AABC Commissioning Group

AIA Provider Number 50111116

Measurement and Verification of Heat for Thermal Energy Credits

Course Number: CXENERGY1723

Thomas D. Prevish, Ph.D., P.E.

NorthWest Engineering Service, Inc.

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Course Description

The prevalence of Combined Heat and Power (CHP) distributed generation systems has fostered an interest in verifying both the electricity and heat utilized by customers receiving tax incentives offered by state and federal energy efficiency and renewable energy programs. This presentation discusses typical system configurations, accuracy considerations, and regulatory guidelines for counting thermal energy credits, including the role of third-party verification and commissioning.

Learning Objectives

At the end of the this course, participants will be able to:

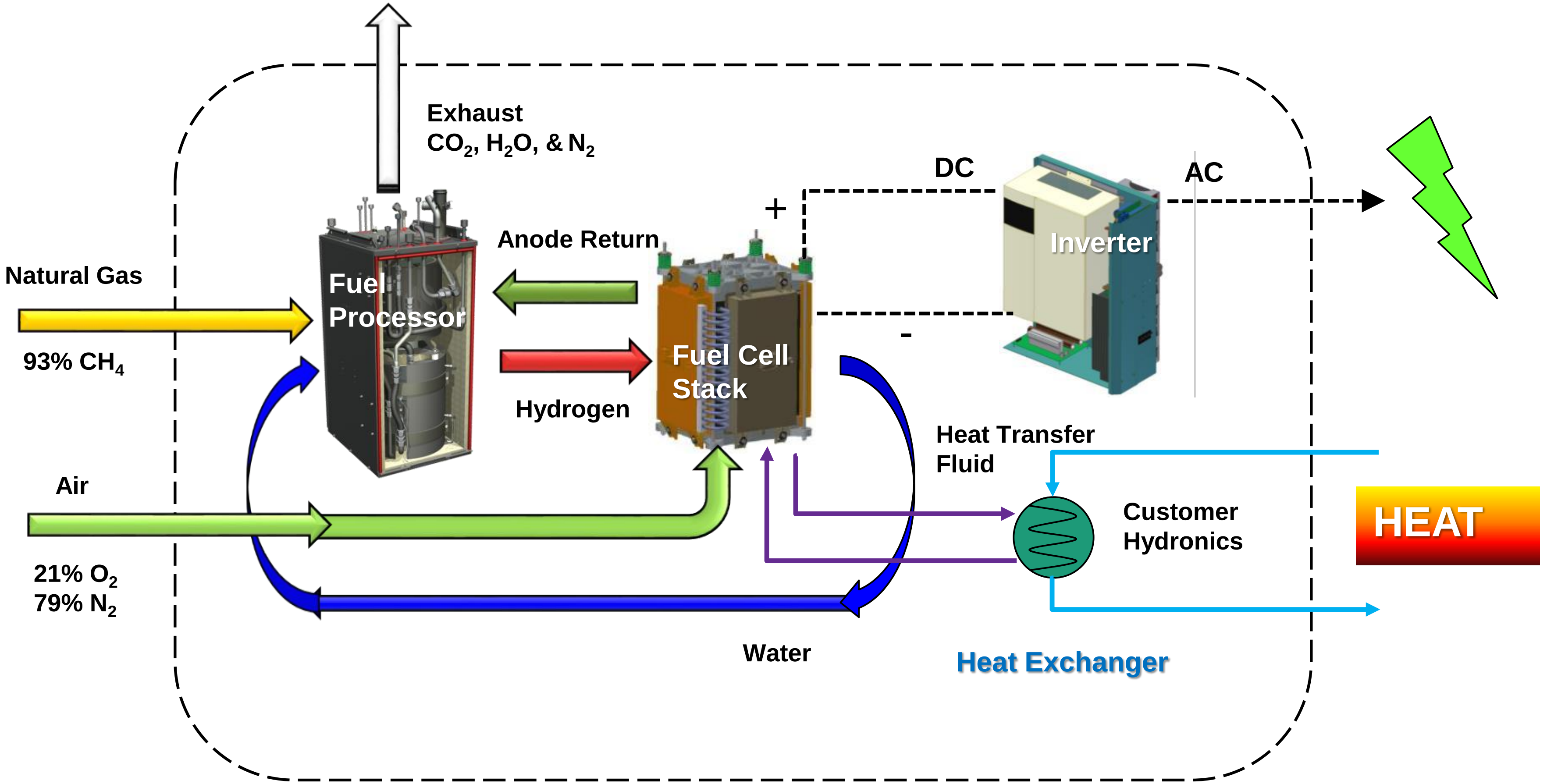
1. Understand how Combined Heat and Power (CHP) systems are generally set up and operate.

