Modeling Residential Combined Space and Water Heating

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Presentation Scope

- Context and motivation for work
- Approach for modeling combis
- Limitations of approach (feedback welcome)
- Example results

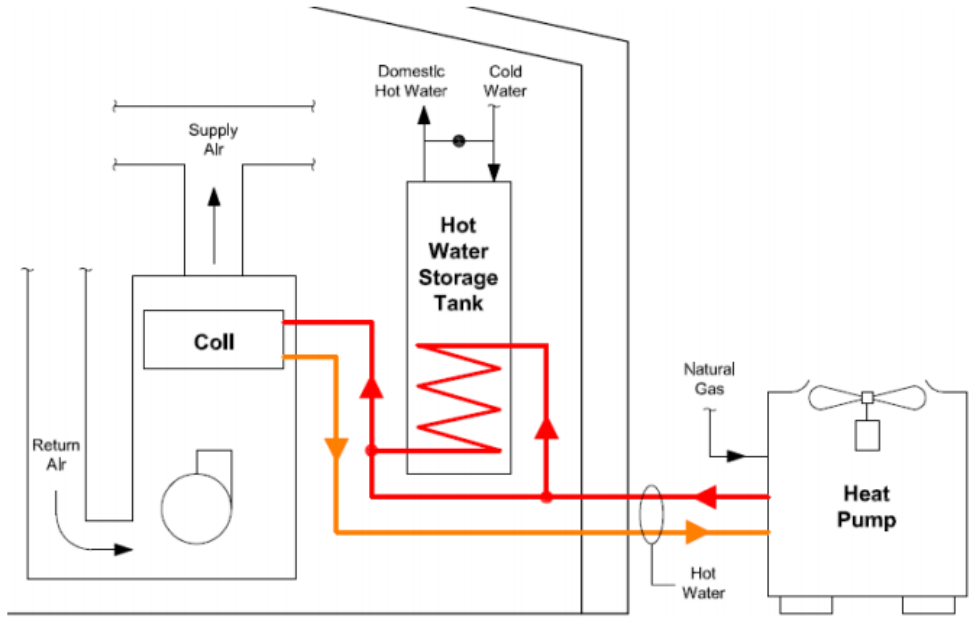
Modeling Advanced Residential Heating

- Ongoing GTI project to develop tools for modeling advanced residential gas heating systems:
  - Modulating, condensing furnaces
  - Gas absorption heat pumps
  - Combined space and water heating (combis)

- Focus on accurate energy consumption prediction

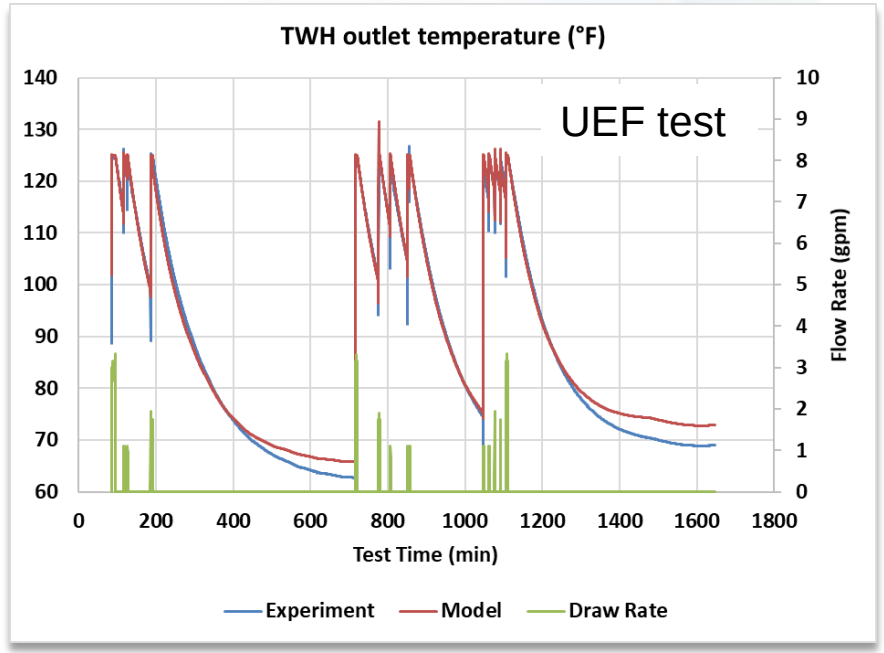
Combined Space and Water Heating Capabilities

