Alternative Energy Systems for Homes & Building Clusters, Moving to Net Zero

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Renewables & Integrated Energy Systems

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Learning Objectives (1)

- Understand the distinction and opportunities with combined, integrated and hybrid energy systems
- Appreciate range of advanced hybrid energy systems that can effectively & efficiently provide heat, ventilation, and even electricity, while integrating renewables and low-to-zero C-emitting fuels
- Understand the drawbacks of certain energy sources, technologies and directions

Learning Objectives (2)

- **Appreciate how energy storage and renewably-derived fuels can allow effective utilization of intermittent or seasonally-variable renewable energy (solar, wind), when coupled with hybrid technologies**
- **Be better able to specify energy systems to move new and existing homes and building clusters toward net-zero**

?

?

What are you looking for

?

? ?

What do I mean by “Net Zero”

Net Zero

- **Overall production of Greenhouse Gases (GHGs) and/or utilization of fossil fuels and/or energy is minimized and approaches zero**

- **It may be a single house/building, or a group of houses/buildings/community, or how the buildings + occupants actually can work to balance GHGs within the larger energy system**

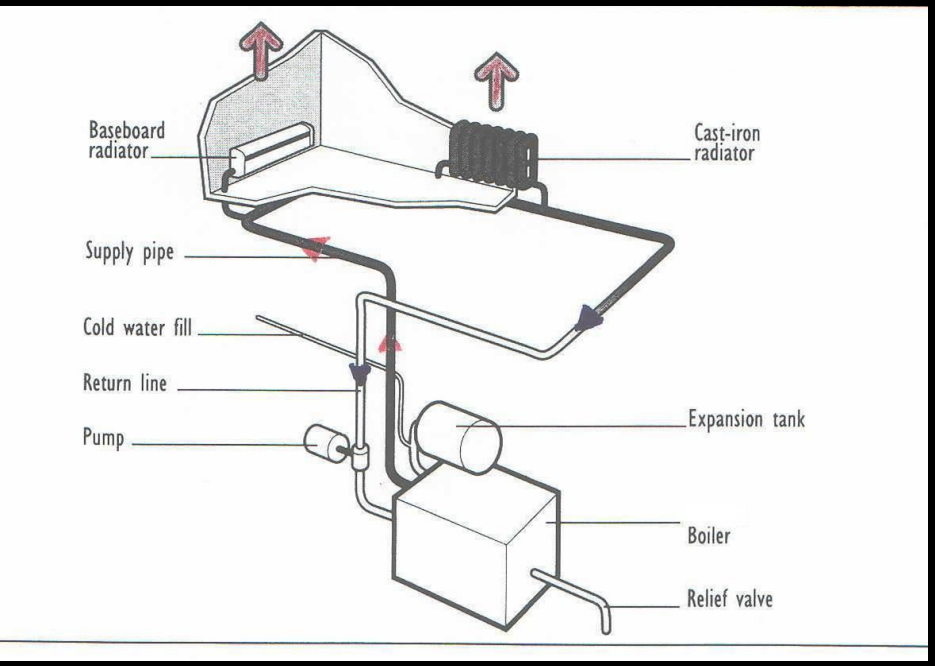
Definitions of Systems

Conventional Energy System

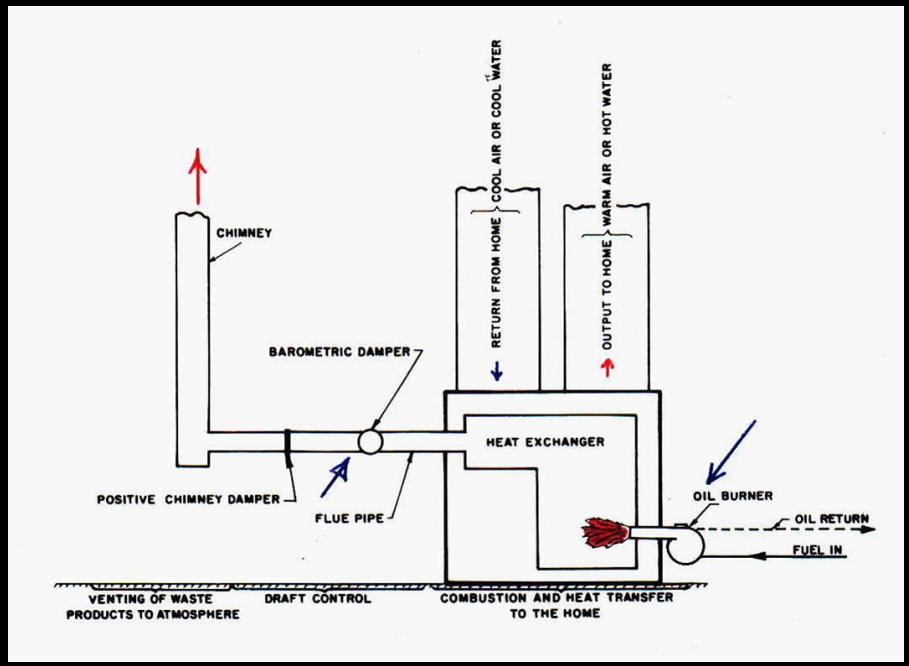
One Energy Source (oil, gas, wood,…)

One Energy Use (space heating, wtr htg,…)

Central Heating Systems



Hydronic



Warm Air

Space Heaters

Hybrid System

Two or more energy sources

Combined System

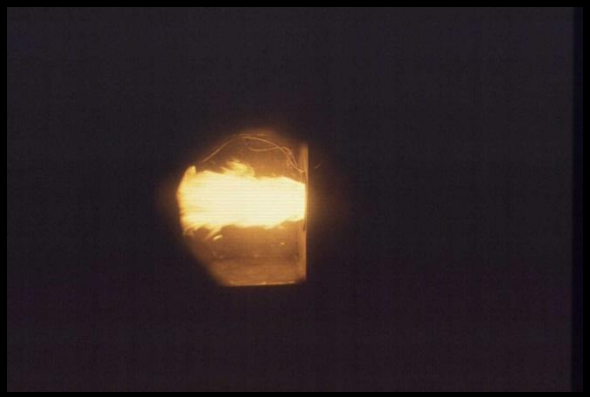
- Supplies 2 energy use functions, usually space heating and tap water heating (DHW)

Integrated System

Carries out 3 or more energy use functions, such as space heating, domestic hot water, heat recovery ventilation, electricity generation, space cooling, …

Can we use oil as we move towards net zero ?

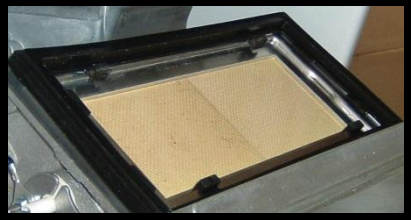
Oil



With oil burners having a lower limit between 50k Btu and 70k Btu, the firing rate is way too high for energy demands, unless something can be done with the heat

Oil towards Net Zero

A potential application would be a sophisticated combination system with a large amount of efficient energy storage, or the coupling of multiple dwellings to one combination source



Gas and Net Zero

With new gas burner technology allowing high turndown to very low firing rate, coupled with condensing system, gas combination condensing systems may be an effective means to move towards very low energy applications

These now pave the way for integrated and hybrid technologies, such as . . . .