2. Understand why some states are considering Thermal Energy Credits and tax incentives.

3. Understand how difficult it can be to accurately measure heat output from CHP systems.

4. Understand how commissioning can play a role in CHP systems and thermal energy tax credits.

What are Combined Heat and Power Systems? One Example



$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$ + Power & Heat

These are also termed Cogeneration Systems

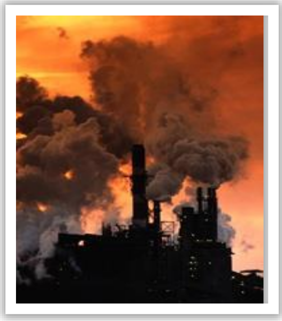
Advantages of Combined Heat and Power Systems

Power from the Grid	Power from CHP

Natural Gas

Efficiency: 35%

125 units



Electricity → 43.8 units per year ← Electricity

Natural Gas

Efficiency: 80%

63.5 units

Heat → 50.8 units per year ← Heat

Natural Gas

Elec Eff: 40%

CHP Eff: 86%

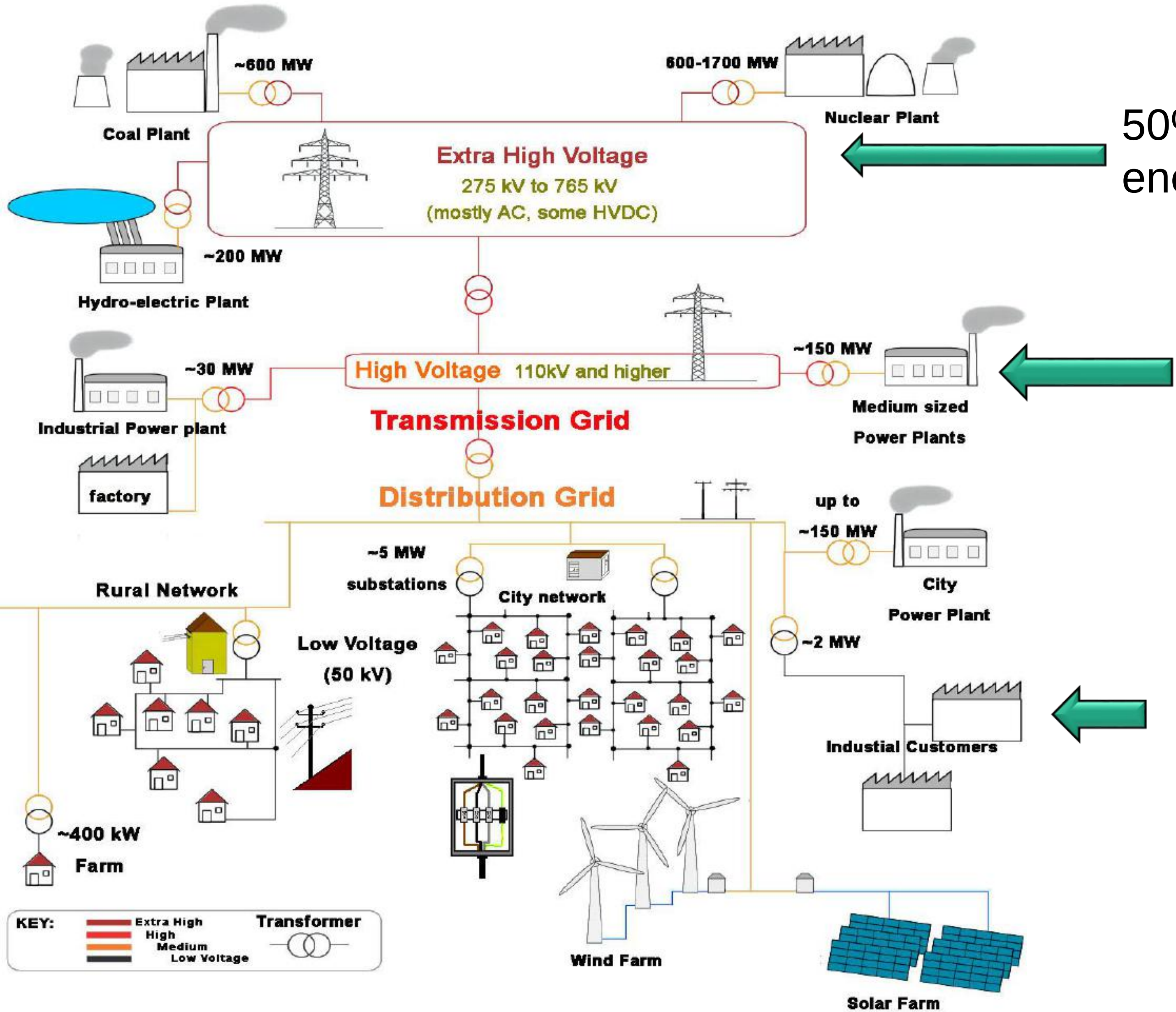
110 units

189 units total

110 units total

Combined Heat and Power saved
42% reduction in fuel and CO_2

Advantage of Distributed Energy Generation



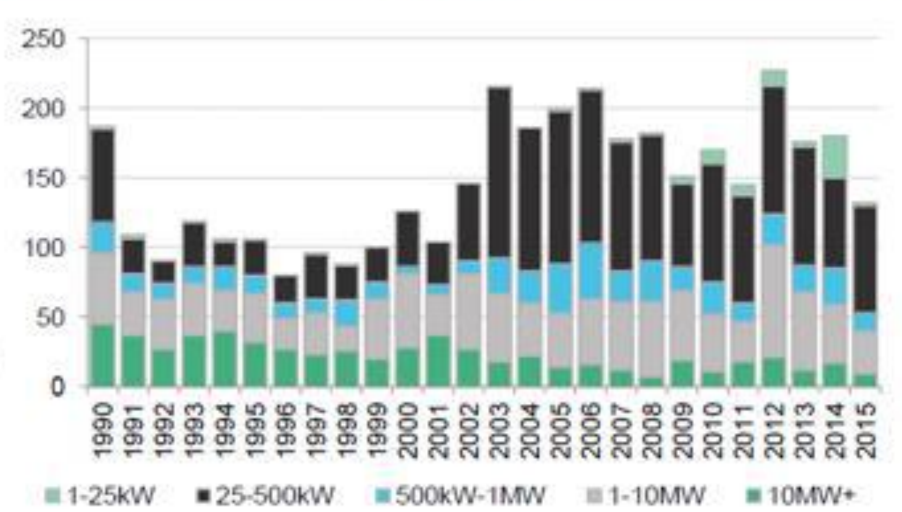
50% to 70% of energy is lost as heat

7% to 10% is lost in transmission and distribution

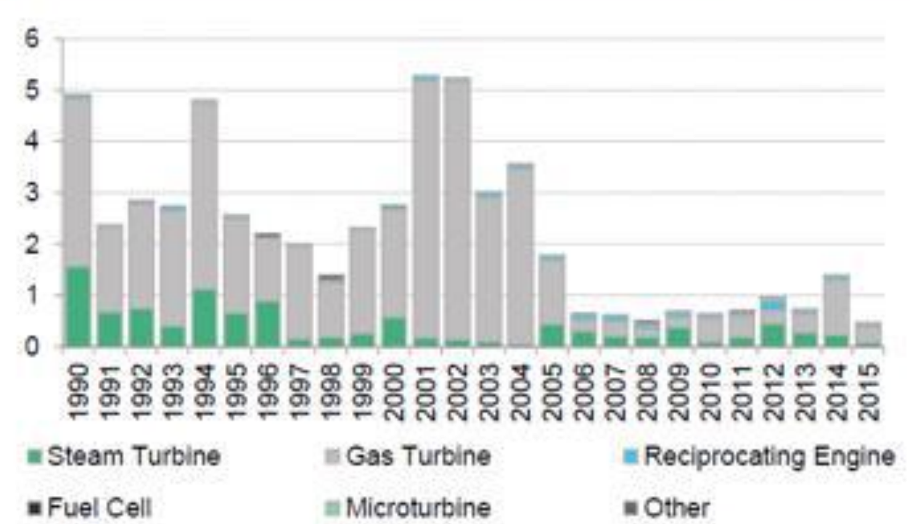
60% to 80% of the fuel's original energy is lost before it reaches the customer!