- Elements:
  - Boiler (or GAHP) / storage water heaters
  - Indirectly heated storage tanks
  - Hydronic air coils → Air Handler Units
  - Hydronic radiant / baseboards heaters
  - Water-to-water heat exchangers
  - Solar-thermal integration
- Inadequacies:
  - Tankless water heaters

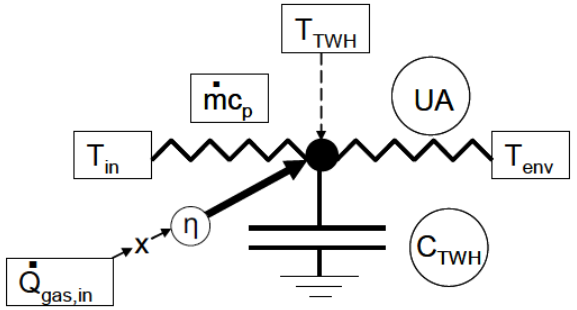


Modeling Tankless Water Heaters (3/12 Recap)

- Current approach (inadequate):
  - Storage water heater with 1 gal capacity, 0 standby loss, constant efficiency
- Better approach:
  - Lumped Heat Capacity model (Burch et al NREL – 2008)
  - $C\frac{dT_{\mathrm{TWH}}}{dt} = \eta\dot{Q}_{\mathrm{gas}} - \dot{m}c_p(T_{\mathrm{TWH}} - T_{in}) - UA(T_{\mathrm{TWH}} - T_{env})$
  - C – thermal capacitance, η – steady state efficiency, UA – standby loss coefficient (relative to HX)



Predicts UEF gas consumption within 3%



Modeling Tankless Combis – Heat Plant

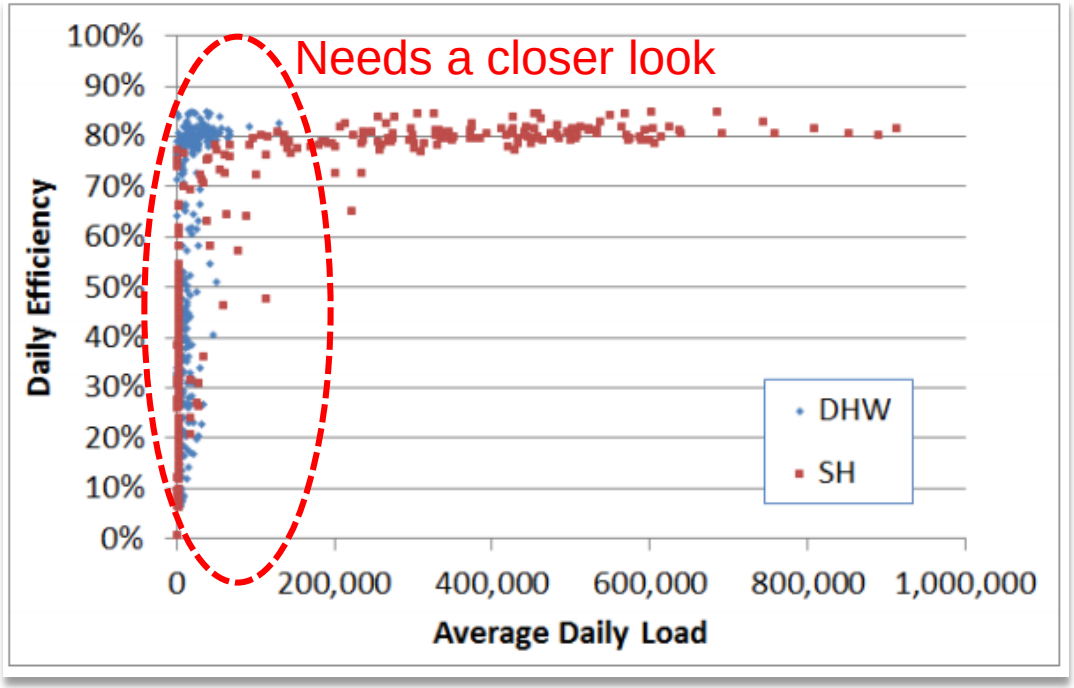
- Extending the LHC Model (adding new term):