Gas Integrated System (eKoComfort)

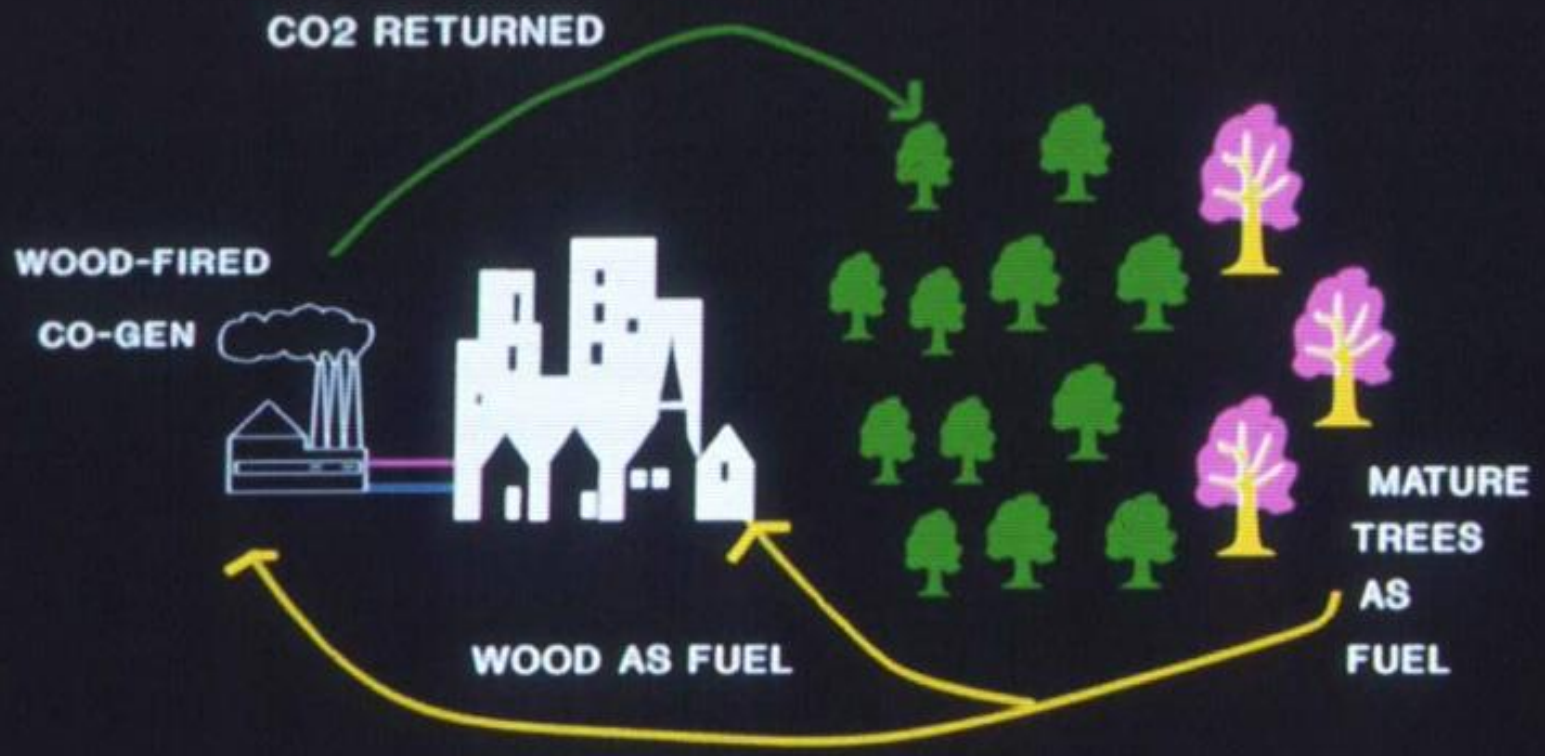
Space Heating, Water Heating, Heat Recovery Ventilation

- Condensing over 90% in all applications
- Hi-modulating Burner 10:1
- Efficient electrics (ECMs)
- Air flow, heat, water
- Can provide both forced air and radiant heating
- Enables optimization of total system + other hybrid energy sources

Renewable Energy

BIOMASS

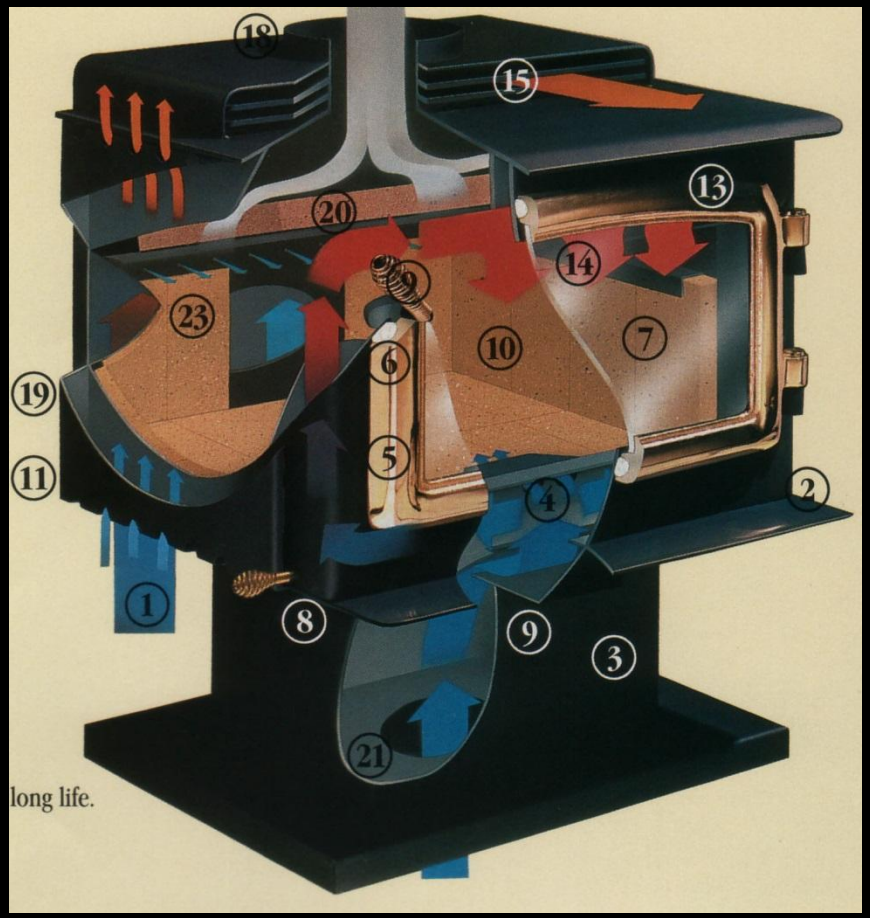
RECYCLING CARBON (Closed Cycle)



USE OF MATURE TREES AS FUEL FOR CLEAN, EFFICIENT PROCESS HEAT, COGENERATION, OR SPACE HEATING, COUPLED WITH GOOD FOREST MANAGEMENT, RESULTS IN NO NET CO2 TO ATMOSPHERE

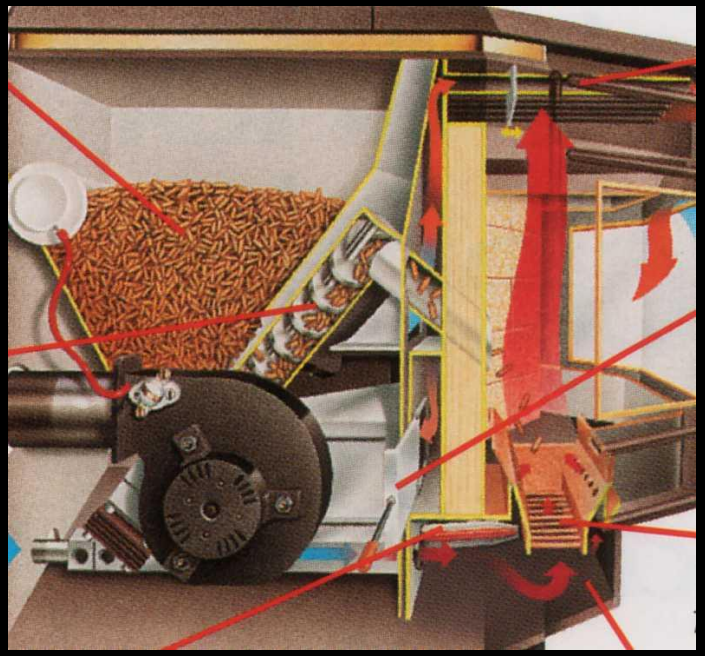
Space Heater
Woodstove

Characteristics of Advanced Combustion Woodstove Moving towards Net Zero

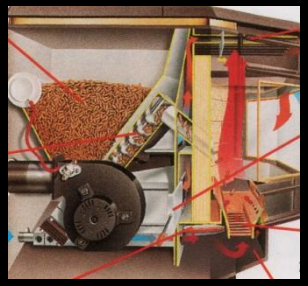


- Effective infrared heating source
- Ceramic glass door transparent to R radiation
- EPA 1990 < 4.0 g/h
- Preheated prim & sec air
- Insulated comb. chamber & baffle
- Air wash for door
- Air shield on side and back
- Extremely attractive, chaotic fire for “pleasure”
- SMALL !
- No catalyst

Pellet Stoves



Characteristics of Good Pellet Stove



- Tested to EPA to ensure
  - low emissions
  - high efficiency due to low excess air (up to 80%)
- Wide firing range (often 5:1), most with low output & good air control over range
- Air wash for fire viewing
- Small diameter flue (3-4”)
- Some can burn other biomass (corn, …) (Hi ash)