U.S. Small Scale CHP Deployments

US Annual CHP build by system size (# of projects)



US Annual CHP build by technology (GW)

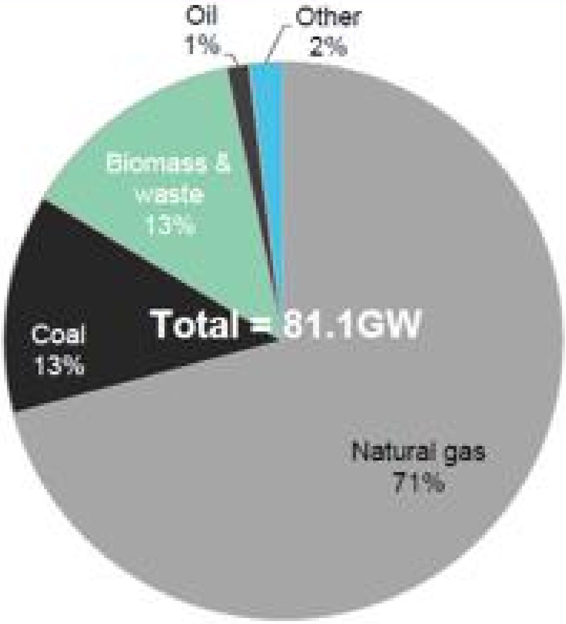


- Fleet of CHP systems slowly but steadily growing
- Expansion dominated by smaller systems, in size range amenable to industrial and commercial campuses

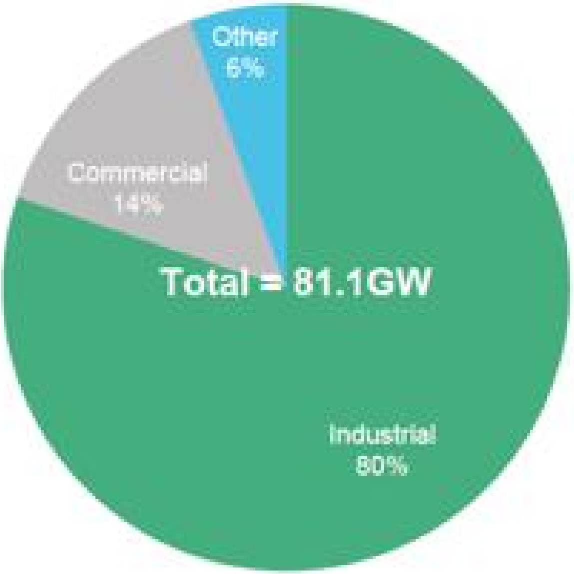
Source: Bloomberg New Energy Finance, DOE CHP Installation Database

U.S. CHP Deployment Mix as of 2015

US CHP deployment by fuel source



US CHP deployment by sector



- Natural gas dominates cogeneration market
  - Gas prices during ramp-ups of new CHP builds are the most likely driver

- Industrial applications have dominated, but commercial builds are significant

Source: Bloomberg New Energy Finance, DOE CHP Installation Database

Where does Renewable Energy enter this picture?