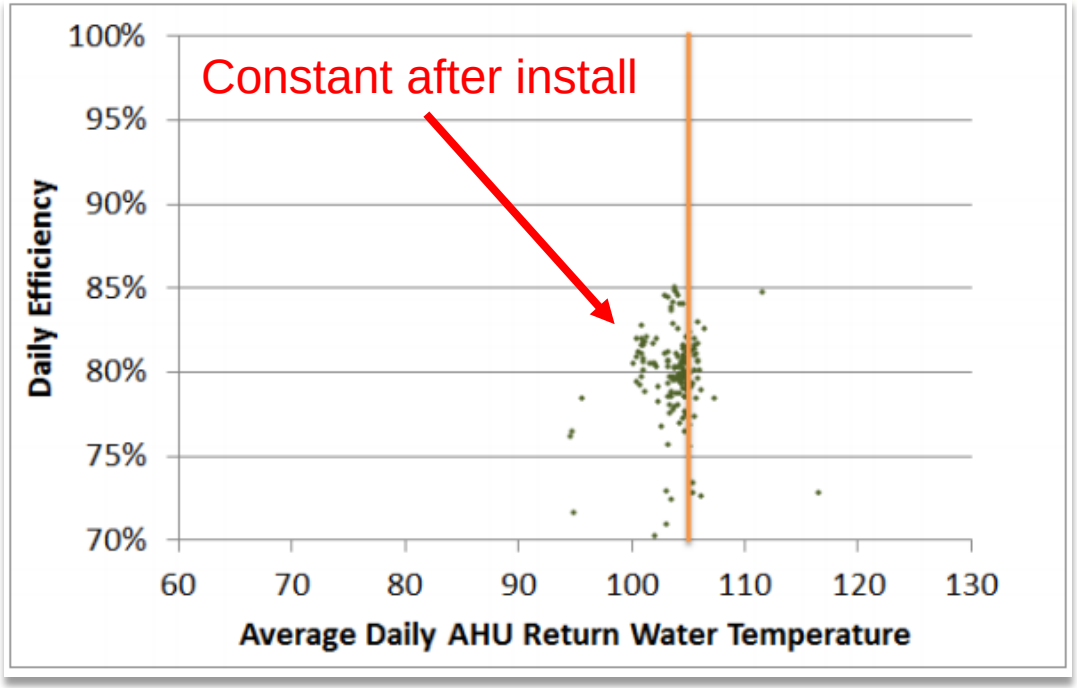
$$C\frac{dT_{\mathrm{TWH}}}{dt} = \eta\dot{Q}_{\mathrm{gas}} - \dot{Q}_{\mathrm{out,DHW}} - \dot{Q}_{\mathrm{out,SH}} - \dot{Q}_{\mathrm{env,loss}}$$

- Space heating can be complicated:
  - Performance (η) depends on return water temperatures
  - Return temperatures depend on: supply air / water temps, AHU sizing, water flow rate, open/closed loop, controls