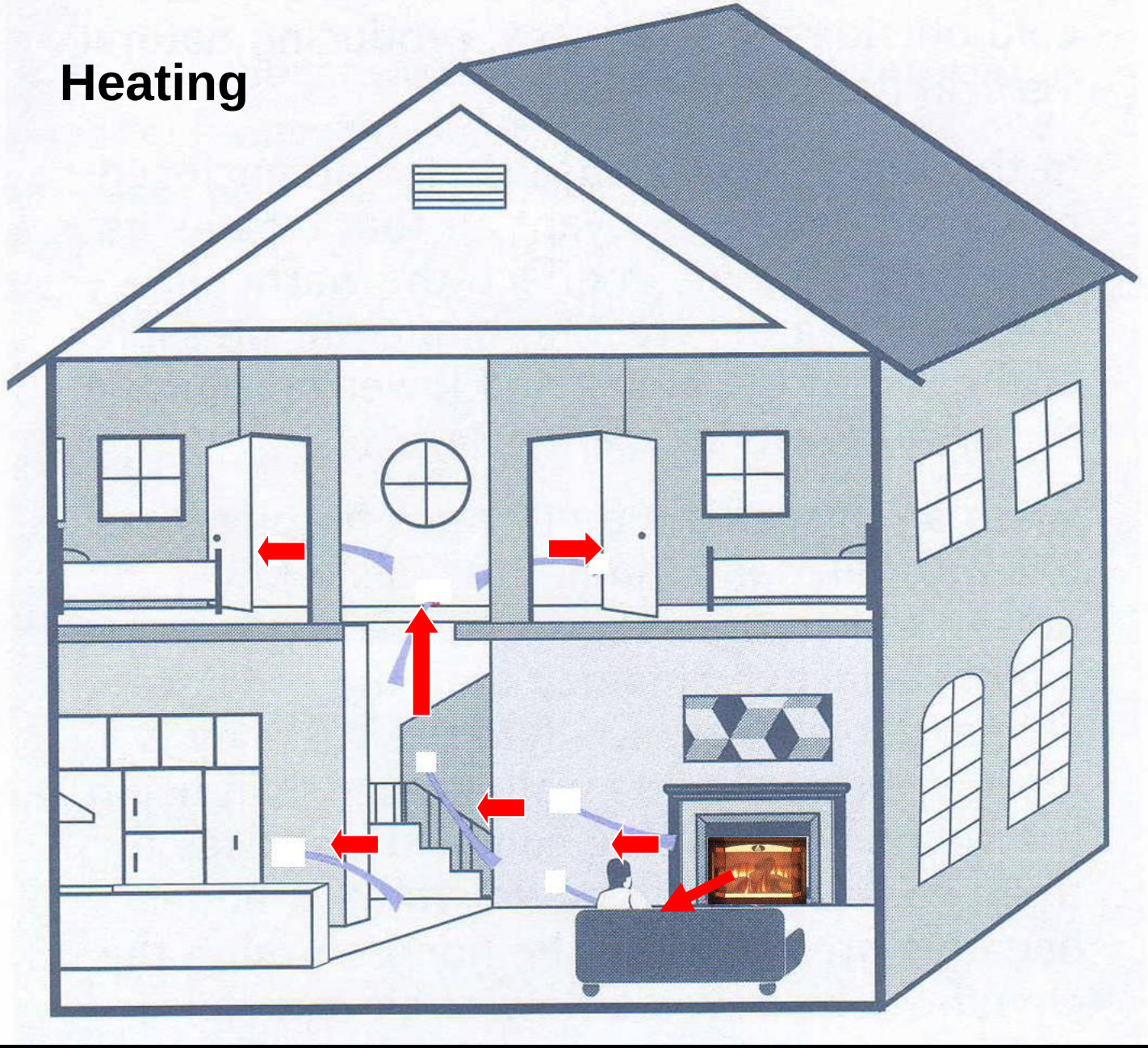
Running a Natural Draft Wood-fired Appliance in a Tight Near Net Zero House

- Choose a low output appliance (Small !)
- Have an inside chimney with proper sizing
- Use unvented double-walled pipe from appliance to chimney
- Have direct source of outside air to appliance, from windward side of house
- On refueling, open air control wide, crack open window on windward side of house, before loading

Locate these radiant space heaters in a major living area, where they can “see” a significant portion of the rest of the house


LEONARDO

Heating

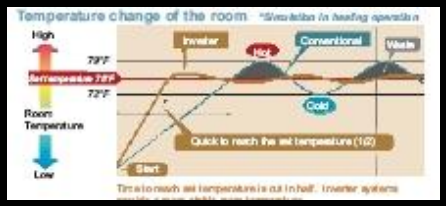


Mini-Split Heat Pumps

Space Heating (& Cooling) in a Near-Net –Zero House with a super-efficient Mini-Split Heat Pump

Mini-Split Advanced Technology

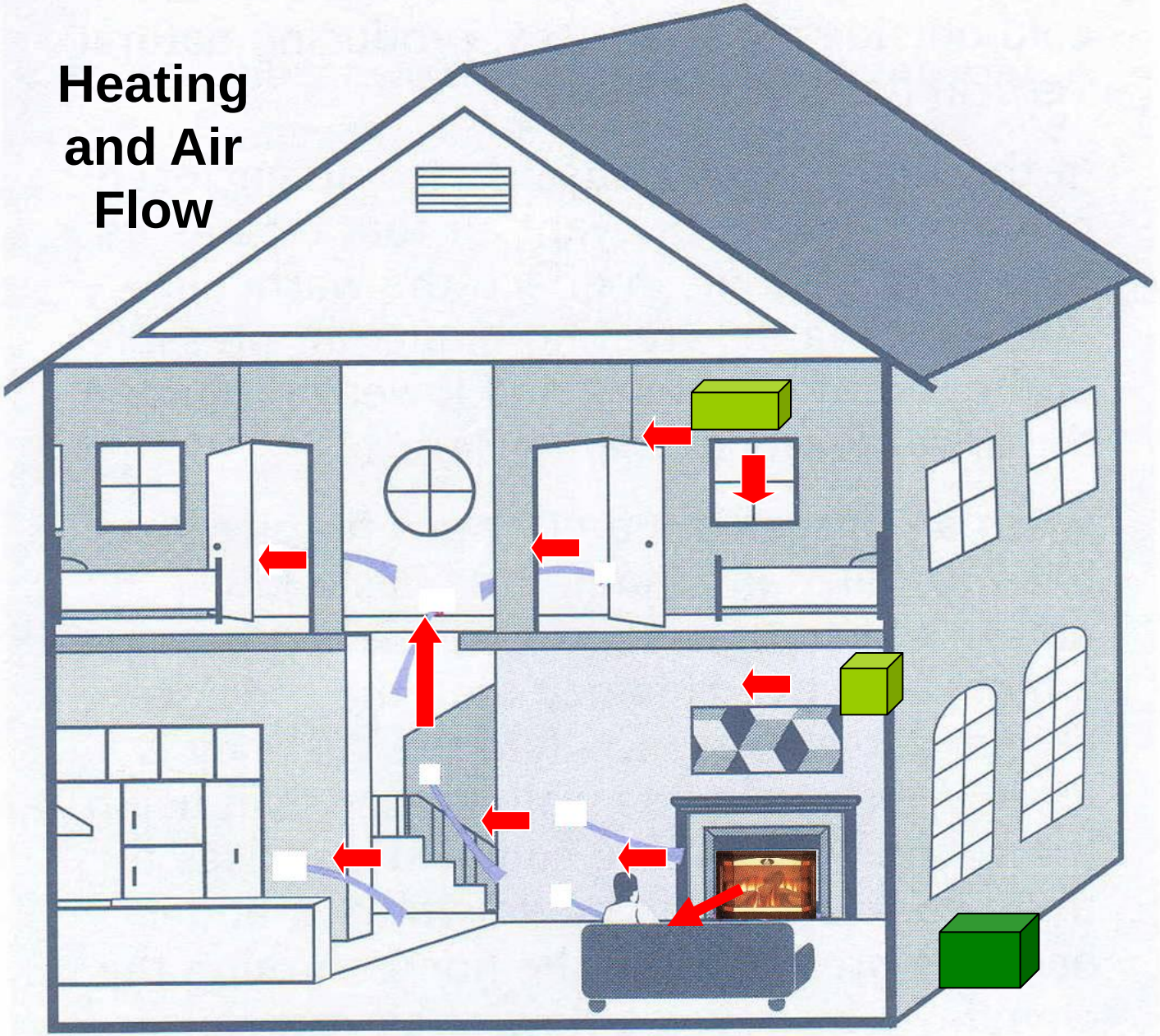
- **Inverter technology to control/vary compressor speed to load**