- Biogas is a relatively easy substitution for natural gas
  - Wood-derived
    - "farmed" trees for fuel
    - low-value pulp and woody mass

  - Anaerobic digestor gas (ADG)
    - i.e., waste treatment plant demos
  - Landfill gases

- Biogases require additional processing before they can be directly substituted
  - Methane value often much less than 90%
  - Remove siloxanes, silica, and other contaminants

This brings us to Renewable Energy Credits (a.k.a. Certificates)

https://www.youtube.com/watch?v=_12VYXms6-c

RECs – Renewable Energy Credits

- 1 MWh of electricity generated from a renewable source

T-RECs – Thermal Renewable Energy Credits

- 1 MWh (3,412,000 Btu) of heat from a renewable source
  - Generating heat is easy
  - USING that heat is the key

Renewable Energy Credits (RECs and T-RECs)

T-RECs are being used in some states for:

- Solar Thermal
  - Solar heating, pool heating, etc.
- Biomass
  - Wood pellets, ethanol, biodiesel, biogas
- Geothermal
  - Air and ground source heating and cooling

All	Solar Thermal	Biomass	Geothermal
AZ, IN, MA, MD, NH, TX, WI	AZ, DC, IN, MA, MD*, NV, NH, NC, PA*, TX, UT, WI	AZ, IN, MA, MD**, NH, TX, WI	AZ, IN, MA, MD, NV, NH, TX, WI

* Solar hot water only

** Excludes woody biomass

Source: <u>Renewable Thermal in State Renewable Portfolio Standards</u>. Clean Energy States Alliance, April 2015

Renewable Energy Credits (RECs and T-RECs)

- Energy used solely for heating is difficult enough to measure
  - Using it for *cogeneration* plants more challenging
    - Why? Is the heat really being used?

- CHP plants typically run with same optimized efficiencies

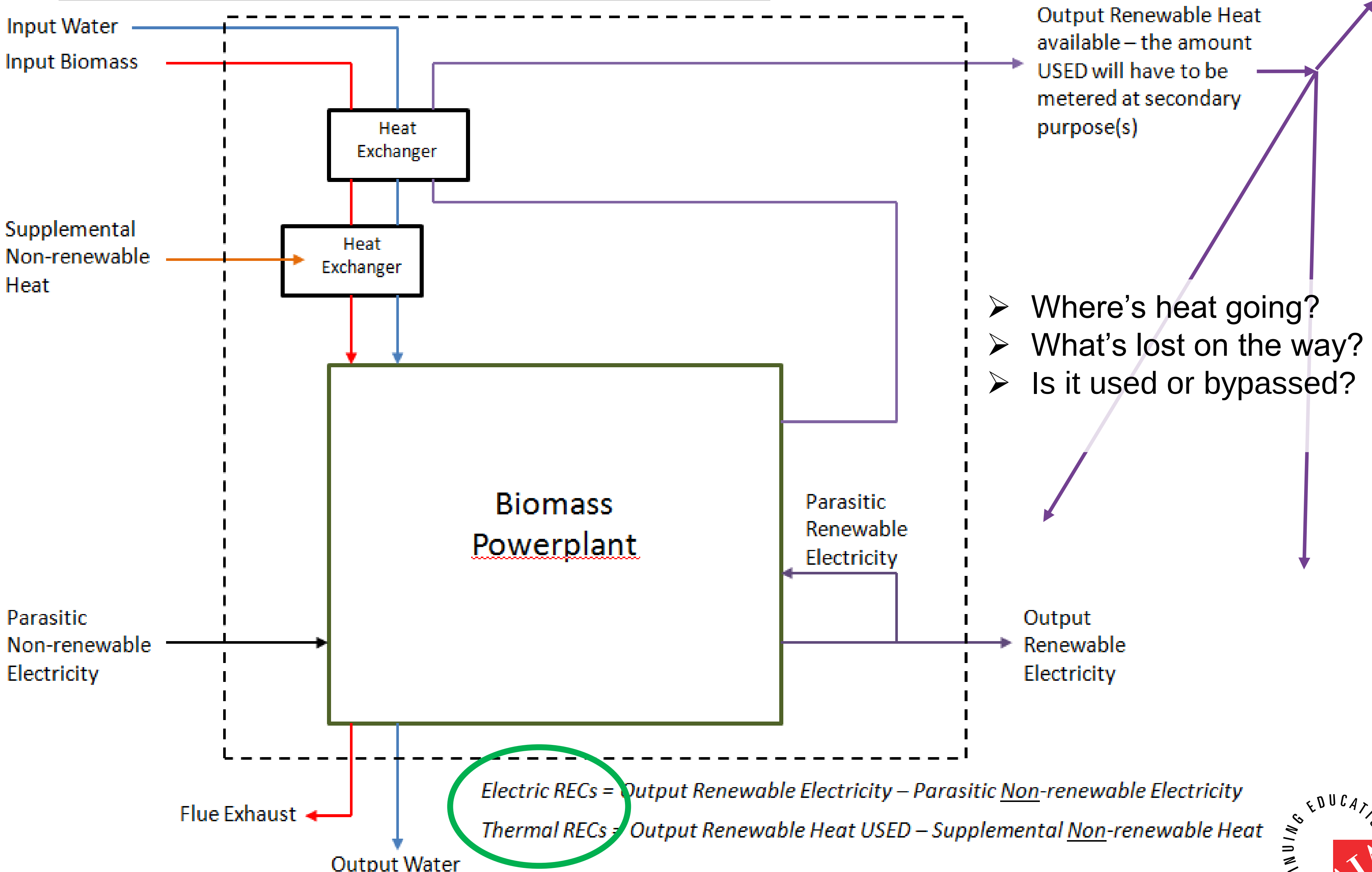
	Small Recip CHP	Larger, Advanced CHP	Relative energy usage in typical buildings
$\eta_{elec} = \frac{\text{Electricity output}}{\text{Fuel input energy}}$	~20%	~45%	~90-50%
$\eta_{heat} = \frac{\text{Heat output}}{\text{Fuel input energy}}$	~55%	~35%	~10-50%

