
APEX
ANALYTICS
Community-specific Cost-benefit Evaluation Framework for Beneficial Electrification
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October 11, 2022

How might we best achieve building electrification goals in Fort Collins?

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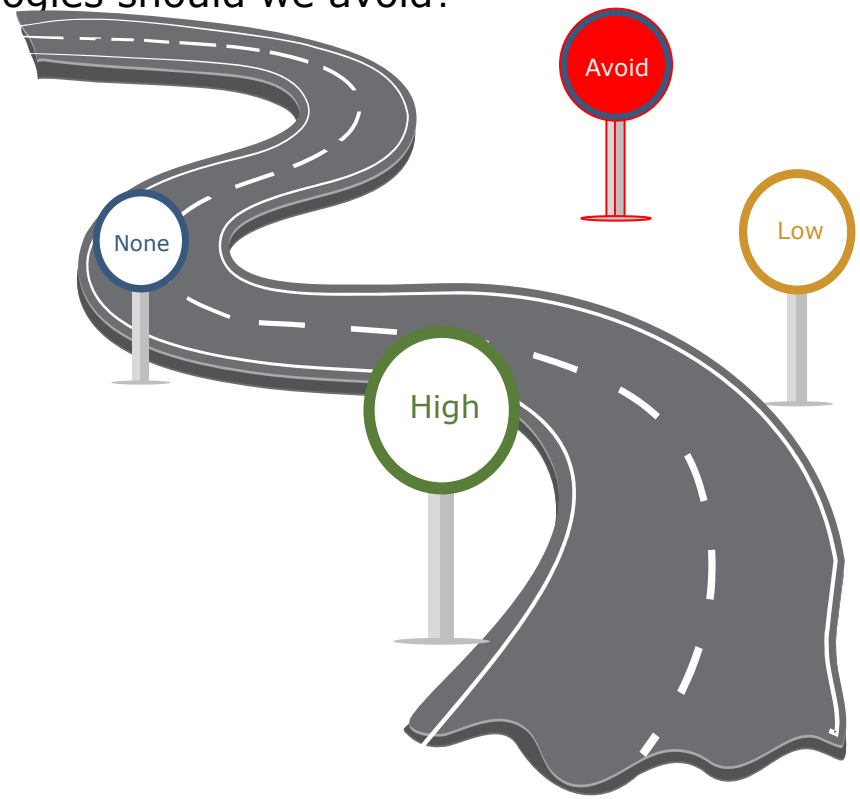
- Which opportunities should we pursue now vs 3-5 years from now? Which technologies should we avoid?



High priority :
Opportunities with high technical potential that deliver significant benefits to customers, utility, and environment

Low priority :
Opportunities that still deliver benefits, but either have smaller potential or have some substantial barriers that will restrict adoption or carry some additional risks that are difficult to quantify

No/Low Impact :
Opportunities that offer tiny technical potential, such that they will have insignificant impacts

High Risk/Avoid:
Opportunities that create significant risks to customers or utility, such as increased outages or costs, which should be avoided at this time

Development of community test

Problem

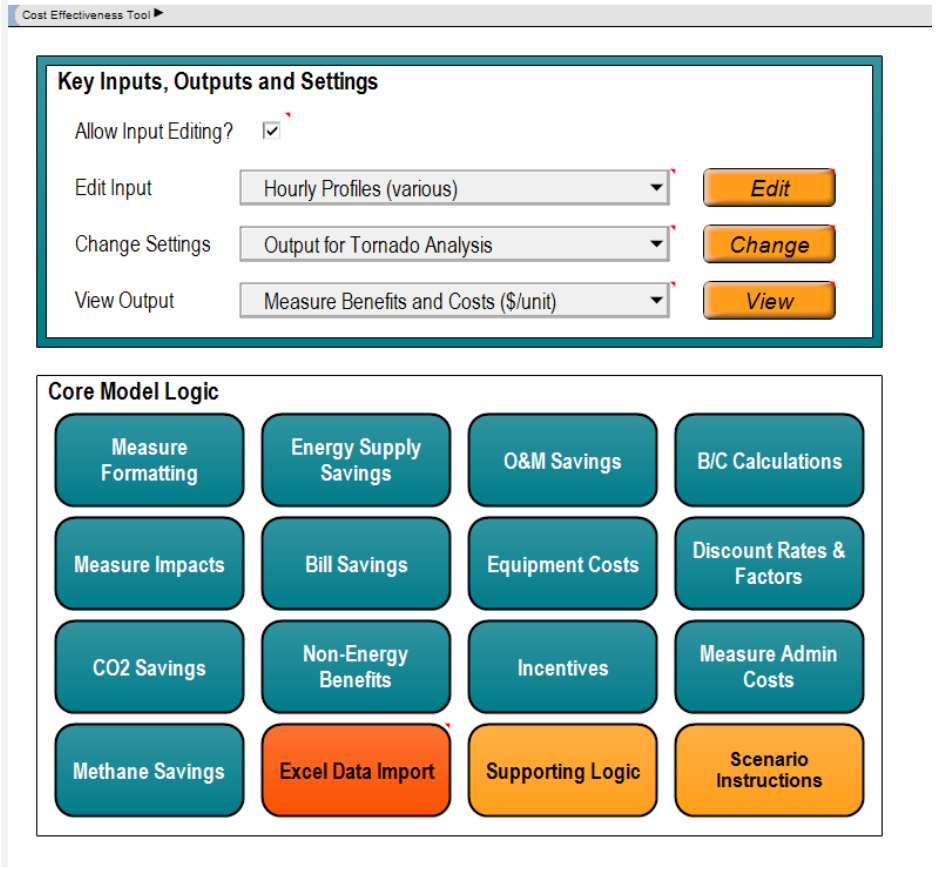
- Building electrification is different because electricity consumption increases
- Traditional benefit-cost approaches not great for our context

Solution

- Follow National Standard Practice Manual (NSPM) guidance for jurisdiction-specific test
- Work with stakeholders to agree on what to include
- Develop NSPM JST-compatible Flexible CE tool in Analytica

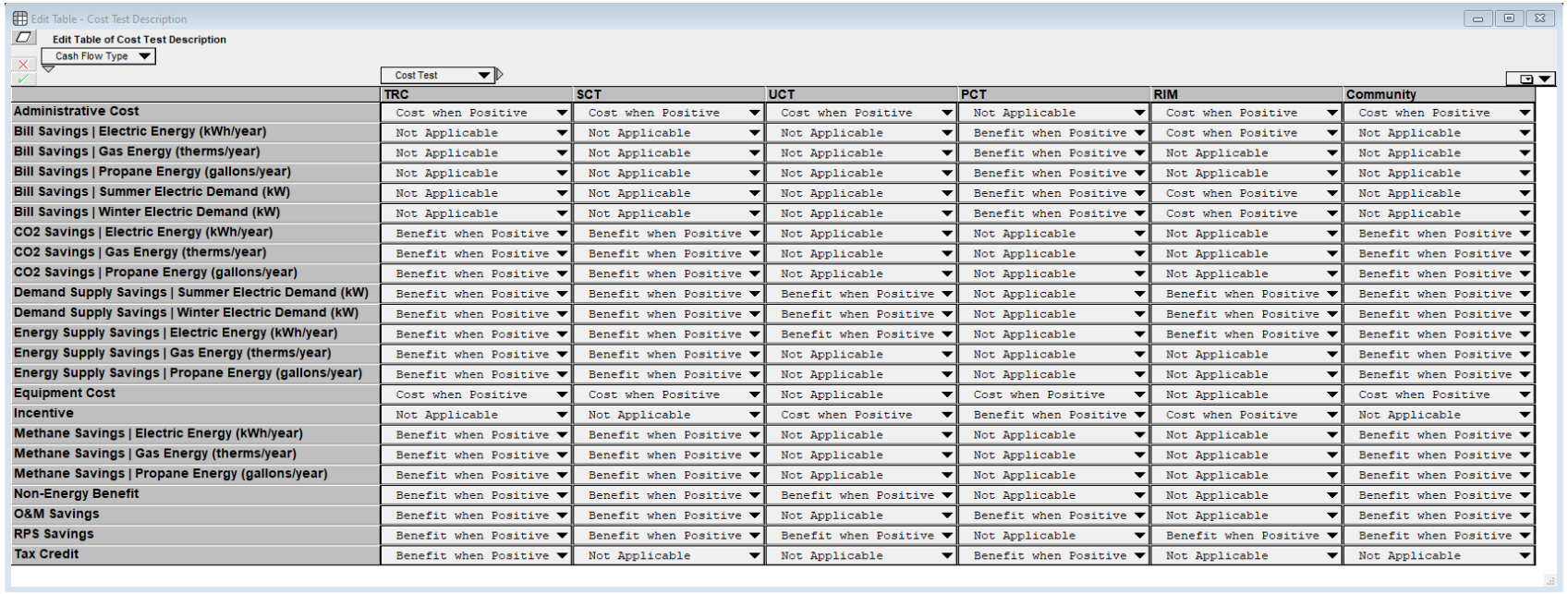
Flexible Cost-Effectiveness Tool: flexCE

- New cost-effectiveness tool offers radical flexibility and transparency
- Jointly developed by Lumina and Apex
- Easy to implement NSPM jurisdiction-specific changes to tests



Flexible Cost-Effectiveness Tool: flexCE

The flexible cost-effectiveness tool allows us to easily make significant changes to the community test inputs for future iterations.



