2019 ETCC Webinar Series

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EMERGING TECHNOLOGIES COORDINATING COUNCIL

Costs and Benefits of Community vs. Individual End-Use for Solar Water Heating

End-Use Loads and System Modeling

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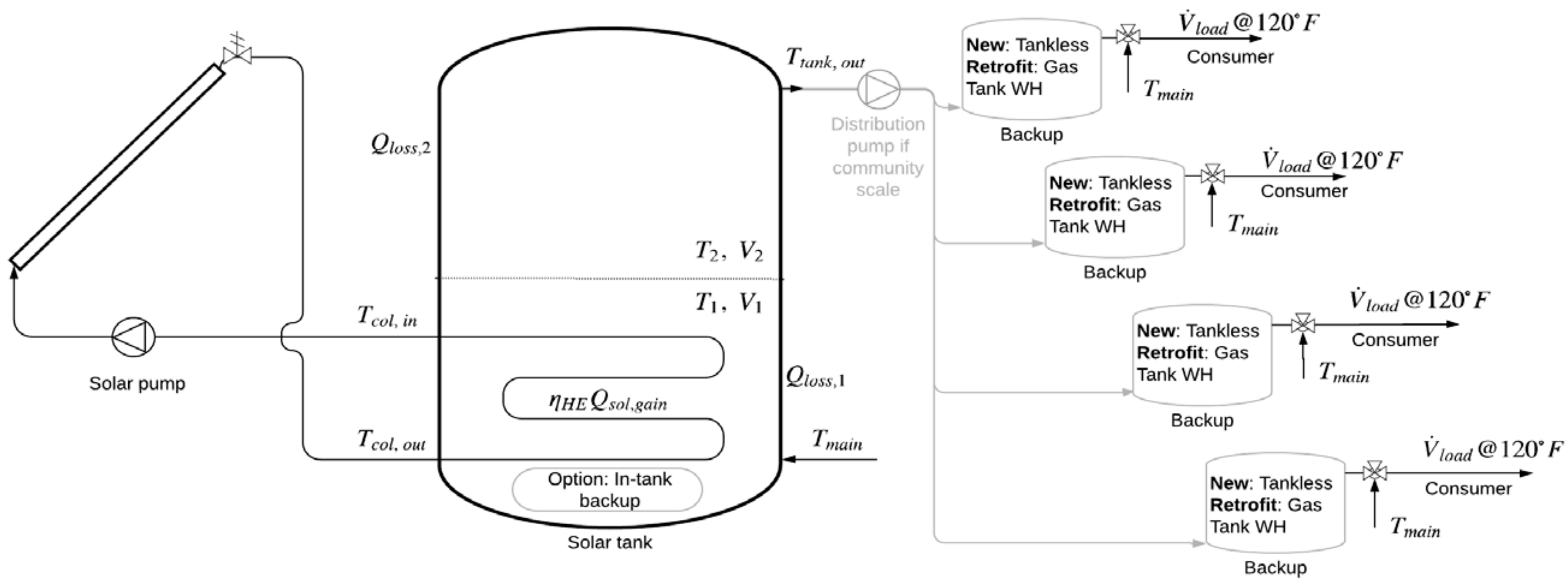
Overview

- Goal
  - Quantify the relative costs and benefits of community-scale solar water heating (SWH) systems in comparison to individual systems under a wide range of consumer characteristics
  - Aggregate societal impacts in energy, economic value, and emissions
- SWH configurations
- Model
  - End-use load profiles
  - System model and simulation