$$\eta_{CHP} = \frac{\text{Elec+Heat output}}{\text{Fuel input energy}}$$

If sized for electric loads,
it's hard to find uses for heat

- Big water users good: hotels, hospitals, food prep, etc.

Typical Renewable Energy Cogeneration Plant



What about other Tax Credits?

Federal Business Energy Investment Tax Credit (ITC)

- Frequently used for CHP projects in last ~10 years
- Still strong for Solar, including thermal output
- Many other thermal energy sources phased out in 2016

From US Dept. of Energy website:

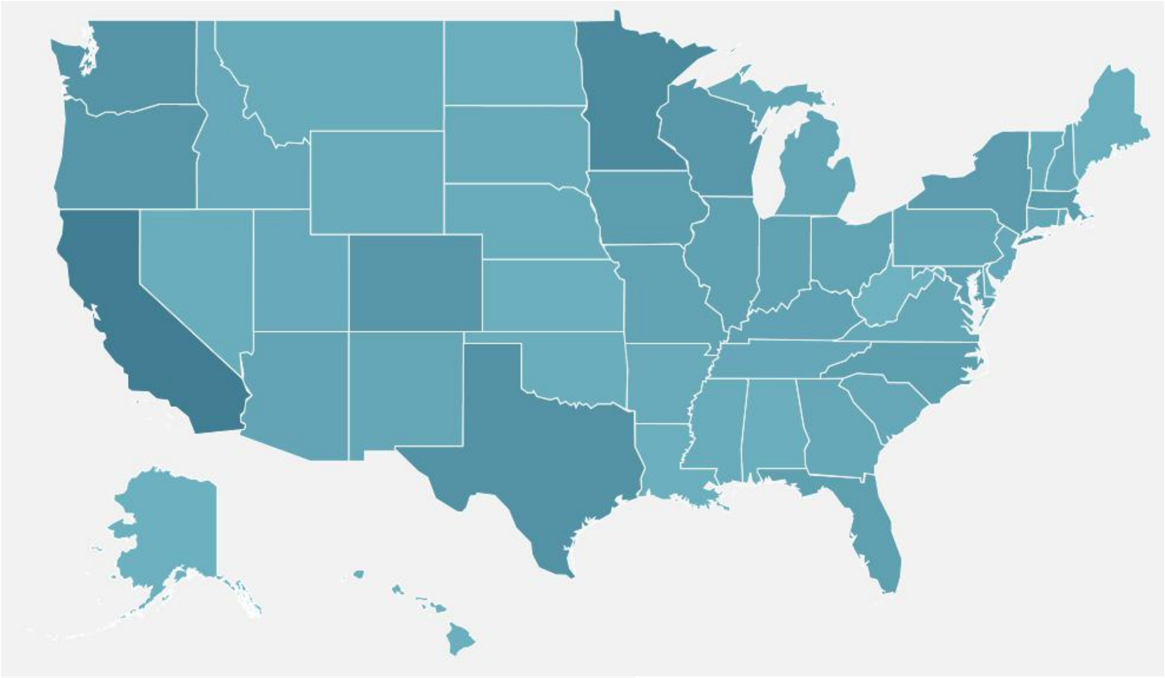
Technology	12/31/16	12/31/17	12/31/18	12/31/19	12/31/20	12/31/21	12/31/22	Future Years
PV, Solar Water Heating, Solar Space Heating/Cooling, Solar Process Heat	30%	30%	30%	30%	26%	22%	10%	10%
Hybrid Solar Lighting, Fuel Cells, Small Wind	30%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Geothermal Heat Pumps, Microtubines, Combine Heat and Power Systems	10%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Geothermal Electric	10%	10%	10%	10%	10%	10%	10%	10%
Large Wind	30%	24%	18%	12%	N/A	N/A	N/A	N/A