Edit Table - Cost Test Description

Edit Table of Cost Test Description

Cash Flow Type: Cost Test

	TRC	SCT	UCT	PCT	RIM	Community
Administrative Cost	Cost when Positive	Cost when Positive	Cost when Positive	Not Applicable	Cost when Positive	Cost when Positive
Bill Savings | Electric Energy (kWh/year)	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive	Cost when Positive	Not Applicable
Bill Savings | Gas Energy (therms/year)	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive	Not Applicable	Not Applicable
Bill Savings | Propane Energy (gallons/year)	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive	Not Applicable	Not Applicable
Bill Savings | Summer Electric Demand (kW)	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive	Cost when Positive	Not Applicable
Bill Savings | Winter Electric Demand (kW)	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive	Cost when Positive	Not Applicable
CO2 Savings | Electric Energy (kWh/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
CO2 Savings | Gas Energy (therms/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
CO2 Savings | Propane Energy (gallons/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
Demand Supply Savings | Summer Electric Demand (kW)	Benefit when Positive	Benefit when Positive	Benefit when Positive	Not Applicable	Benefit when Positive	Benefit when Positive
Demand Supply Savings | Winter Electric Demand (kW)	Benefit when Positive	Benefit when Positive	Benefit when Positive	Not Applicable	Benefit when Positive	Benefit when Positive
Energy Supply Savings | Electric Energy (kWh/year)	Benefit when Positive	Benefit when Positive	Benefit when Positive	Not Applicable	Benefit when Positive	Benefit when Positive
Energy Supply Savings | Gas Energy (therms/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
Energy Supply Savings | Propane Energy (gallons/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
Equipment Cost	Cost when Positive	Cost when Positive	Not Applicable	Cost when Positive	Not Applicable	Cost when Positive
Incentive	Not Applicable	Not Applicable	Cost when Positive	Benefit when Positive	Cost when Positive	Not Applicable
Methane Savings | Electric Energy (kWh/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
Methane Savings | Gas Energy (therms/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
Methane Savings | Propane Energy (gallons/year)	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Not Applicable	Benefit when Positive
Non-Energy Benefit	Benefit when Positive	Benefit when Positive	Benefit when Positive	Not Applicable	Not Applicable	Benefit when Positive
O&M Savings	Benefit when Positive	Benefit when Positive	Not Applicable	Benefit when Positive	Not Applicable	Benefit when Positive
RPS Savings	Benefit when Positive	Benefit when Positive	Benefit when Positive	Not Applicable	Benefit when Positive	Benefit when Positive
Tax Credit	Benefit when Positive	Not Applicable	Not Applicable	Benefit when Positive	Not Applicable	Not Applicable

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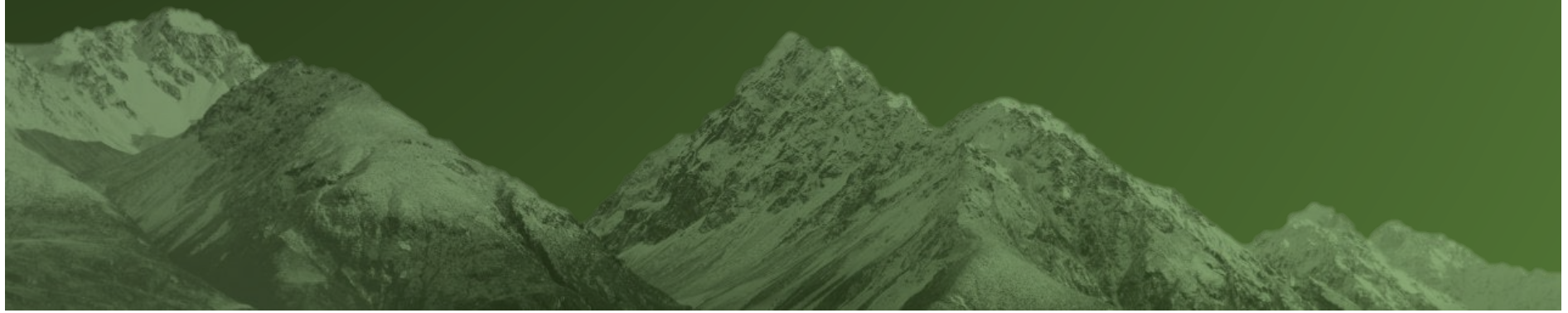
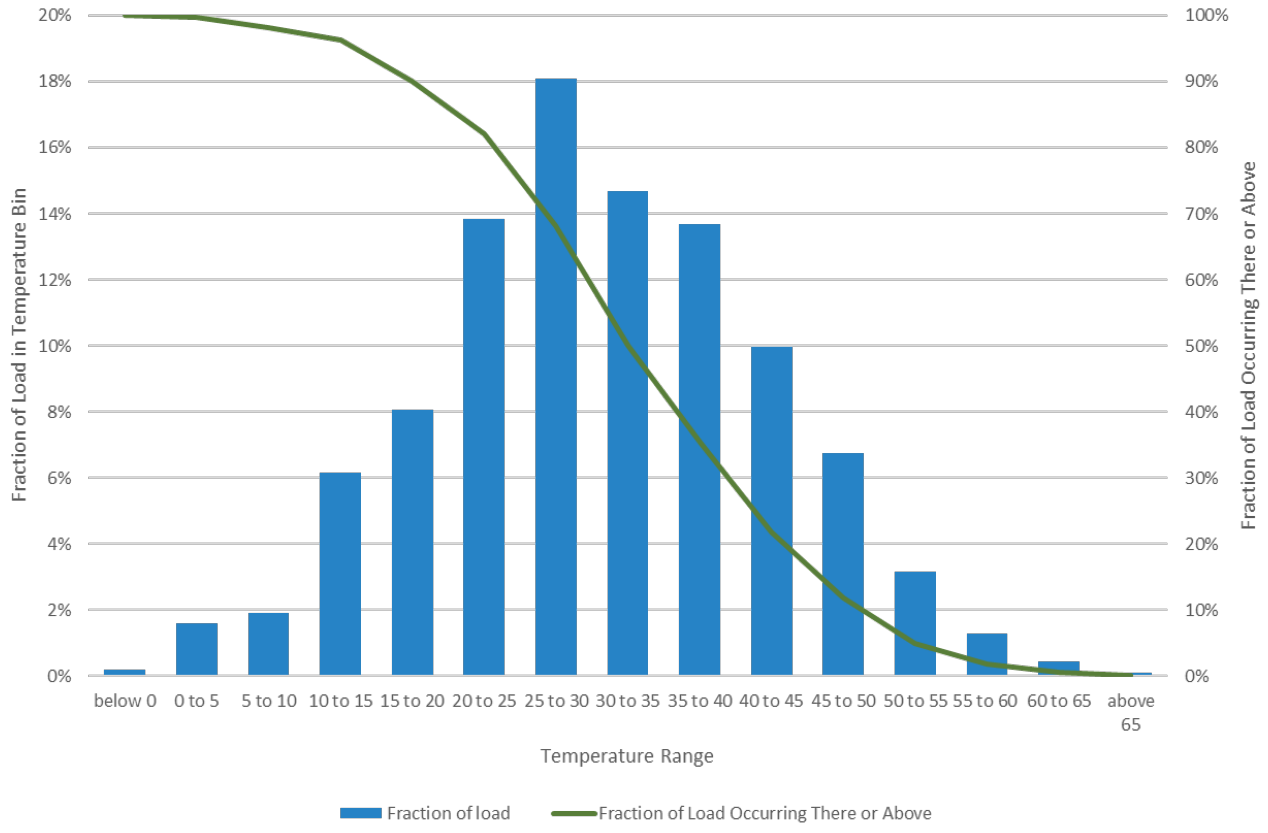
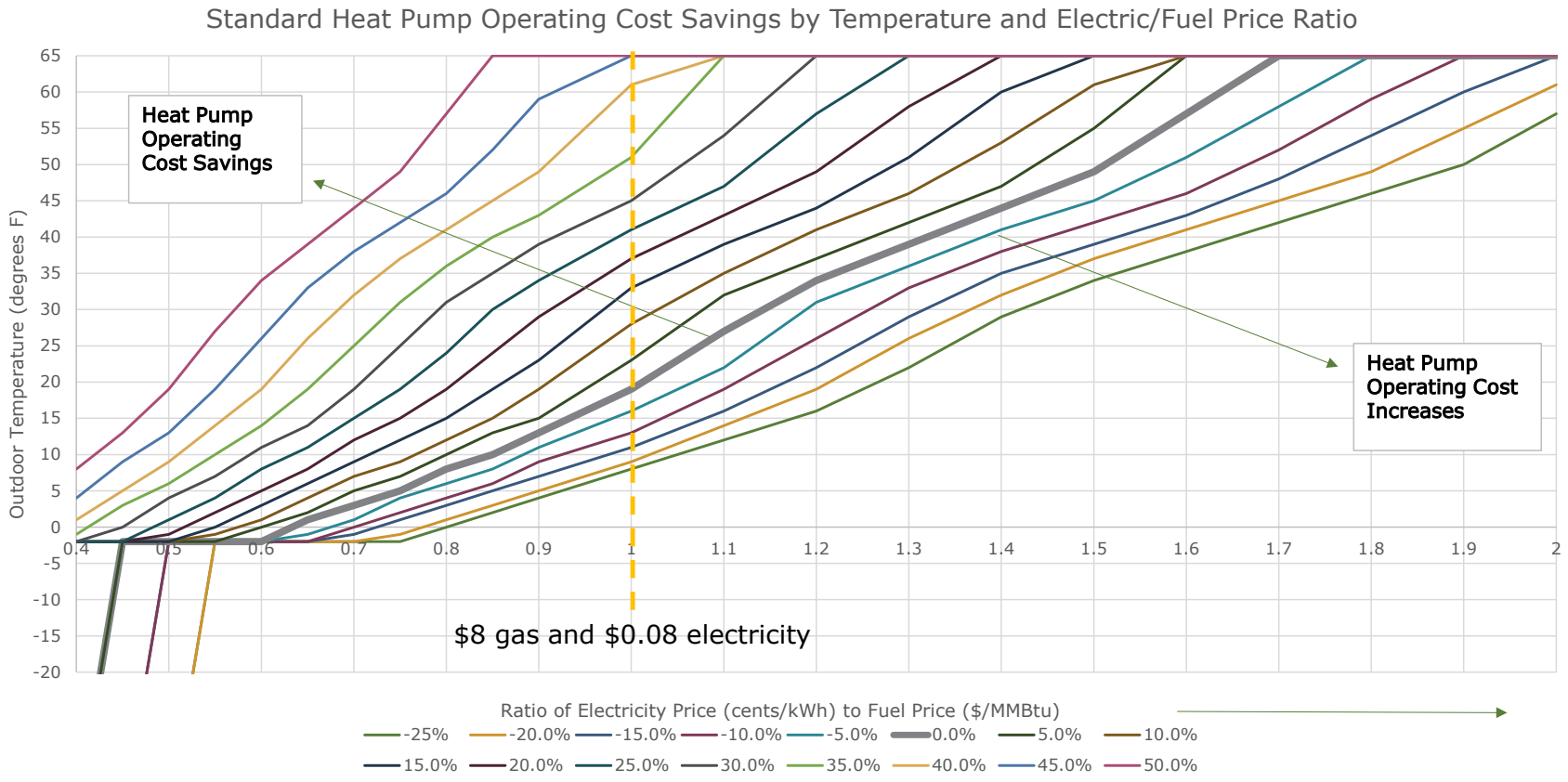
Heat Pump Operation