SWH Configurations

Base case: Individual gas tank WH

Solar thermal: Individual and community scale

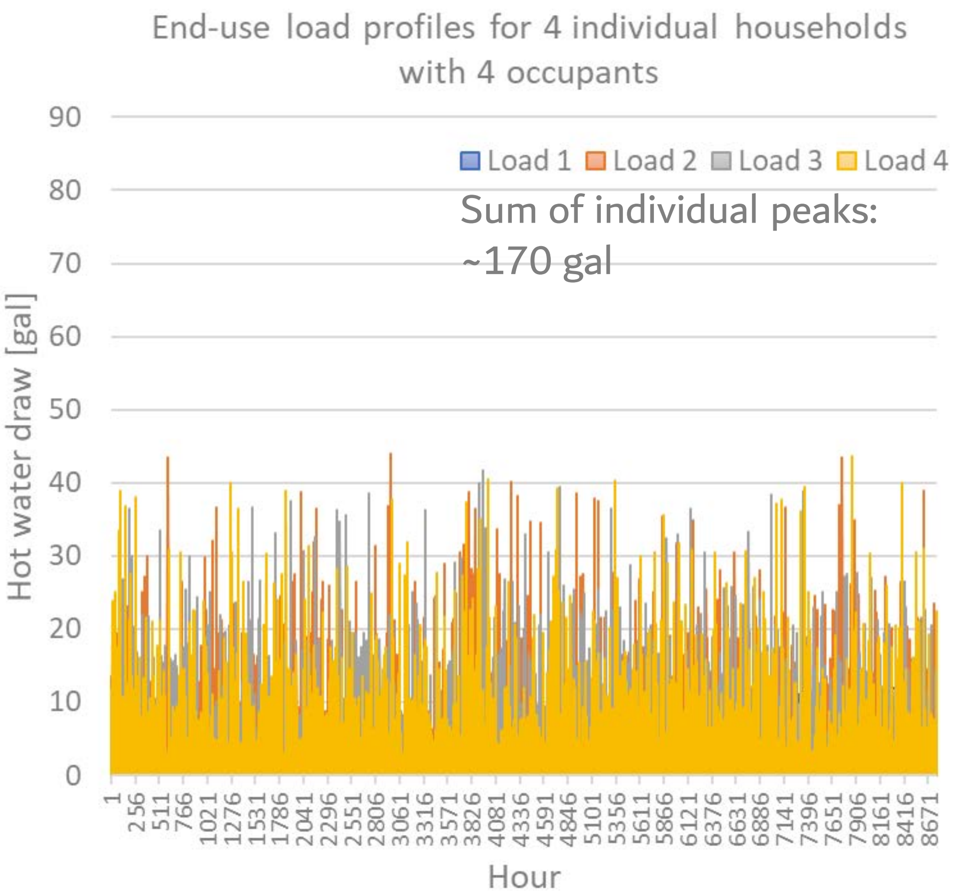


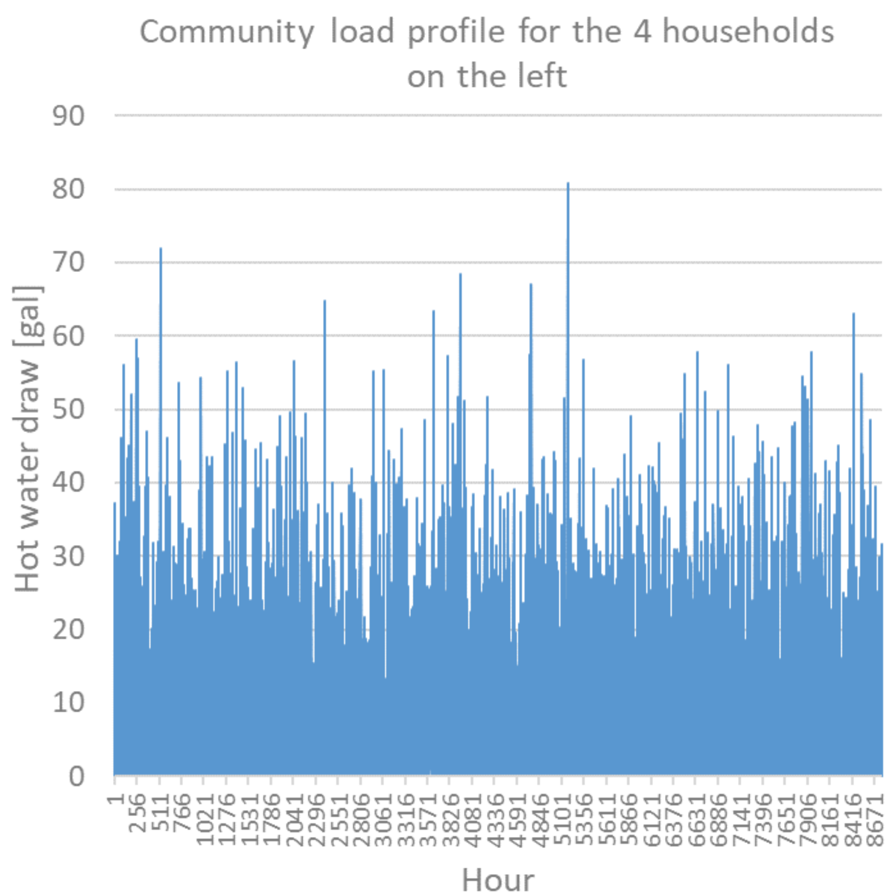
Active solar thermal SWH system for a community of 4 households

End-Use Load Model

- Five event types: faucet, shower, bath, clothes washer, dish washer
- Two day types: weekday and weekend
- Also consider household occupancy and whether someone is at home during the day
- For each event:
  - Calculate number of events per day
  - Draw the volume per event from a distribution
  - Assign event(s) to a given hour using hourly probability distribution functions for each event
  - Impose upper bound on total draw in one hour equal to the household tank size