- **Scroll compressor**
- **Good turndown (5:1), maintaining high effic**
- **Efficient DC motors**
- **Highly-variable fan speeds and directions**
- **Very high SEER >20; good COP at cold temp.**

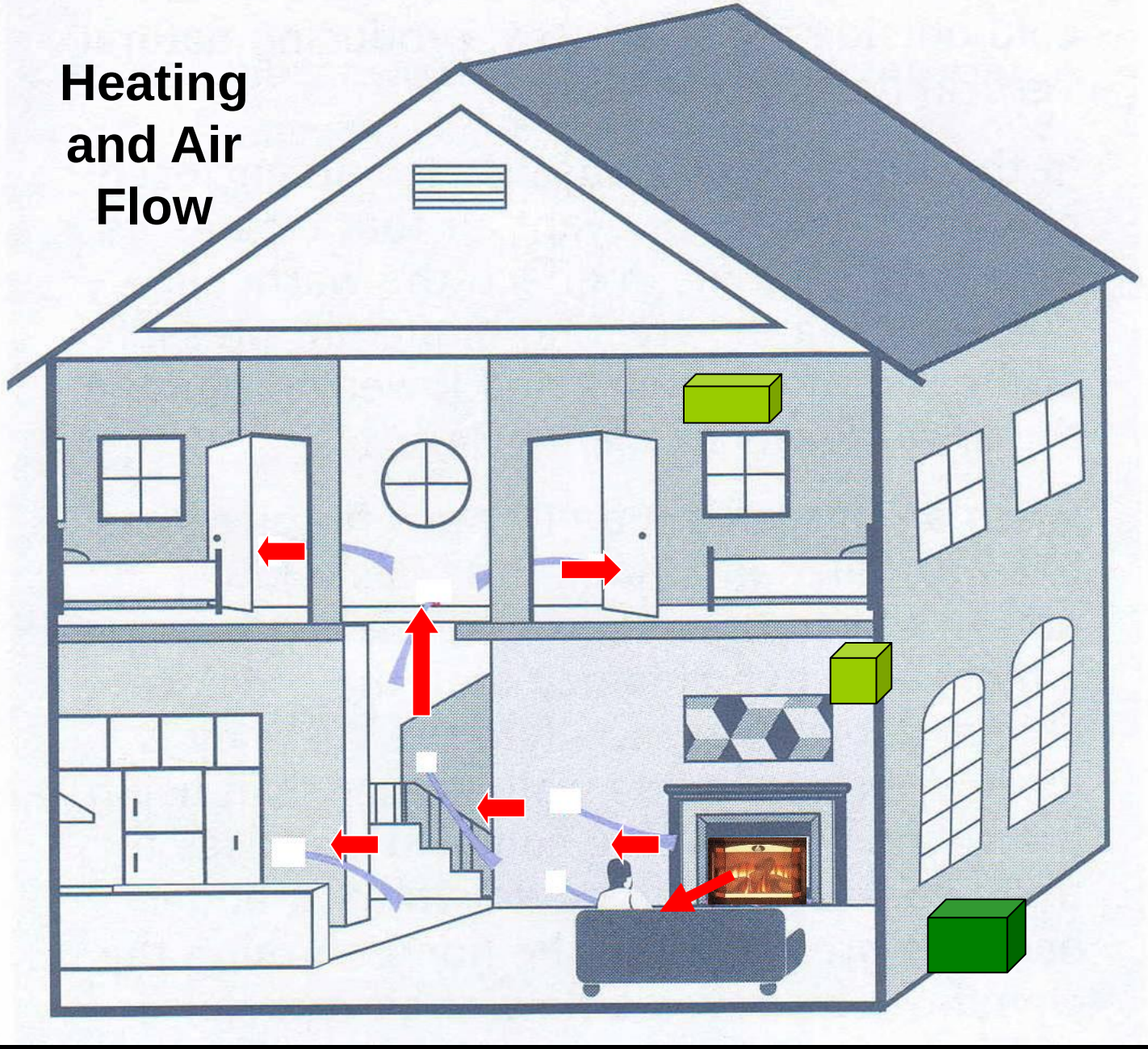
Using an
advanced combustion woodstove
and a
mini-split heat pump
to move your dwelling
towards net zero

Heating and Air Flow



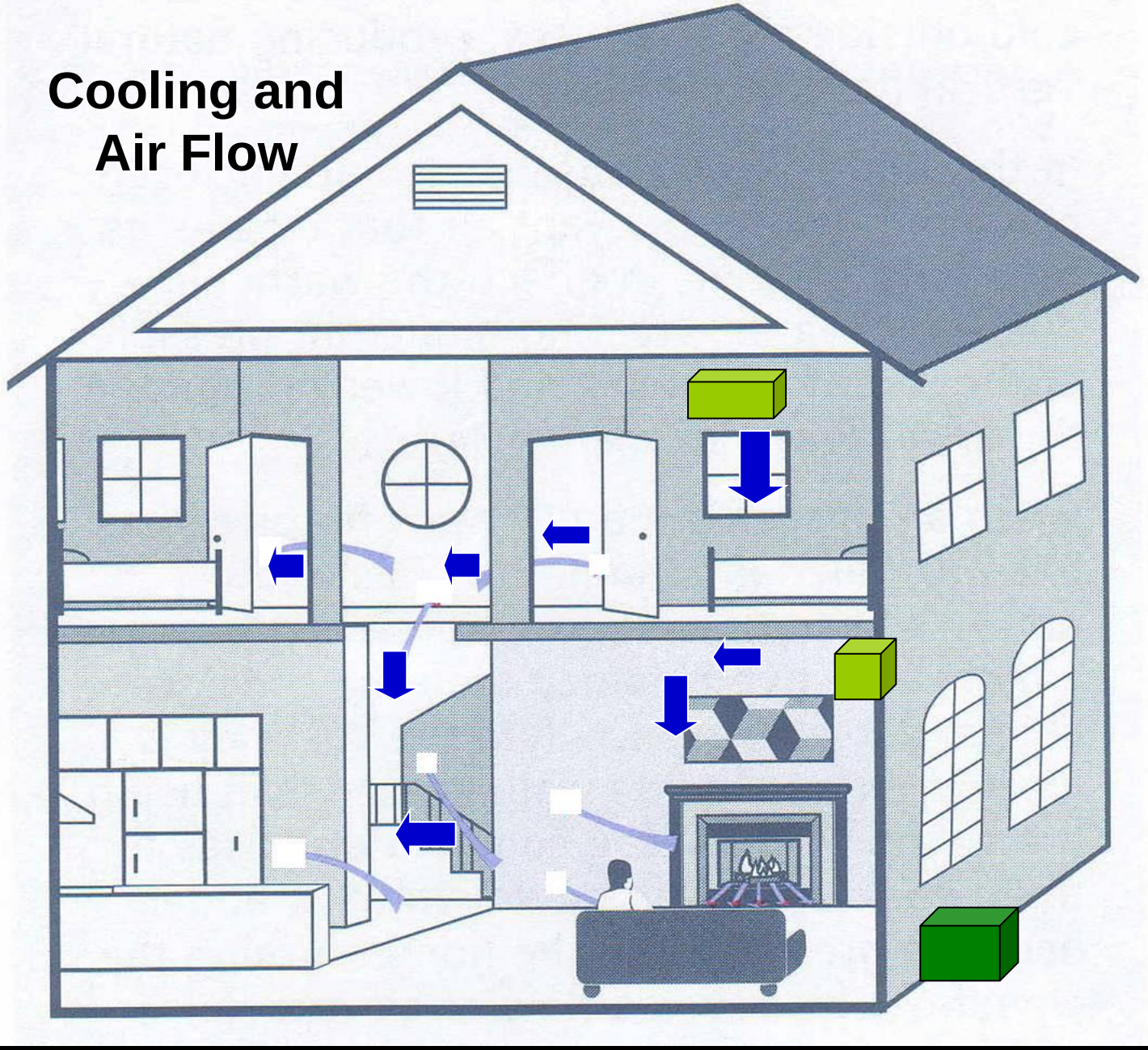
The Mini-Split can also help move the heat from the wood stove around the house, in an “unobtrusive” fashion, using its efficient fan system