- Can use real world behavior to simplify…

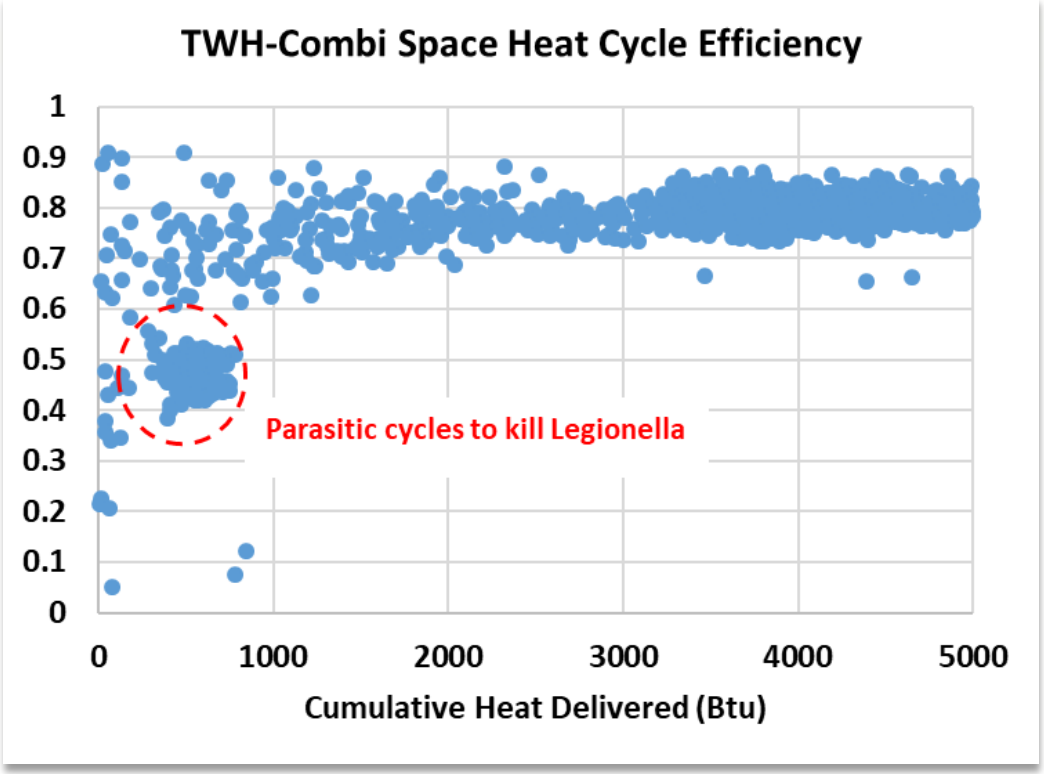
Modeling Tankless Combis – Space Heat

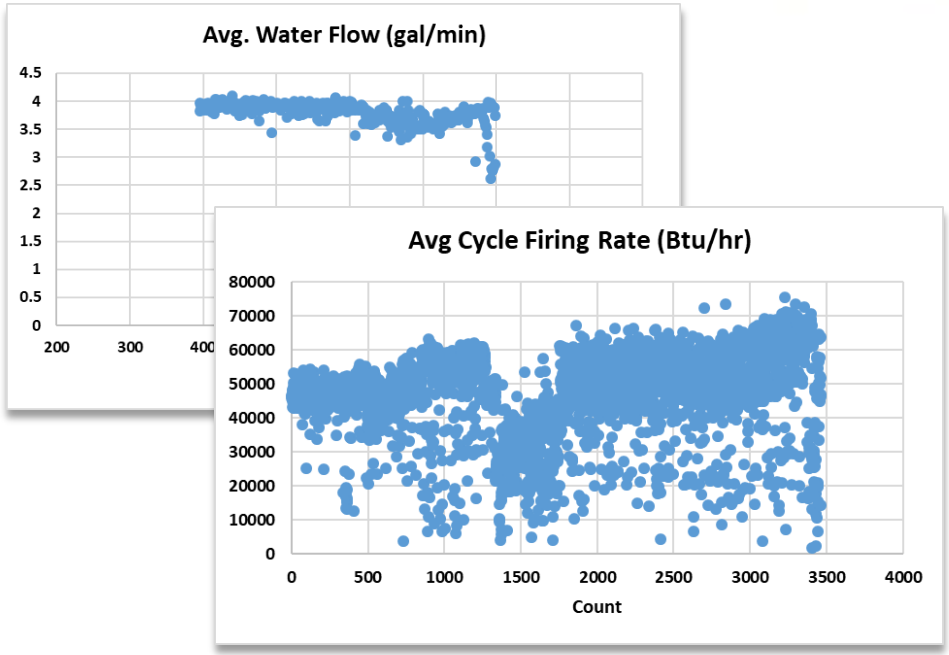




- Cold climate tankless combi pilot (Kingston - GTI, DOE/GO-102016-4474):
  - Condensing efficiencies in SH possible with system optimization

Modeling Tankless Combis – Space Heat





- Performance ~constant per cycle (for given supply/return temps and flow)
  - May not need to model AHU (just use SH loads)