End-Use Load Example





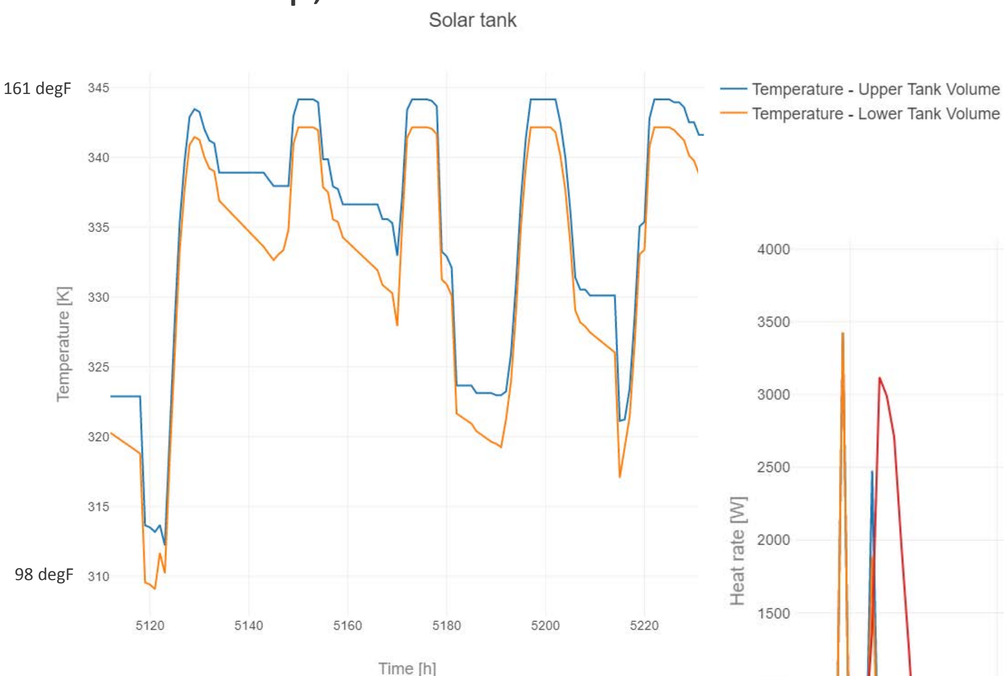
System Model – Python Implementation

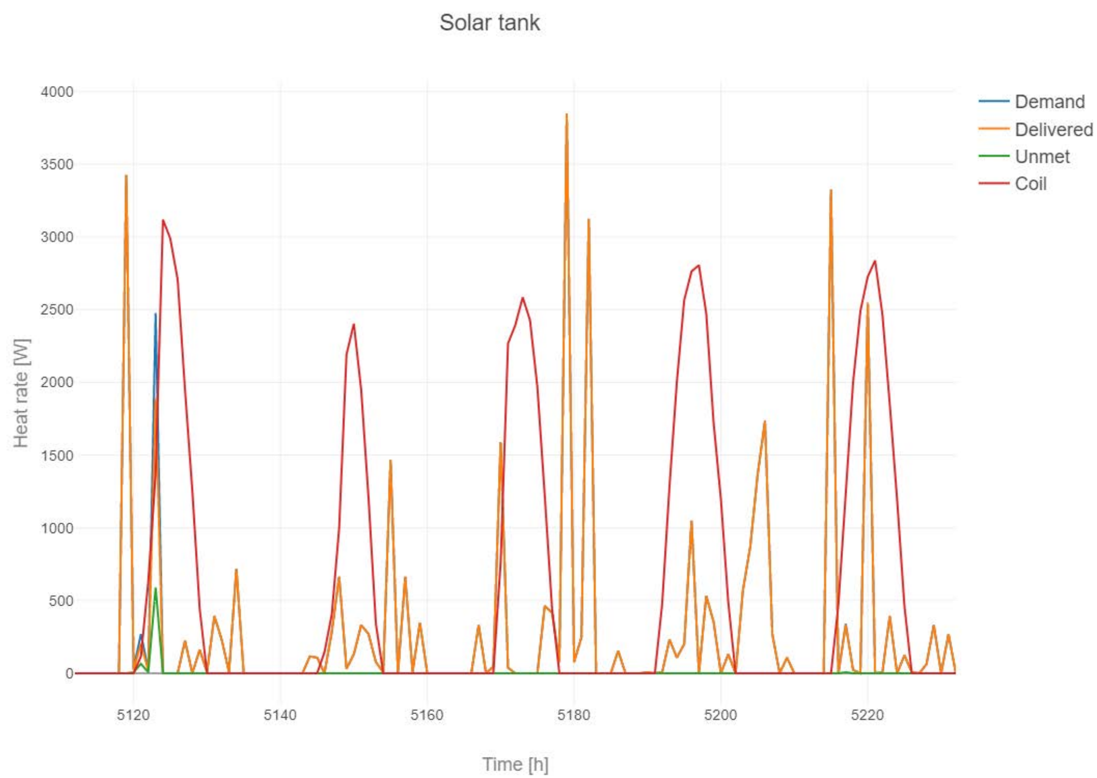
Modules

- components.py
  - Converters: solar thermal collector (flat plate and evacuated tubes), heat pump, photovoltaic, electric resistance element, gas burner
  - Storage: thermal storage tank (implemented as solar thermal coil-in tank and HP coil-in tank), conventional gas tank WH
  - Distribution: pipe loss, pumps, inverter
- models.py
  - Solar thermal system with tankless or gas tank WH backup
  - Solar electric with electric tankless backup
  - Conventional gas tank WH
- source_and_sink.py
  - Weather processor
  - End-use loads

Solar Thermal Performance Simulation

Individual (4 occupants) household, tankless backup, summer





Collector area: 66 sqft
Tank volume: 85.8 gal
Tankless WH input power: 51 kW

Solar Thermal Annual Energy Use

	Retrofit		New	
	Individual	Community	Individual	Community
Energy	**kWh/year**	**kWh/year**	**kWh/year**	**kWh/year**
Net Heat Demand	2,657	11,001	2,657	11,001
Solar Heat Delivered To Tank	4,324	17,054	4,324	17,054
Heat Loss - Lower Tank Volume	242	626	242	626
Heat Loss - Upper Tank Volume	259	659	259	659
Tank Heat Delivered	2,444	10,213	2,444	10,213
Tank Unmet Heat	213	787	213	787
Dumped Heat	1,375	5,522	1,375	5,522
Backup Heat Delivered	213	787	213	787
Energy Use - Gas	753	2,939	251	926
Energy Use - Gas, Summer	216	828	13	16
Energy Use - Gas, Winter	537	2,111	238	910
Unmet Heat	-	-	-	-
Total Heat Delivered	2,657	11,001	2,657	11,001
Project End-Use Load	0	0	0	0
Energy Use - Electricity	139	1,312	139	1,312
Energy Use - Electricity, Summer	66	577	66	577
Energy Use - Electricity, Winter	73	735	73	735
Average Temperature	**degF**	**degF**	**degF**	**degF**