Heating and Air Flow

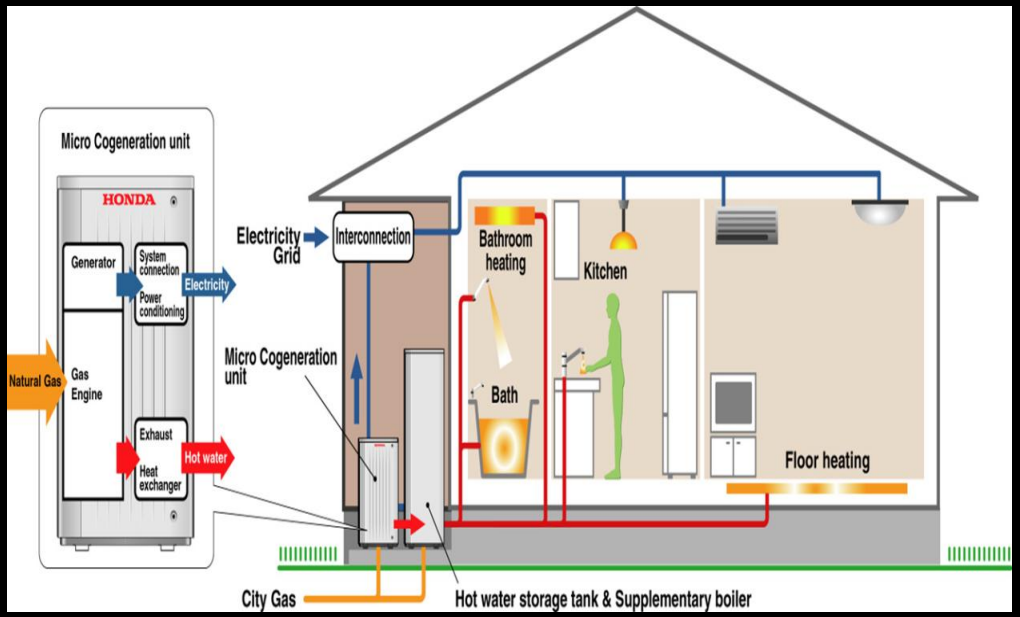


The mini-split can also provide air movement and cooling in the summer

Cooling and Air Flow



Integrated System
Micro-cogeneration
Space Heating, DHW, Electricity



Cogeneration Stirling Engine with External “Combustor”

- Gaseous, Liquid or Solid Fuel or Solar– AC or DC “backbone”
- Generates heat and electricity
- Optimize BOP
- Alternative renewable energy sources

Potential Issue with Micro-Cogeneration Systems

For many system, to always operate at peak efficiency, there must either be means to significantly **modulate some of the outputs in relation to others**, or to find other applications or sinks for those excess outputs, either on a short or long term basis

There may be a need for electricity, but not for so much heat, or vice-versa.

In a similar vein . . .

Intermittent Renewable Energy

Intermittant Renewable Energy

Renewable energy sources, particularly wind and solar, are not always there when we need the energy, but can be there (in significant quantities) when we do not require the energy.

To ensure optimal utilization and performance, some form of energy storage may be the best solution

Energy Storage

Heat Storage Short-term

Liquid (water)

High thermal mass solids

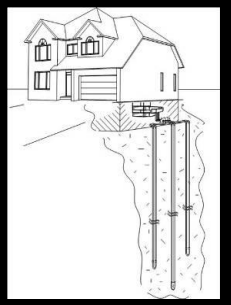
Phase-change

Energy Storage

Heat Storage – Medium/Long Term

Boreholes

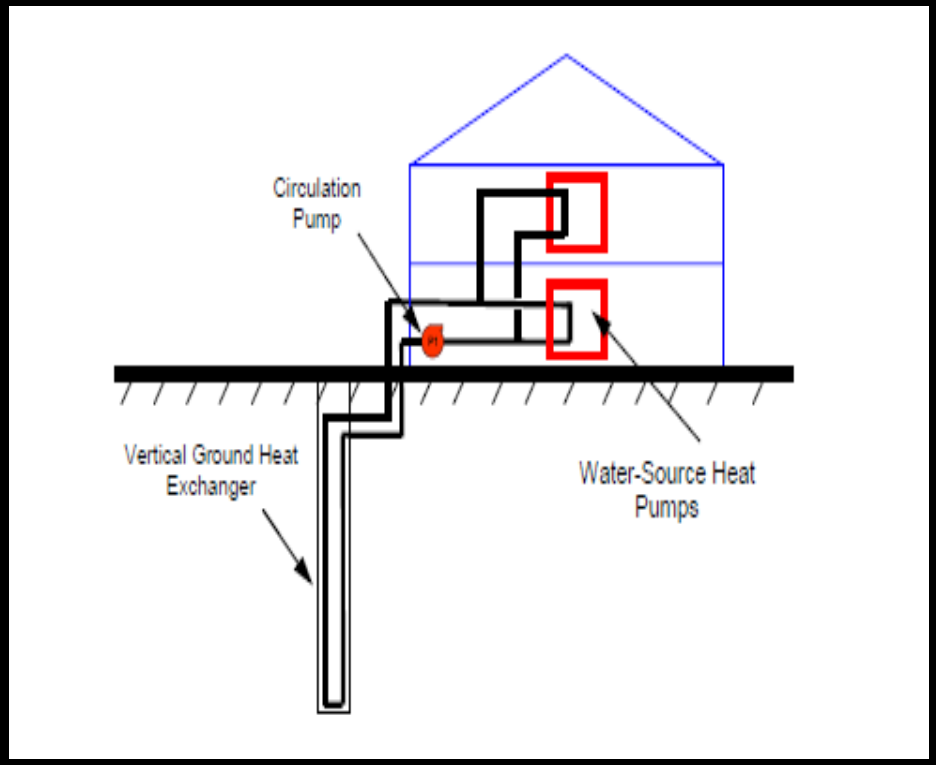
Residential (solar or microcogen)



Industrial waste heat

Community (solar)

Micro-Cogeneration with Borehole Heat Storage & Water Source Heat Pump



Energy Storage - Electricity

Lithium-Ion Batteries

Super Capacitors

PHEV

Charging at low demand and putting electricity back into dwelling at time of peak demand

Pumped Storage

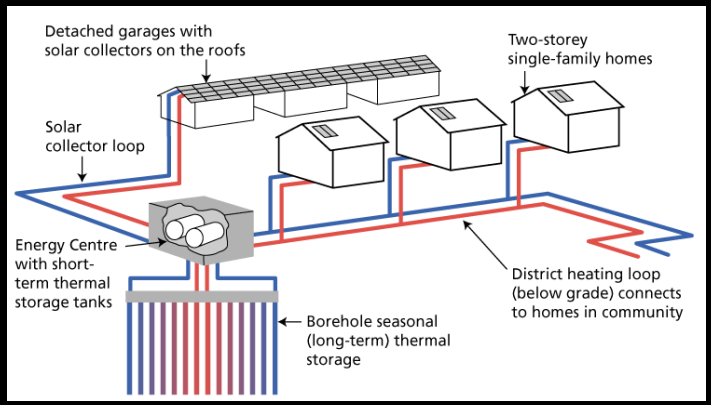
Renewably-derived Hydrogen

Solar Energy

Heating

Solar Hot Water

Solar Heated Community with Seasonal Borehole Storage

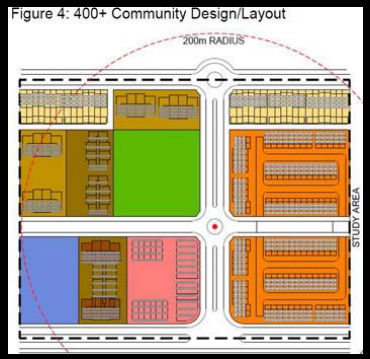


Heat delivery based on eKocomfort technology, considering low exergy heat with high comfort