  - Need SH efficiency characterization

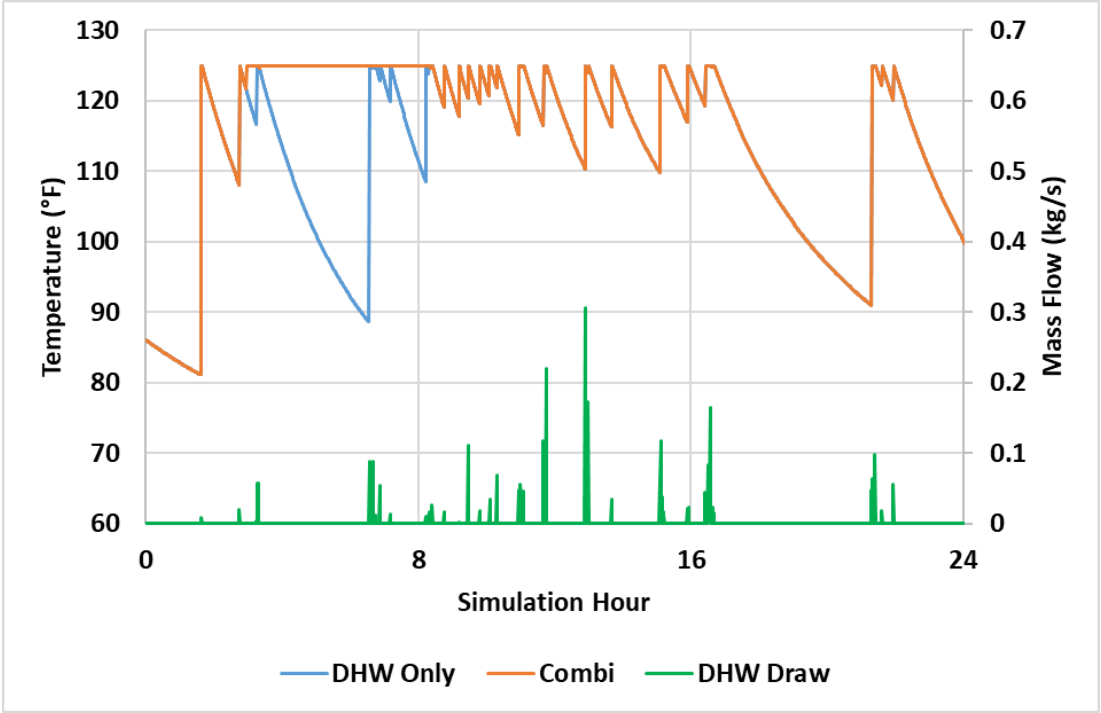
Modeling Tankless Combis – System Model

$$C\frac{dT_{\mathrm{TWH}}}{dt} = \eta_{\mathrm{DHW}}\dot{Q}_{\mathrm{gas}} - \dot{Q}_{\mathrm{out,DHW}} - \dot{Q}_{\mathrm{env,loss}}$$ How water demand

$$C\frac{dT_{\mathrm{TWH}}}{dt} = \eta_{\mathrm{SH}}\dot{Q}_{\mathrm{gas}} - \dot{Q}_{\mathrm{out,SH}} - \dot{Q}_{\mathrm{env,loss}}$$ Space heat demand