Fort Collins space heating loads occur primarily between 20 and 40 degrees F.



Operating Economics of Heat Pumps for Space Heating depend on Temperature and Cost of Electricity Relative to Gas.



Operating Economics of Heat Pumps for Space Heating depend on Temperature and Cost of Electricity Relative to Gas.

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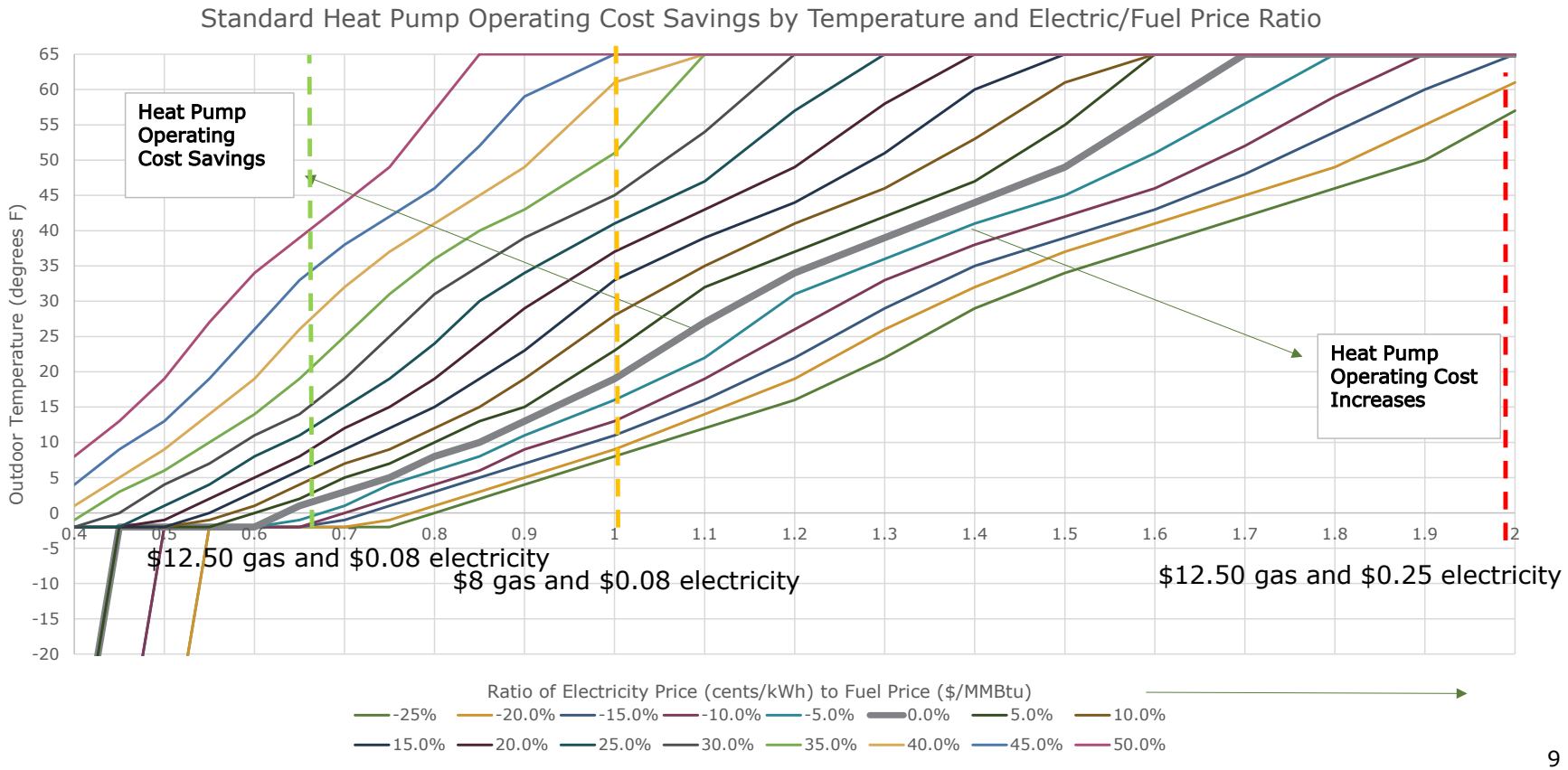
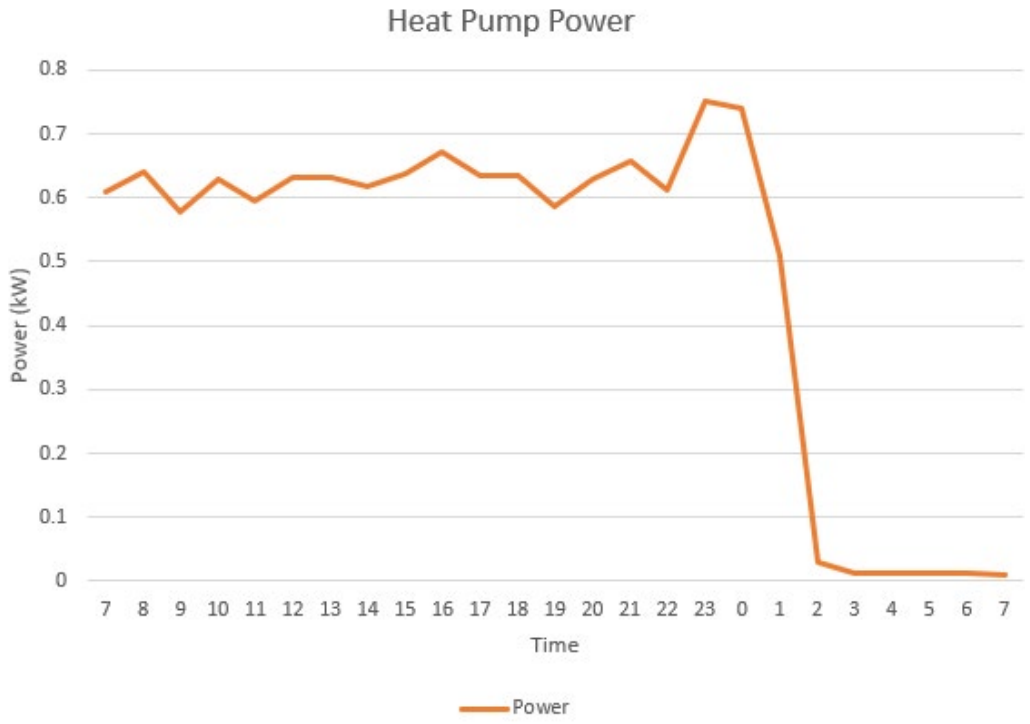
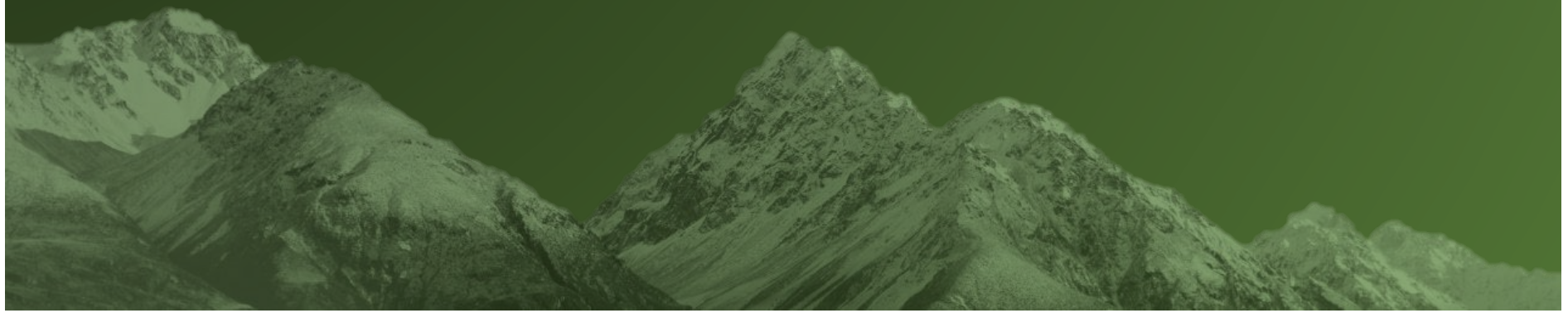