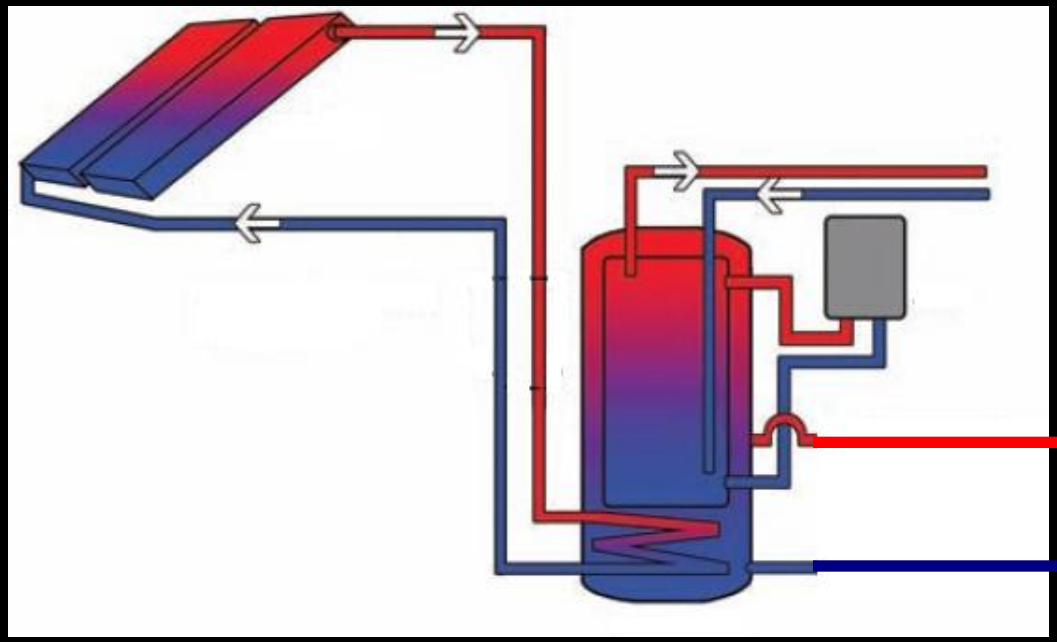
Solar Heating
Drake Landing Alberta (9500 DD)

Drake Landing, 52 home subdivision near Calgary has achieved of 97% solar fraction, and has been awarded the World Sustainable Energy Trophy

With our builder & utility partners, we are now looking at 400 and 1000 home installations in the Yukon and at Fort McMurray (really NORTH!!)



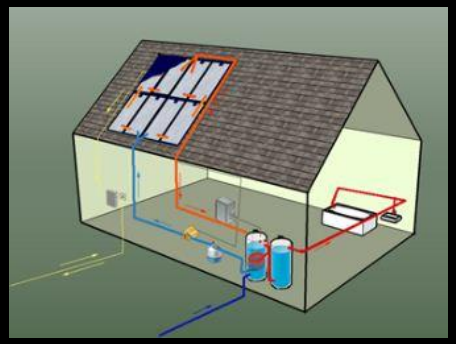
Hybrid Integrated Appliance



Space Heating, Water Heating, Ventilation Driven by Solar Energy & High-Modulation Gas-Fired Condensing System (possibly PV-driven)

What’s next ??

PVT
Photovoltaics + Thermal



New Renewable Fuels

Renewably-derived Hydrogen
blending with natural gas,
across the gas network

Bio-fuels and bio-diesel (liquids)

Alcohols and blends

Alternative solid fuels (corn, straw,
composite …)

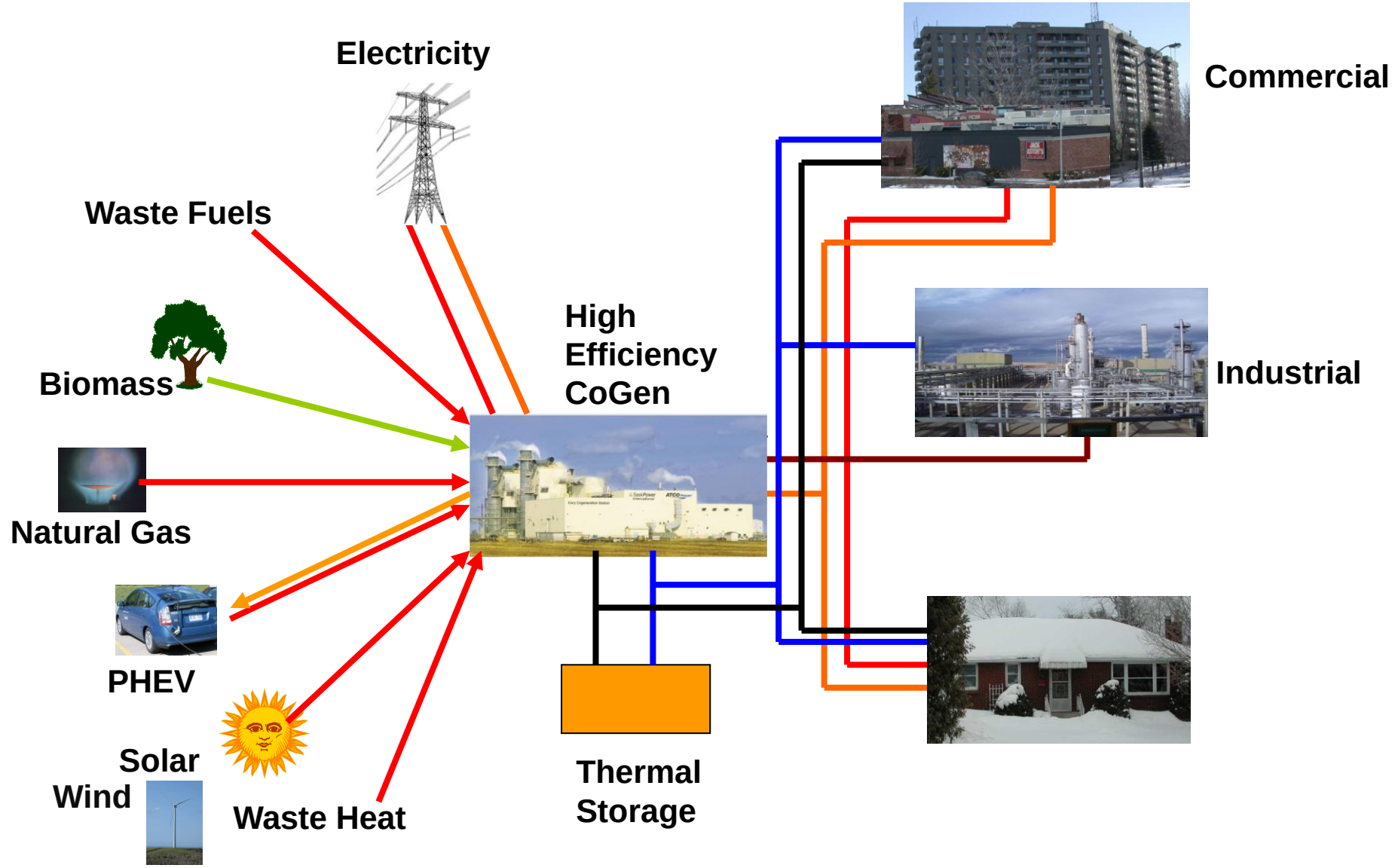
WASTE HEAT

Smart Energy Networks

Homes & Communities:
Heat, Electricity, Fuel

Wind

Smart Energy Networks



Summary

- **Integrated, Hybrid Technologies offering high modulation in output, offer superior means to utilize renewable energy resources and to move to low to net zero energy homes, buildings and communities.**

- **High efficiency woodstoves, coupled with high performing minisplits look like an interesting, efficient, pleasant and comfortable pathway towards net zero for many homes**

- **Energy storage for both heat and electricity offers the means to more effectively to utilize renewables and other energy forms much more effectively**

- **With natural gas appearing to be available for a long time at low prices (despite the little blip at the moment), efforts should be made to integrate renewables with gas, to ensure a smooth long term transition to a renewable energy economy.**

- **Smart Energy Networks, both at the local (house) and community level, are intelligent way to effectively use all our energy resources to their utmost, while minimizing GHGs and moving to overall net zero.**

Review of Objectives (1)