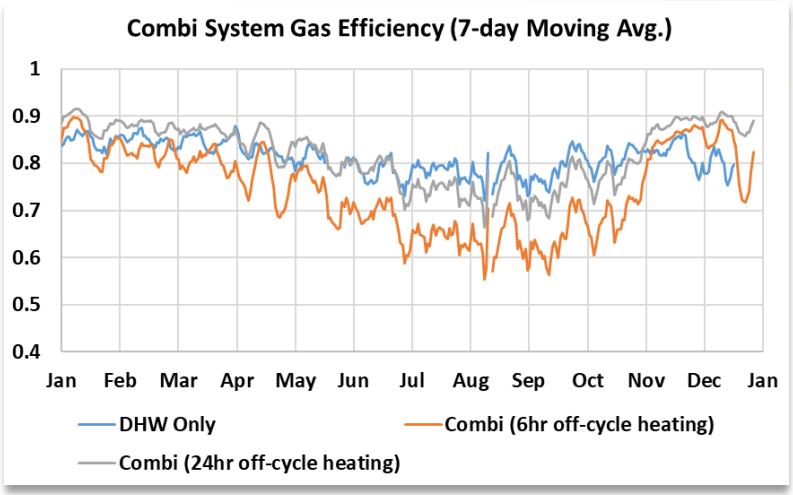
$$C\frac{dT_{\mathrm{TWH}}}{dt} = \dot{Q}_{\mathrm{env,loss}}$$ Standby

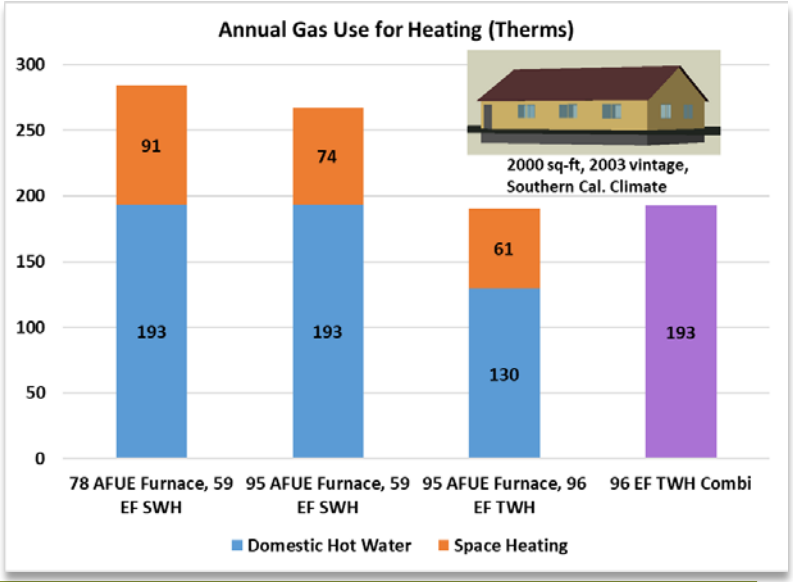
- Assumptions:
  - DHW priority (no overlap)
  - AHU optimized and meets SH loads
  - Constant steady state efficiency



Modeling Tankless Combis – Example

- Approach advantages:
  - Simple & easy to implement
  - Captures just enough physics
  - Characterized by 3-5 parameters
- Potential Limitations:
  - Mismatch of space and water heating loads resolution
  - Advanced combi controls may be difficult to capture





Wrap-up

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- Ongoing work – feedback welcome
  - Will calibrate against lab data
- Parallel project characterizing tankless
- Further questions?
  - afridlyand@gti.energy
- Work supported by:

UTD Utilization Technology Development