How to we keep people warm during extreme cold weather?

- Capacity of heat pumps drops
- Hybrid heat pumps use existing gas furnace (0 grid impacts)
- Full electrification heat pumps use electric resistance (10 kW+/home)



Measure Screening



Measure Screening Criteria

- Participant Cost Test
- Ratepayer Impact Test
- Community Test
- GHG Abatement Cost
- Bill Savings and Incremental Cost
- Lifetime GHG Impacts
- Winter Peak Demand Impact

Best opportunity: Replace burned out or new CAC with heat pump, leaving furnace for cold weather



VS



Pros: Only costs ~$500 extra, saves 50-80% of load
Cons: Only applicable in situations where somebody was already buying a new CAC

Full displacement with electric resistance = expensive for the utility and ratepayers

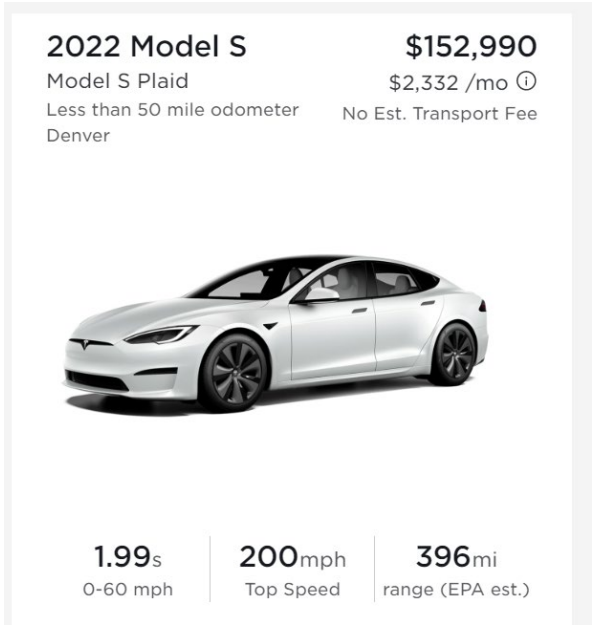
- Fort Collins will become winter peaking sometime in 2030s.
- Each additional kW of winter peak costs $100+/year to meet with gas combustion turbines
- **Present value of capacity cost for 10 kW electric resistance was calculated as $17,000. Electric resistance backup heat is still a bad idea.**

Adding heat pumps to homes with gas and without AC is a tough sell

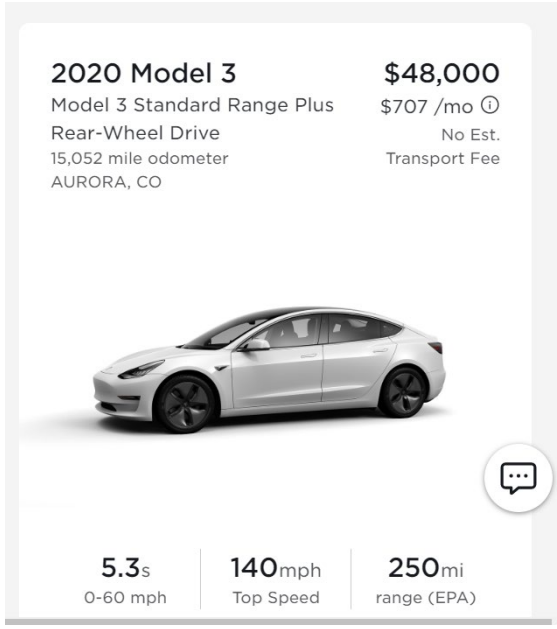


There is no economic case to the customer with gas without the cooling benefits of heat pumps.

Cold climate heat pumps cost A LOT



VS



Consider for 100% displacement, but still need to solve backup heat problem

Key Findings

- Existing space heating, water heating, and new buildings account for over 95% of 2040 GHG emissions from buildings
- Full electrification of heating adds ~10 kW winter peak demand per home
- Keeping electricity prices low relative to gas is the key to heat pump operating economics
- Partial displacement measures add significant electricity consumption w/out adding peak load – benefits pay for high rebates
- Partial displacement of furnaces with central heat pumps at all efficiency levels offers large carbon savings at low costs
- Proper controls configuration enables much higher GHG savings per heat pump

Phased approach

Phase 1:

Build market awareness, customer knowledge, and contractor capability

- *What would it take for contractors to almost always install a heat pump instead of an air conditioner?*
- Offer contractor training and downstream rebates for ALL heat pumps – not just cold climate
- Prioritize broad-based hybrid solutions

Phased recommendations

Phase 2:

Throttle widespread adoption in most cost-effective applications

- Adopt codes for new construction
- Build midstream offerings (manufacturers/distributors)
- Improve heat pump economics through rate design

Phased recommendations

Phase 3:

Push toward zero carbon

- Adopt codes for heat pumps/heat pump water heaters in all new installations
- Require all-electric new homes
- Could happen sooner outside of regular code review/adoption cycles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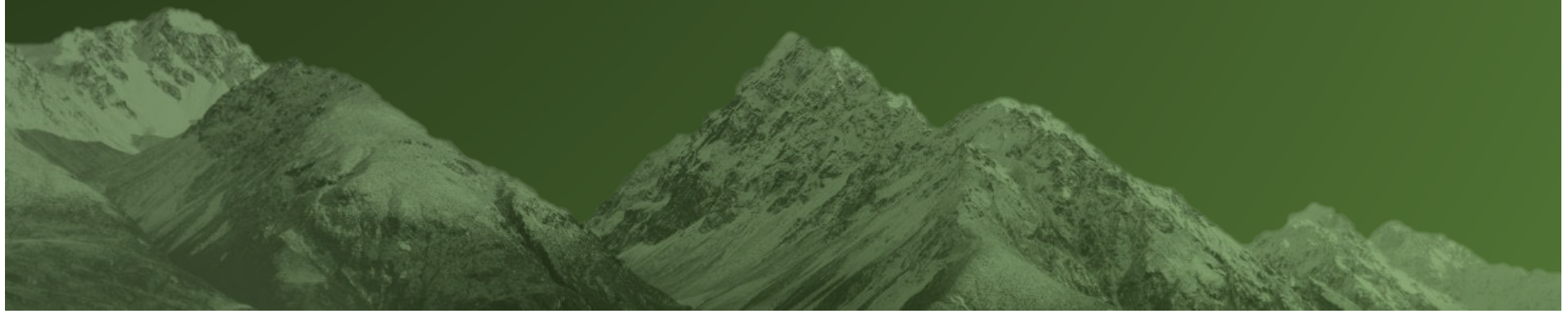
Any Questions?
Justin Spencer, justins@apexanalyticsllc.com
Thank you to City of Fort Collins and City of Longmont.