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If further questions,

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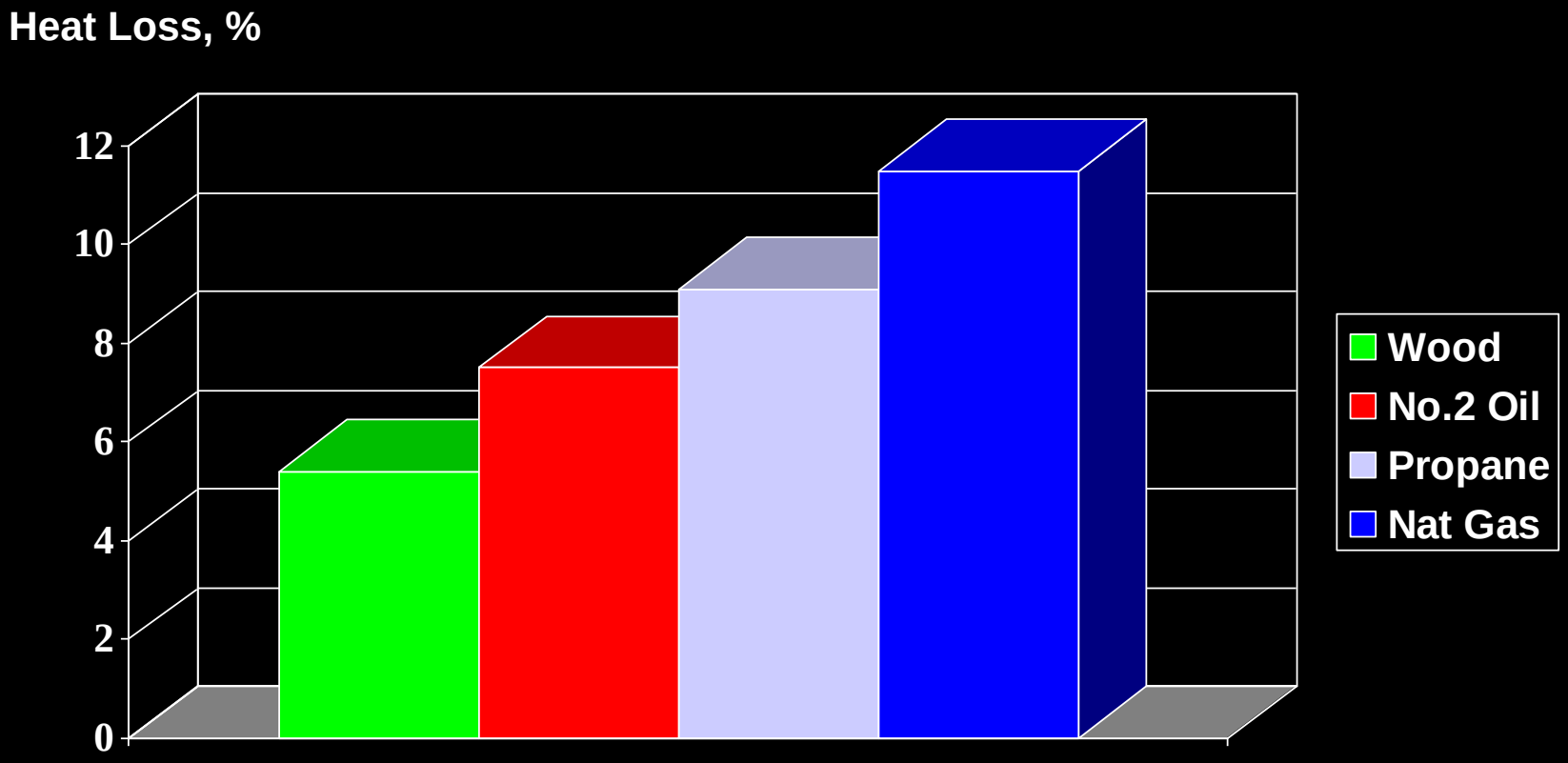
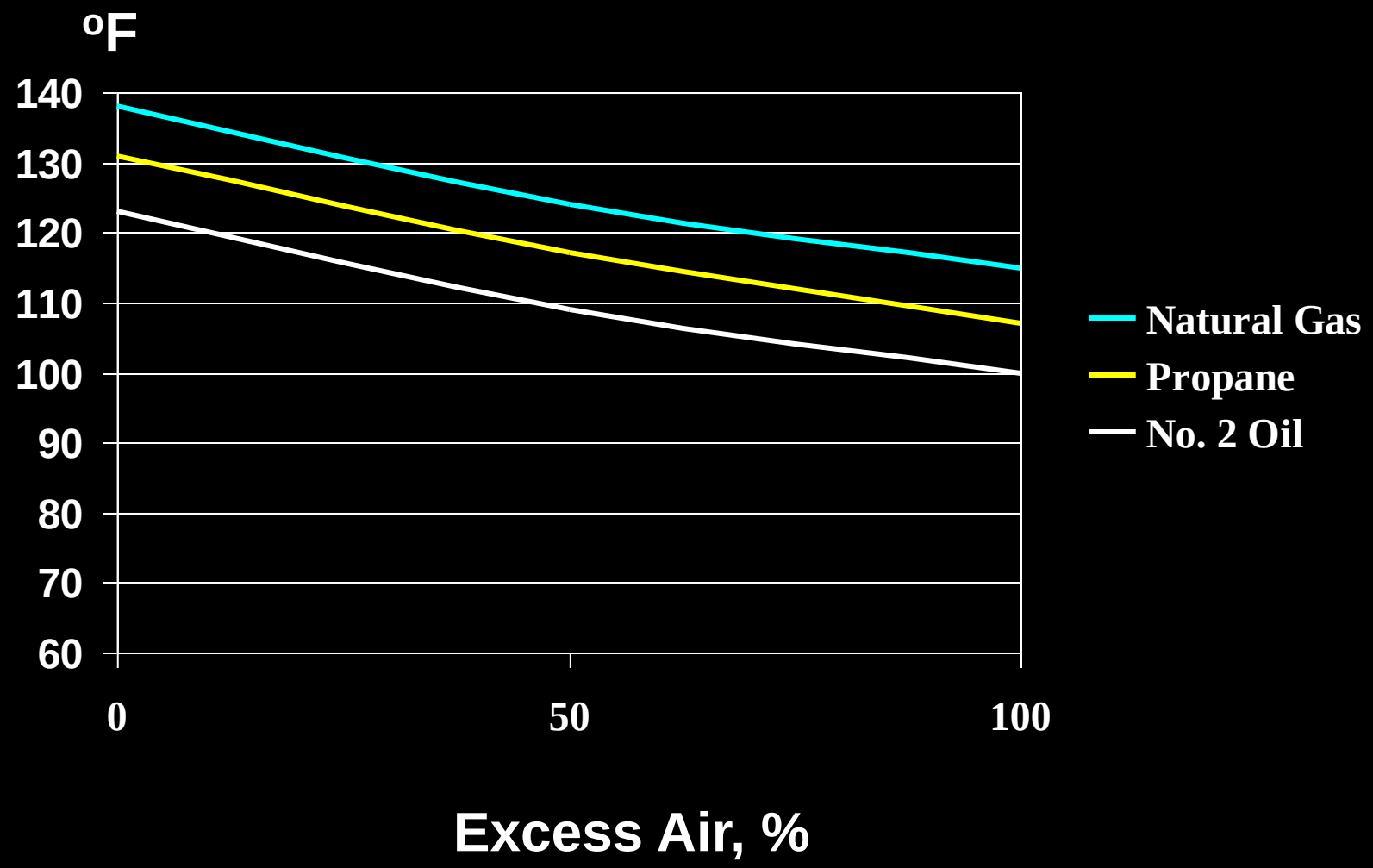
Fuel Energy Contents

Heating Oil	140 kBtu/gal
Natural Gas	1 007 Btu/ft^3
	100000 Btu/therm
Propane	92.7 kBtu/gal
Electricity	3413 Btu/kwh
Mixed Hardwood	22 Mbtu/fullcord
Wood Pellets	336 kBtu/bag or
	16.8 MBtu / ton

Hydrogen Losses for Different Fuels



Dewpoints for Different Fuels



Gas in a house moving to Net Zero

Condensing boilers with high modulation ideally suited to fan coils, radiant floors and low energy housing

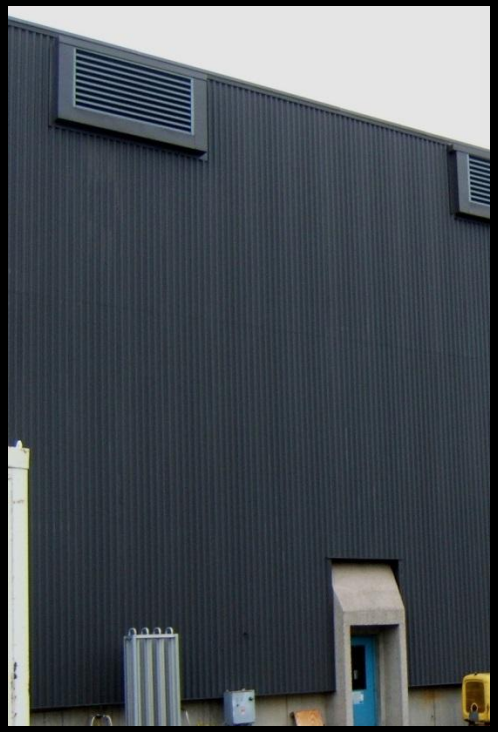
Can a condensing boiler condense in lowered energy housing?