What about other Tax Credits?

Some states have specific tax credits that may apply

- California and New York have been historically strong supporters
- Many questions have arisen over the last decade about validity of advertised energy savings

Number of Incentives by State:



Source: DSIRE – US DOE-funded database

What about other Tax Credits?

Have taxpayers been getting their money’s worth?

- Maturing market and reducing capital costs?
  Yes, probably.

- Have the early adopters saved the money they were sold on?

- Verification studies often found systems not fully utilized, operating inefficiently, bypassed, or even taken out of service
  - Thus the reason many regulations have added:
    - Independent verification – (design and measurement)
    - Continuous monitoring
    - Periodic building tune-ups

What's so hard about measuring efficiency?

$$\eta_{CHP} = \frac{\text{Elec+Heat output}}{\text{Fuel input energy}}$$

Electrical Output

- Reasonably straightforward
  - Multi-meters, power analyzers

Heat Output

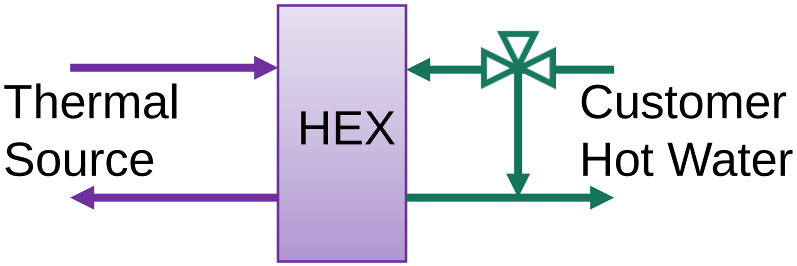
- How many lines and bypasses?
- Which side of the heat exchanger?
- Requires (mass)flowrates and temperatures

Fuel energy

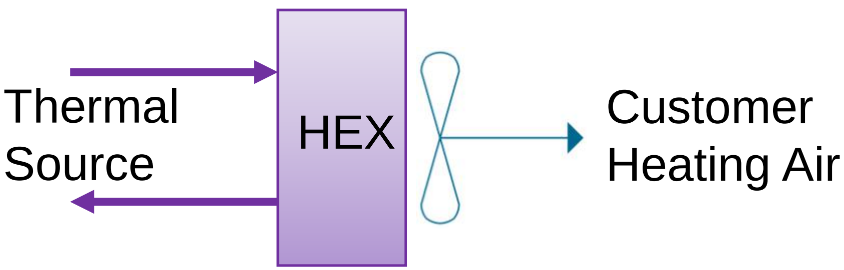
- Lower vs Higher Heating Value
- Changing fuel composition

Topic for another day

What’s so hard about measuring heat?