Appendix Slides



Existing Fossil Fuel Recommendations (near)

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Focus on partial displacement heat pumps, water heating	Change heat pump/central AC rebates to promote heat pumps	Increase education and support
• No requirement for full electrification • No extra rebates for full electrification	• Stop incenting central AC; require heat pumps for central cooling efficiency rebates • Remove cold climate requirement for central heat pumps • Keep ductless rebates • Offer new base rebate (e.g. $500-1000) for ANY heat pump installed, regardless of efficiency or commissioning • Offer additional high efficiency rebate (e.g. $1000 more) for high efficiency heat pump with controls commissioning	• Provide customer education/support focused on key benefits, payback, and set expectations • Provide contractor training/support focused on promoting use of lower switchover temps • Provide customer education/support focused on heat pump operations (scheduling, maintenance, differences vs gas furnace)

Existing Fossil Heating Recommendations (med/long)

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Medium-term	Long-term
• Consider extra rebate incentives for early retirements of existing fossil equipment • Develop low-income heating program • Develop measures to incent use of proper controls to increase usage at colder temperatures (adding lockouts, lower switchover temps, etc.)	• For 2028 code implementation cycle, require all central AC installations be heat pumps • Develop additional offerings focused on full electrification based on improving technologies of various kinds

Measure Screening Details

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PCT (Customer):

- Positive net benefits: customer comes out ahead w/out rebates, negative needs rebate to offset.
- For IQ, negative net benefit needs to be offset with incentive.

RIM (Ratepayer):

- Positive net benefits: ratepayer comes out ahead, negative is red flag
- Difference between Ratepayer – Customer = Max Incentive

Community:

- Includes emissions and non-energy benefits
- Positive net benefits: community comes out ahead

CO2 Abatement Cost:

- (Community Test without GHG)/(tons of GHG)
- Lower is cheaper; compare to $76 in community test

Total Bill Savings; Incremental Cost

- Annual bill savings net of fossil and electric impacts; Positive is good;
- Upfront incremental cost to customer

Winter Peak Demand Impact

- Winter peak impact in kW
- $1700/kW cost not included in other tests

Lifetime GHG Impacts

- Tons of CO2e saved over life of measure
- Results for measure implemented in 2022 with dropping electricity GHG impacts

Composite Measure Score

- 4/5 are high priority
- 3/2 are low priority or no impact
- 1 is to be avoided

Best opportunity: Replace burned out or new CAC with heat pump, leaving furnace for cold weather

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Standard and medium efficiency HP with 30 degree switchover (50% displacement)

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	ROB	$ (380)	$ 1,236	$ 2,774	$ (90)	$ 12	$ 450	0	15.9	4
16 SEER CHP | Gas furnace | CAC | CAC ROF - HE | 50% Disp | Fort Collins	ROB	$ (196)	$ 1,111	$ 2,895	$ (93)	$ 29	$ 450	0	16.3	4
16 SEER CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	ROB	$ (2,196)	$ 1,111	$ 1,095	$ 18	$ 29	$ 2,250	0	16.3	3

Standard and medium efficiency HP with 20 degree switchover (80% displacement)

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | CAC | CAC ROF | 80% Disp | Fort Collins	ROB	$ (381)	$ 2,033	$ 4,738	$ (99)	$ 12	$ 450	0	25.8	4
16 SEER CHP | Gas furnace | CAC | CAC ROF - HE | 80% Disp | Fort Collins	ROB	$ 10	$ 1,777	$ 5,010	$ (103)	$ 49	$ 450	0	26.7	5
16 SEER CHP | Gas furnace | CAC | CAC ROF | 80% Disp | Fort Collins	ROB	$ (1,990)	$ 1,777	$ 3,210	$ (35)	$ 49	$ 2,250	0	26.7	4

We want people to use heat pumps as much as possible – better controls are key!

Adding heat pumps to homes with gas and without AC is not very cost-effective

- Adding heat pumps to homes without AC generally has poor customer and community economics.
- Homes with propane may have a different story

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | No AC | RET | 50% Disp | Fort Collins	RET	$ (9,082)	$ 2,572	$ (1,839)	$ 217	$ (105)	$ 7,200	0	14.0	2
16 SEER CHP | Gas furnace | No AC | RET | 50% Disp | Fort Collins	RET	$ (10,932)	$ 2,405	$ (3,264)	$ 315	$ (90)	$ 9,000	0	14.2	2
CC CHP | Gas furnace | No AC | RET | 50% Disp | Fort Collins	RET	$ (13,542)	$ 2,073	$ (5,382)	$ 444	$ (52)	$ 11,700	0	15.0	2
14 SEER CHP | Gas furnace | No AC | RET | 80% Disp | Fort Collins	RET	$ (9,084)	$ 3,369	$ 124	$ 80	$ (105)	$ 7,200	0	23.9	3
16 SEER CHP | Gas furnace | No AC | RET | 80% Disp | Fort Collins	RET	$ (10,542)	$ 2,946	$ (1,029)	$ 126	$ (52)	$ 9,000	0	25.1	3

Cold climate heat pumps cost A LOT

- Economics are not very good
- Provide benefits, but incremental cost is much higher, sinking participant economics
- Consider for 100% displacement, but still need to solve backup heat problem

Measure (Efficient name | Baseline heat name | Baseline cool name | Upgrade type | Displacement Case | City Name)	PCT	RIM	Communi	CO2 Abatement Co	Total Bill Saving	Incremental Co	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
CC CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	$ (5,140)	$ 1,071	$ (1,572)	$ 181	$ 35	$ 4,950	0	16.4	2
CC CHP | Gas furnace | CAC | CAC ROF | 80% Disp | Fort Collins	$ (5,027)	$ 1,800	$ 482	$ 67	$ 46	$ 4,950	0	26.6	3
CC CHP | Gas furnace | CAC | CAC ROF | 100% Disp | Fort Collins	$ (6,112)	$ 2,337	$ 713	$ 63	$ 38	$ 5,850	10	32.4	1

Adding heat pumps to propane-heated homes with boilers = mixed economics

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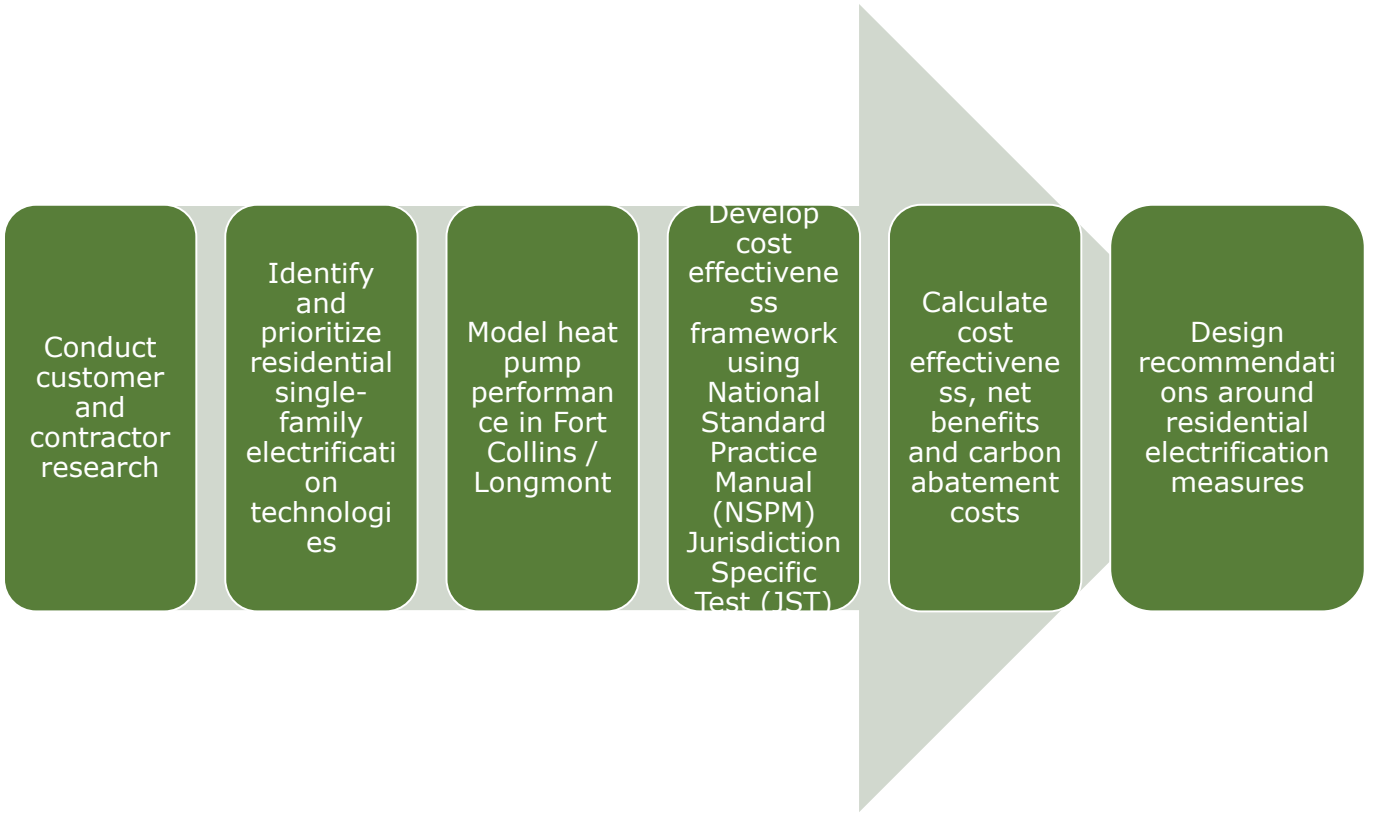
- A cold-climate ductless heat pump displacing propane boiler usage has poor participant economics (but maybe not so bad after the Inflation Reduction Act!)
- Other economics are strong