- Yes, if radiant floor 
- Likely, if fan coil to warm air 
- Possible in conventional hydronic, by integrating outdoor reset; reducing flowrate; now oversized heat exchange, service water preheat, preheat ventilation air, as with . . .

With housing moving towards net zero

- **Space heat demands are falling**
- **Domestic hot water an increasing fraction**
- **With tight envelope, need for ventilation air**

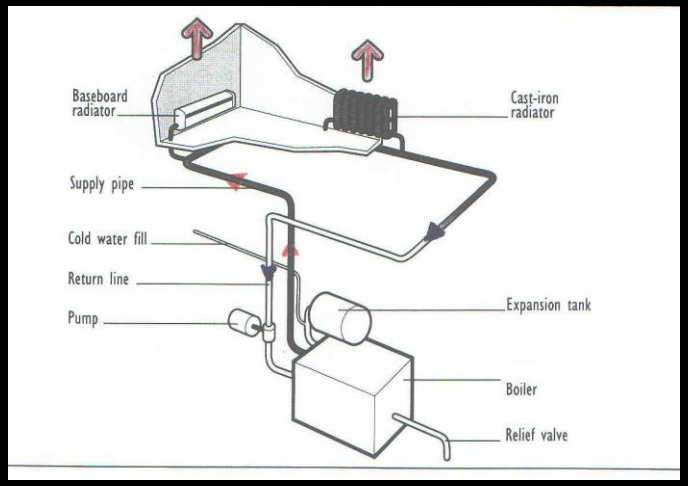
Photovoltaics + Thermal (PVT)

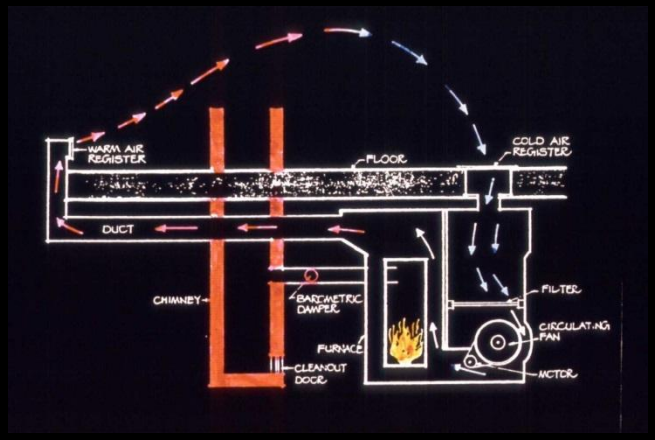


10 top questions to ask about micro cogeneration….

1. **What drives the conversion of natural gas to electricity ?**
   - Thermodynamics and technology (10% for Stirling, 20 % + for ICE, and 30 % + for Fuel Cells)
2. **What drives the recovery of heat ?**
   - Return temperature of heat transfer fluid, radiant floors best
3. **What drives the matching of the unit to building loads ?**
   - Power to heat ratio, ability to modulate, part load efficiency, supplementary firing capability
4. **What is meant by "embedded" micro cogeneration ?**
   - Electricity generated on customer's side of meter, works best with "Net Metering"
5. **What changes when a "Feed-In-Tariff" is being considered ?**
   - Electricity generated independently of end user, and fed to grid using a dedicated meter
6. **What is the best value proposition for micro cogeneration ?**
   - Lease unit from gas utility, who collect emissions credits and electricity demand reductions
   - Offset coal based electricity, thereby reducing attributable emissions (Saskatchewan and Ontario)
   - Unload electricity distribution system to minimise transmission losses
   - Evaluate micro cogeneration against a reference case satisfying the same electrical AND thermal load
7. **Can a micro cogeneration system be used when the grid is unavailable (i.e. during an outage) ?**
   - At present no, most systems are designed to sell electricity, and need the grid to start
8. **Who are the major players worldwide ?**
   - < 10 kWe: Whispergen, Honda/Climate Energy, AISIN (Toyota), YANMAR, Marathon, Senertec-DACHS
   - > 10 kWe: YANMAR, Cummins, G-Box 50 by European Power Systems (Ontario)
9. **Has a dominant architecture emerged ?**
   - Likely to be asynchronous permanent magnet alternator + rectifier + inverter, where locally certified inverter carries disconnect and islanding protection, some circuit management and electrical storage may also prove worthwhile, technology to convert heat to cooling in summer would be a game changer
10. **Is there a Canadian product coming to market ?**
    - Yes, a 6 kW on-grid / off-grid capable prototype with condensing heat recovery is being tested now

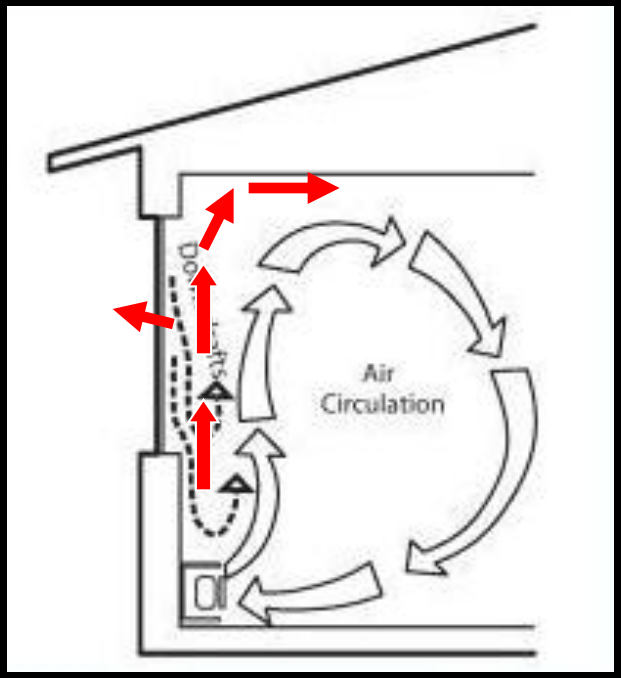
A mix of heating types ?





Electric Baseboard

Does this really happen?



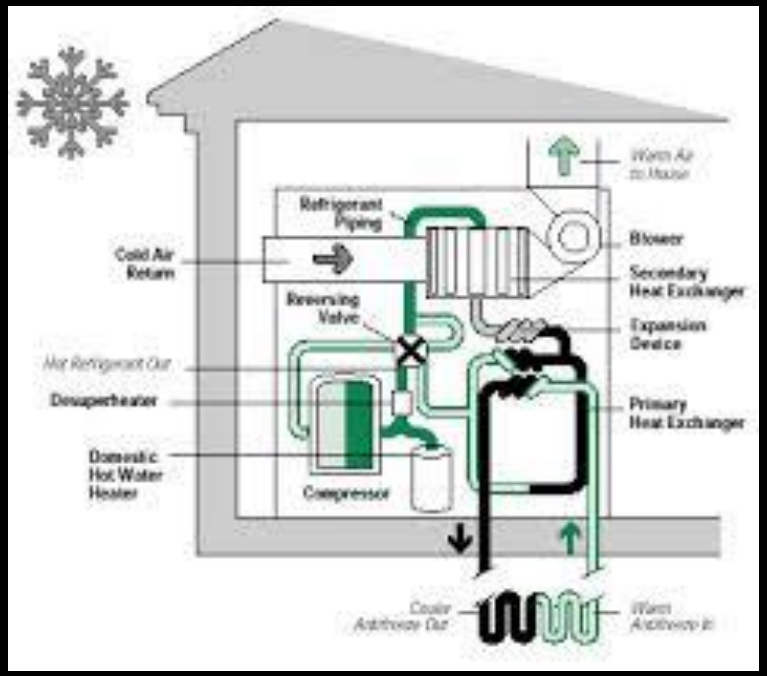
- Heat goes up against point of major heat loss
- Stays on house periphery or ceiling
- Needs some forced circulation
- High cost of electricity

Characteristics of Efficient, Safe Gas Fireplace or “Stove”

- Direct vent (sealed combustion)
- Ceramic viewing glass front
- Good input/output modulation
- IID or easily shut-off / relit pilot
- Effective circulating fan with DC motor
- Free-standing or iInsulated outer casing
- High P.4 seasonal efficiency
- Properly sized & well-located in major living area

Heat Pumps


HALLOWELL


Warm Air to House
Refrigerant Piping
Blower
Cold Air Return
Secondary Heat Exchanger
Reversing Valve
Expansion Device
Hot Refrigerant Out
Desuperheater
Primary Heat Exchanger
Domestic Hot Water Heater
Compressor
Cooler Antifreeze Out
Warm Antifreeze In