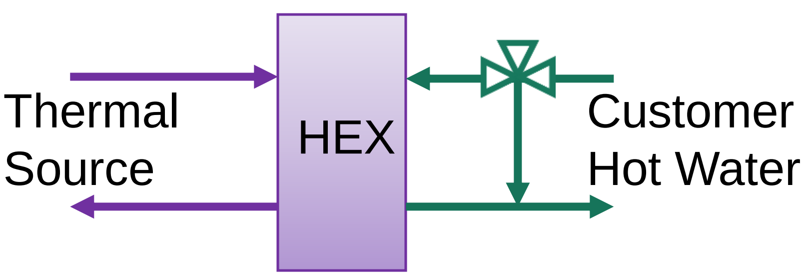


- Flows from < 1 lpm to 1000s of gpm
- What‘s going through the bypass?
- Where do you put the instrumentation?
  - Assumptions on customer use?
  - 10-20 pipe diameters available?



- Measure input liquid and assume HEX η?
- Measure airflow and bulk mean air temps?
- Measure power and use fan curve?!

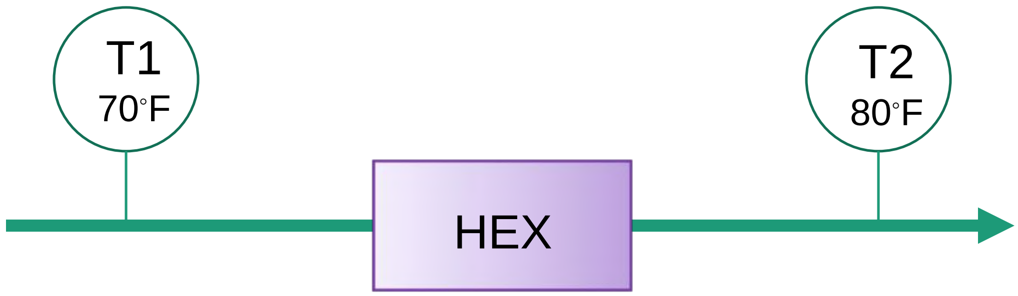
Shudder



6-18 months later . . .

- Now what crap is flowing through your pipe?
- What’s heat exchanger effectiveness?

What’s so hard about measuring heat? Typical example



V = 100 gpm water

c = 0.998 Btu/lb-F

ρ = 62.22 lb/ft^3

Thermocouples: +/- 2°F (1% FS)
Flowmeter: +/- 10 gpm (10% Rdg)
Specific Heat uncertainty: +/- 0.0025 Btu/lb (.25%)
Density uncertainty: +/- 0.16 lb/ft (.25%)

Heat = ρVc(T2-T1)

Nominal: 62.2; 100; 0.998; (80-70) → 498 kBtu/hr [146 kW]

Max: 62.38; 110; 1.00; (82-68) → 771 kBtu/hr [226 kW]

Max: 62.06; 90; 0.996; (78-72) → 268 kBtu/hr [78 kW]

Measurement uncertainty: +55% / -46 !!!!

What's so hard about measuring heat?

So how do we proceed?

- ➢ Not by getting better <u>individual</u> equipment

1) Use dedicated heat or BTU meter
   - ➢ <u>matched</u>, calibrated RTDs
   - ➢ calibrated flowmeter
     - in appropriate range
     - for appropriate fluid
   - ➢ installed in-line (or may have to "hot tap" later)

2) Regularly check fluid properties (specific heat, density)

3) Minimize data acquisition errors and interference

Even then, it's tough to get better than +/- 10% accuracy

- ➢ *Low temperature rise is the culprit*
  - *Even at +/- 0.2°F RTD accuracy, in the previous example, this is still responsible for >8% uncertainty*

Why should Commissioning Providers Care?

1) That's your tax money, too!

2) It requires professionals to ensure meaningful results
   - Codes and Standards bodies recognize this
   - Government regulations are starting to specify:
     - Regular calibration checks
     - Credentialed professionals to review

Make sure YOUR employees' credentials aren't omitted

3) Regular calibration checks an avenue to continuous Cx

4) Be ready for the future:
   - More building efficiency regulations
   - Microgrids and Resiliency

Review Learning Objectives

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Conclusions

- Know equipment capabilities and limits
- Get into project early
  - It's nearly impossible to measure accurately from outside the pipe
- Stay involved with local and national codes and regulations
  - Don't let your credentials be excluded due to an oversight
    - Code changes take years!

This concludes The American Institute of Architects Continuing Education Systems Course

CONTACT INFORMATION

tomp@nwesi.com

(503) 639-7525