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
CC DHP | Gas boiler | Cooling blend | RET | 50% Disp | Fort Collins	RET	$ (13,391)	$ 1,906	$ (5,487)	$ 446	$ (38)	$ 11,700	0	15.2	3
CC DHP | Gas boiler | Cooling blend | RET | 80% Partial Disp | Fort Collins	RET	$ (13,279)	$ 2,635	$ (3,432)	$ 220	$ (27)	$ 11,700	0	25.4	3
CC DHP | Gas boiler | Cooling blend | RET | 100% Full Disp | Fort Collins	RET	$ (15,363)	$ 3,172	$ (4,102)	$ 216	$ (35)	$ 13,500	10	31.2	1
CC DHP | Gas boiler | Cooling blend | ROF/New Central Cooling | CC DHP | 100%	ROB	$ (10,363)	$ 3,172	$ 398	$ 72	$ (35)	$ 9,000	10	31.2	1
CC DHP | Propane boiler | Cooling blend | RET | 50% Disp | Fort Collins	RET	$ (9,725)	$ 1,906	$ (395)	$ 104	$ 312	$ 11,700	0	20.4	3
CC DHP | Propane boiler | Cooling blend | RET | 80% Partial Disp | Fort Collins	RET	$ (7,185)	$ 2,635	$ 5,030	$ (63)	$ 555	$ 11,700	0	34.0	4
CC DHP | Propane boiler | Cooling blend | RET | 100% Full Disp | Fort Collins	RET	$ (7,803)	$ 3,172	$ 6,397	$ (68)	$ 687	$ 13,500	10	41.8	1
CC DHP | Propane boiler | Cooling blend | ROF/New Central Cooling | CC DHP |	ROB	$ (2,803)	$ 3,172	$ 10,897	$ (175)	$ 687	$ 9,000	10	41.8	1

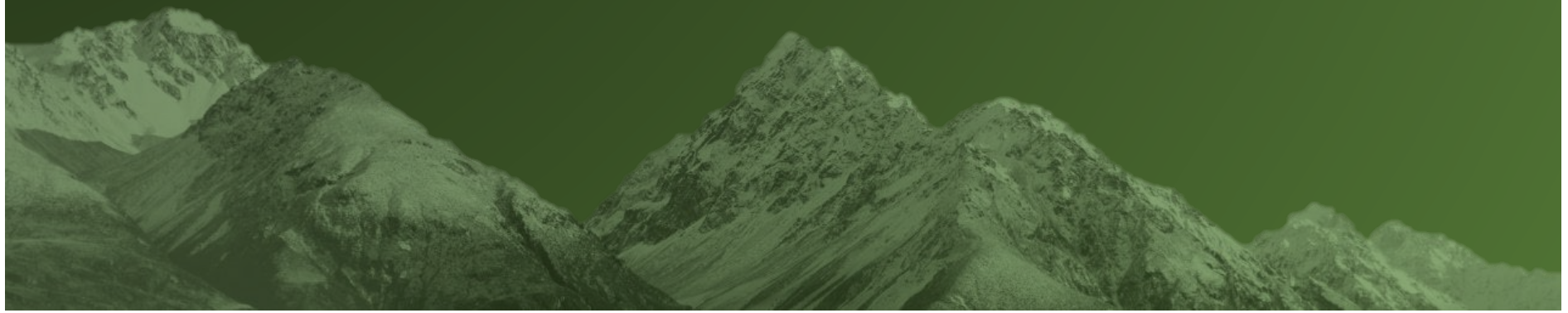
Research Approach



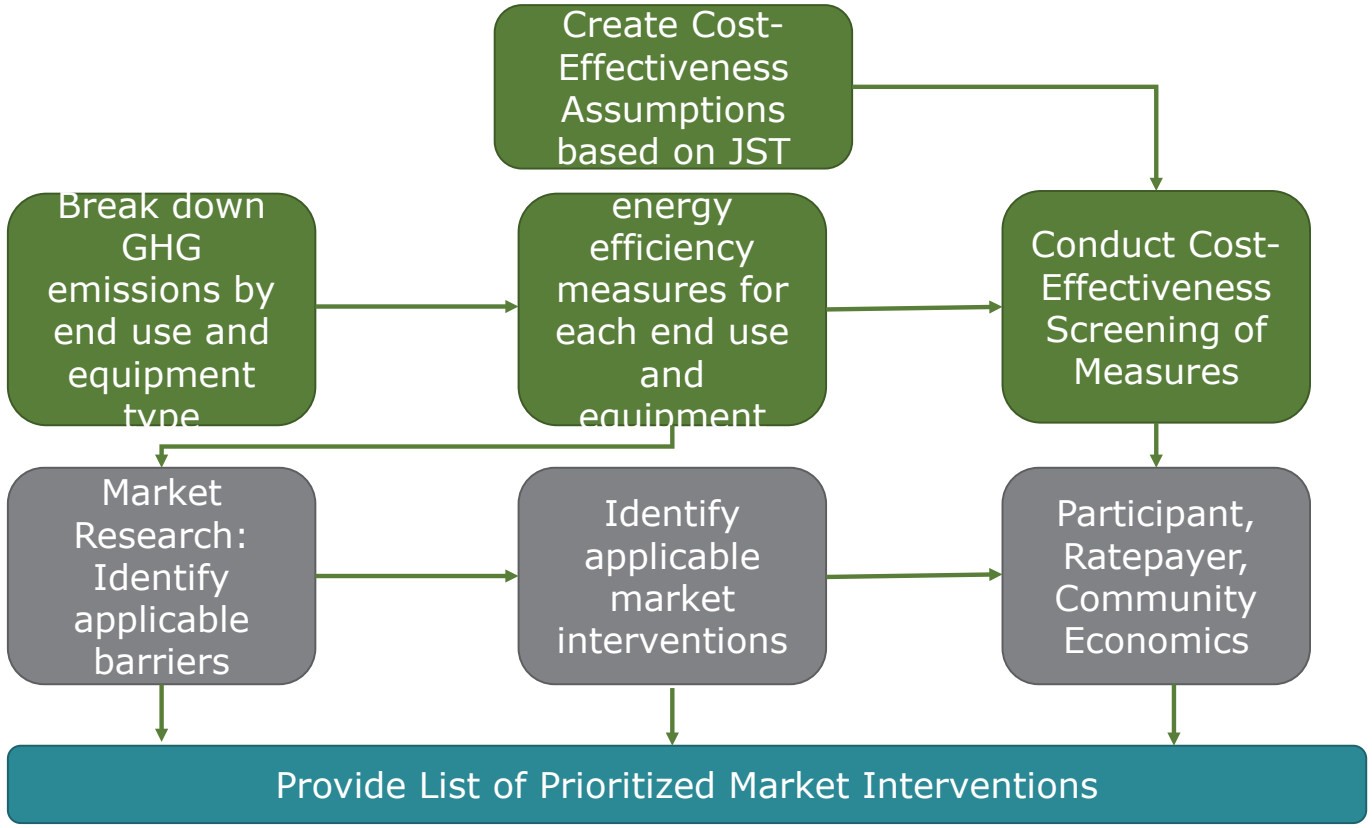
Existing Fossil-Fueled Space Heating Near-term Recommendations

Focus on partial displacement heat pumps, water heating.	Change heat pump/CAC rebates to promote heat pumps.	Increase education and support
• No requirement for full electrification • No extra rebates for full electrification	• Stop incenting central AC; require heat pumps for central cooling efficiency rebates. • Remove cold climate requirement for central heat pumps. • Keep ductless rebates. • Offer new base rebate (e.g. $500-1000) for	• Provide customer education/support focused on key benefits, payback, and set expectations • Provide contractor training/support focused on promoting use of lower switchover temps • Provide customer

Approach



Overall Approach



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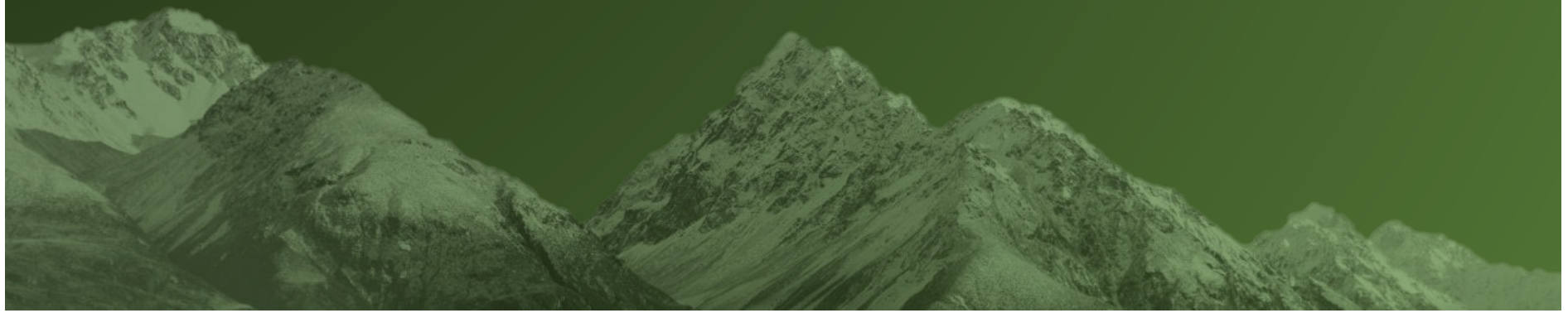
Understanding the problem: Building End Use Emissions



Residential space and water heating make up the majority of non-electric building greenhouse gas emissions.