Temperature - Upper Tank Volume	134	135	134	135
Temperature - Lower Tank Volume	129	131	129	131
Temperature - Tank Coil Out	132	134	132	134
Hot Water Set Temperature	120	120	120	120
Temperature - Ambient	57	57	57	57
Temperature - Water Main	55	55	55	55
Solar Fraction	0.92	0.93	0.92	0.93

Sizing	
Solar	Conventional
CSI Handbook	DOE guideline
Collector sqft: 1.2 GPD	Peak hour demand
Tank gal: 1.3 collector sqft	

CSI GPD calculation applied per household

Individual (4 occupants)

Collector Area: 66 sqft
Tank volume: 86 gal
Tankless WH: 51 kW

Community (4, 4, 3, 5 occupants)

Collector Area: 264 sqft
Tank volume: 343 gal
Tankless WH: 51, 51, 44, 57 kW

Distribution losses are not included

Principal Sources

End-Use Loads

- NREL “Tool for Generating Realistic Residential Hot Water Event Schedules” (Hendron, et al.) (www.energy.gov/eere/buildings/downloads/dhw-event-schedule-generator)
- California Study “Development of Realistic Water Draw Proles for California Residential Water Heating Energy Estimation”, Kruis, Wilcox, Lutz & Barnaby (2016)
- Water Research Foundation, “Residential End-Uses of Water Study”

System Modeling

- M. Wetter, W. Zuo, T. S. Nouidui, and X. Pang, “Modelica Buildings library,” J. Build. Perform. Simul., vol. 7, no. 4, pp. 253–270, Jul. 2014.
- NREL SAM Manual and documentation (https://sam.nrel.gov/)
- U.S. Department of Energy - Energy Efficiency & Renewable Energy, “Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Water Heaters,” Washington, D.C., 2001.
- SRCC OG-100, OG-300
- ASHRAE 93:2003, ISO 9806:2013, ISO 12975, SRCC Standard 100

Further research findings and results will be available in the report published as the project is finalized.

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