locating cogeneration with wind facilities or solar farms enables such developers to have some degree of guaranteed supply and therefore garnering less discounted PPA's. When such a co-location is not near a use for the thermal output of the cogen, then an organic rankin cycle system can be added to the mix, thereby adding about 10% electrical efficiency to the mix. It is but one more example of how energy efficiency is within our grasp and resilient micro-grids will add to the overall resiliency of our overall energy systems.



CHP vs. Renewable Energy – Hybrid Solutions

• Smallest footprint	• Largest footprint	• Small footprint/large area
• Low capital cost	• High capital cost	• Low capital cost
• High cost of power	• Low cost of power	• Low cost of power
• Radiant heat used	• No radiant heat	• No radiant heat
• Highest emissions	• Low emissions	• Low emissions
• Close to customer	• Close to customer	• Far from customer
• Power on demand	• Power storage needed	• Power storage needed

Optimal solution would be to use all 3 in a hybrid solution. Using each as it becomes more financially beneficial to the end customer. Site power comparison based off 2MW natural gas genset.

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