- 72% of expected 2040 GHG building emissions (all gas/propane) come from residential sector – and some multifamily is in commercial
- Without intervention, 70% of 2040 residential emissions will be from existing building stock and 30% will be from new building stock

End Use	Existing/New	% of 2040 Residential GHG Emissions
Space Heating	Existing	52%
Space Heating	New	23%
Water Heating	Existing	16%
Water Heating	New	6%
Other	Existing	2%
Other	New	1%

- 84% of existing homes have furnaces; 65% of homes with furnaces have central AC.

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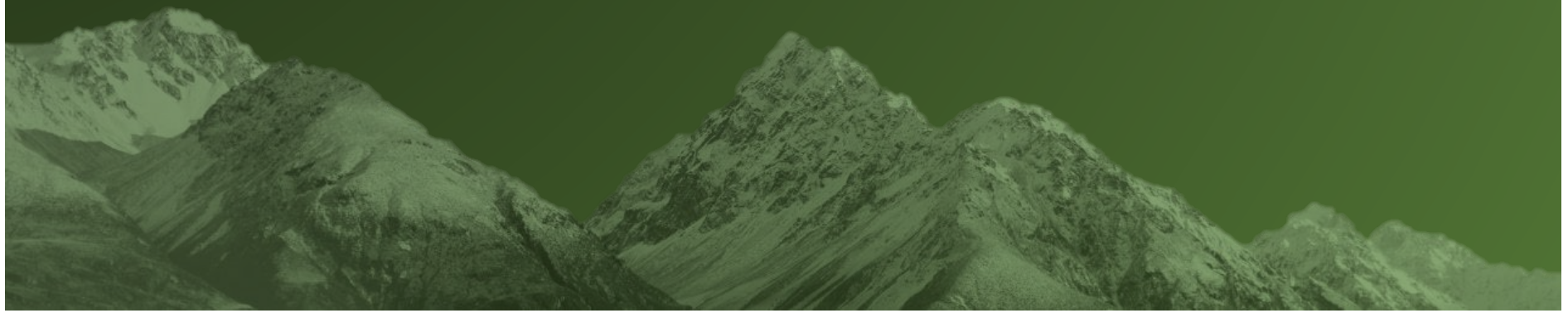
Potential grid constraints



Fort Collins has room for ~70 MW of additional winter heating demand before it becomes winter peaking.

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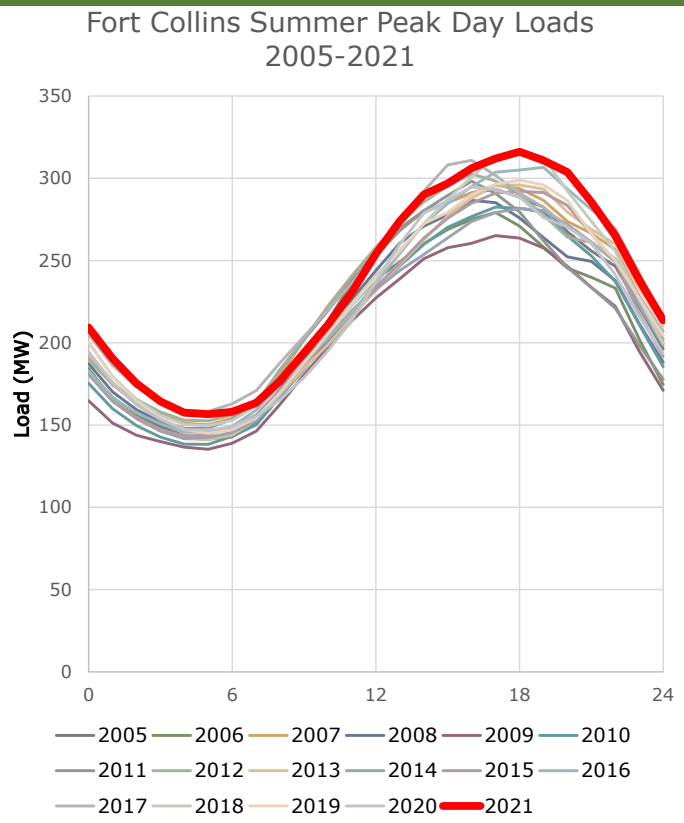

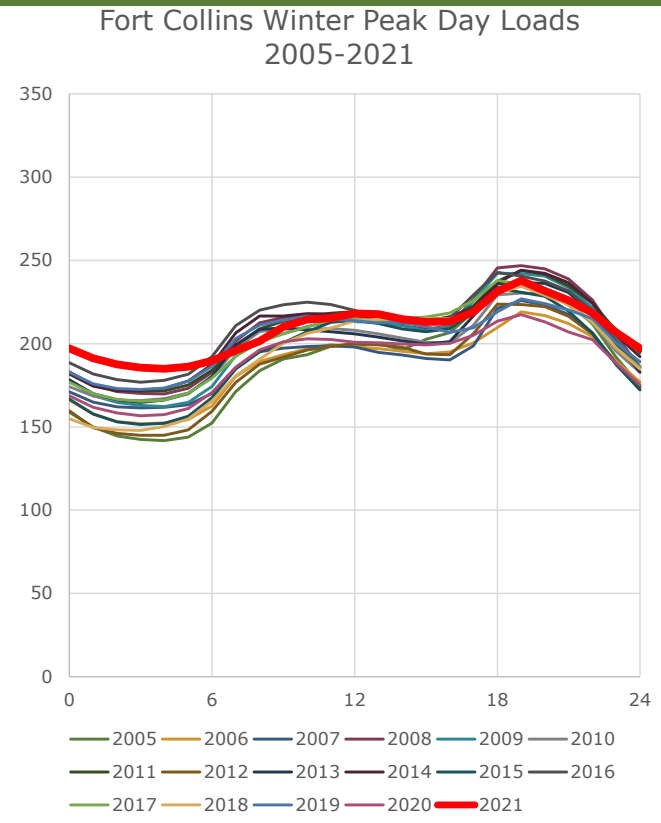

Longer term winter peak impacts are important.

- Electrification technologies have highly variable winter peak impacts
  - Hybrid heat pumps (keeping gas equipment) may have 0 impact on absolute peak, because they won't run on the coldest days
  - Full electrification heat pumps have large impacts on the grid (10 kW or more) due to electric resistance backup heat
  - Heat pump water heaters have modest impacts (~0.5 kW)

- Impacts felt both at generation/transmission level and at distribution level (both low voltage transformers and substation circuit level)

- 70 MW / 10 kW = 7,000 single family homes switch to all electric heat before switch to winter peaking

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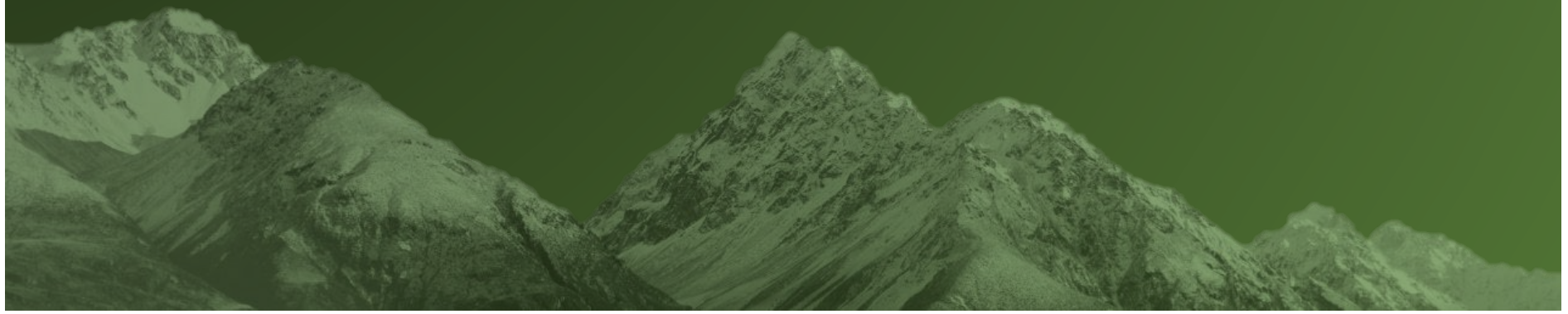
Market opportunities



First Consider Residential Building Equipment Stocks

Residential Building Equipment Stocks	Baseline Equipment	GHG impact in 2040	Measure Economics
Existing Fossil Heating	Furnace/AC (most common); Furnace/No AC; Boiler/No AC	Very Large	Very Good
New Homes	Fossil Furnace/AC; Fossil DHW; Other	Very Large	Great
Existing Fossil Hot Water	Water Heaters	Large	OK
Existing Other	Cooking; Dryers; Lawn equipment	Very Small	Poor
Existing Electric	Furnace/AC; Furnace/No AC; Resistance Heat (IQ/ renter)	Very Small	Mixed

Three different market pathways exist to influence the future equipment stock.

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Replace on burnout (ROB)

- Large stock of air conditioners, furnaces, boilers, and water heaters will get replaced as they reach end of life (~5% annual turnover)
- Influence the equipment that gets purchased and installed

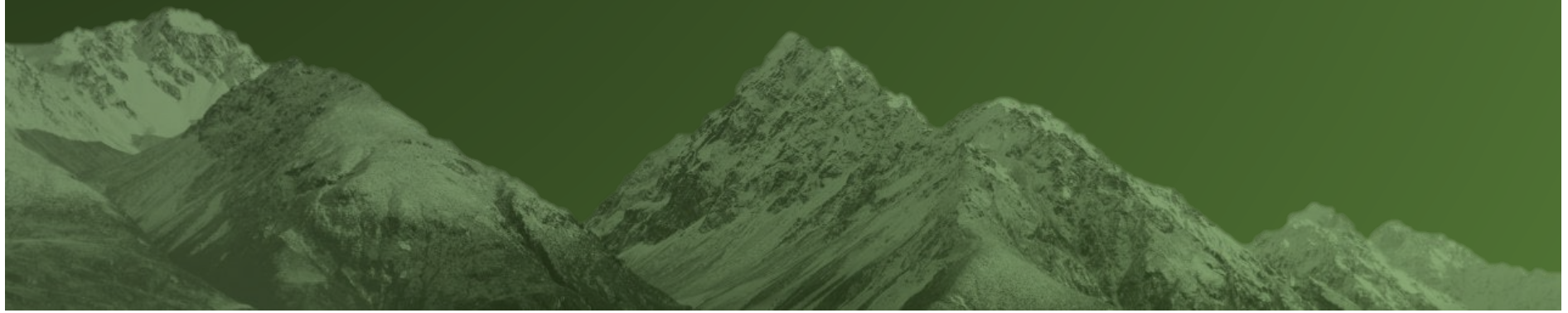
New construction (NC)

- New homes built every year
- Influence the design and equipment specified in new homes
- Also includes people adding cooling to home for first time or adding conditioned space

Retrofit (RET)

- Large stock of air conditioners, furnaces, boilers, and water heaters could be replaced
- Convince homeowners to install new equipment/retire existing equipment early

Results



Interpreting the Results

- Net Benefits = Net present value of lifetime net benefits (total benefits minus total costs)
- Carbon abatement costs = $ cost per avoided ton of carbon
  - $/ton < $76
- Focus on 3 perspectives:
  - Customer, Ratepayer, and Community tests

Customer:

- Positive net benefits: customer comes out ahead w/out rebates, negative needs rebate to offset.
- For IQ, should show bill savings, negative net benefit needs to be offset with incentive.

Ratepayer:

- Positive net benefits: ratepayer comes out ahead
- When ratepayer + customer > 0, possible for everybody to come out ahead

Community:

- Includes emissions and non-energy benefits
- Positive net benefits: community comes out ahead

Interpreting the Results

Metric	Participant	Ratepayer	Community
Electric Bill Savings	Benefit	Cost	N/A
Other Fuel Bill Savings (natural gas / propane)	Benefit	N/A	N/A
Electric Energy / Demand Supply Savings	N/A	Benefit	Benefit
Other Fuel Supply Savings (natural gas / propane)	N/A	N/A	Benefit
Avoided Emissions (CO2, Methane)	N/A	N/A	Benefit
Equipment upgrade (incremental)	Cost	N/A	Cost
Incentive	Benefit	Cost	N/A
Non-Energy Benefits	N/A	N/A	Benefit
Program Admin	N/A	Cost	Cost

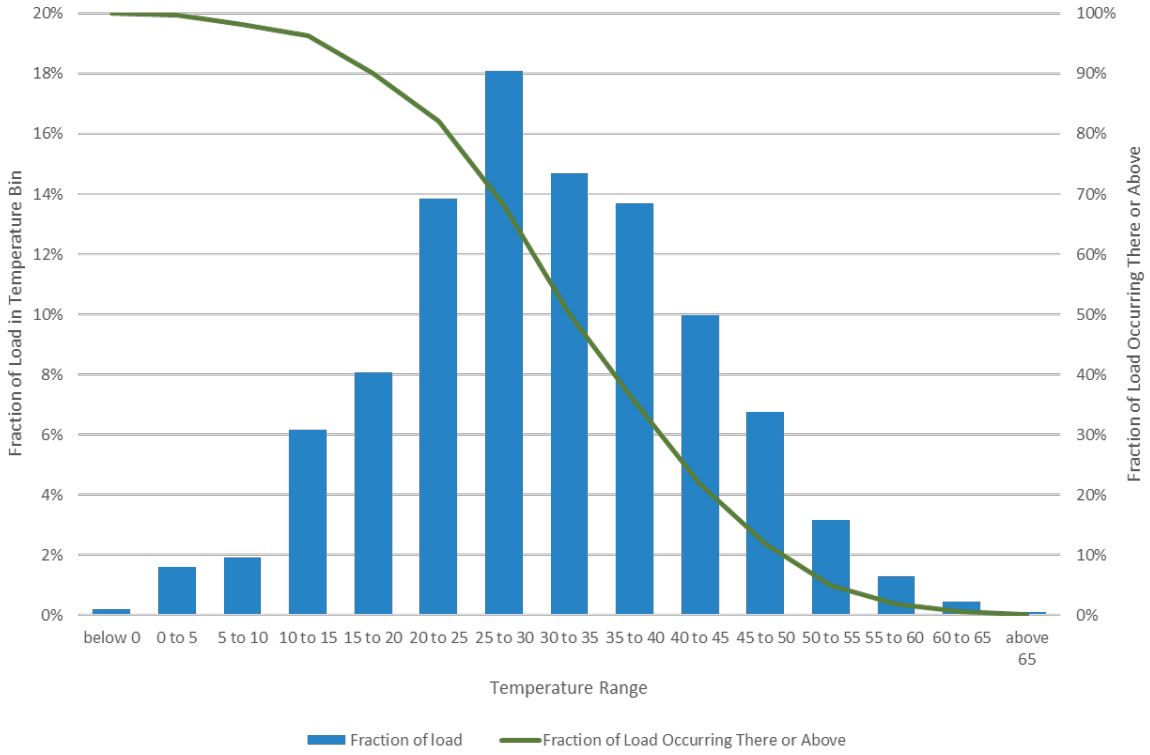
- Incentive set to ZERO = Ratepayer Net benefit minus Participant Net benefit = Incentive Ceiling
- Community: Overall including Non energy benefits

EXISTING FOSSIL-FUELED SPACE HEATING

Existing Fossil Heating

Baseline Equipment	Fraction of Homes	Electrification Solution	Cooling Equipment ROB	Early Retirement	New Cooling
Existing Furnace with CAC	56% (Longmont) 58% (Fort Collins)	Central Heat Pumps	Convince people replacing their CAC to install central HP	Convince people to early retire CAC in favor of central HP	N/A
Existing Furnace without CAC	39% (Longmont) 33% (Fort Collins)	Central Heat Pumps	N/A	Convince people to add central heat pump	Convince people adding cooling to get central heat pump
Existing Boiler without AC	3% (Longmont) 4% (Fort Collins)	Ductless Heat Pumps	N/A	Convince people to add ductless heat pump	Convince people adding cooling to get efficient ductless heat pump

Fort Collins space heating loads occur primarily between 20 and 40 degrees F.



How do heat pumps work?

- Heat pumps moves heat from one place to another place, against the direction that it wants to flow, just like a water pump moves water against the direction that it wants to flow

- Key characteristics:
  - Energy required per unit of heat moved increases as temperature drops (just like water pump working against a larger hill)
  - Capacity of heat pump also drops as temperature drops (just like a water pump working against a larger hill)

- A central heat pump is exactly the same as a central air conditioner, except for adding a reversing valve and different controls.

- A ductless AC is exactly the same as a ductless HP, except for taking out the reversing valve and heating-enabling controls.

At cold temperatures, most heat pumps cease to work.

- Normal, non-cold climate heat pumps have capacity drop off rapidly below ~20 degrees, and cease to work around 0.
- Cold climate heat pumps have the same issue, but their capacity drops off more slowly and they cease to work below -15. E.g. they get you an extra 15 degrees of operation.
- If heat pumps get buried in snow, they cease to function.
- Ground source heat pumps do not have the same problem – they continue to work at cold temperatures, because they are using the ground instead of the outdoor air as their heat source.

Heat pumps in northern Colorado generally require a backup for health and safety.

- Central heat pumps in other climates are frequently installed with electric resistance strips built into the air handler.
  - Pros: 100% electrified; Lower first cost for new construction
  - Cons: Adds ~10-12 kW of winter peak load; still struggles to meet the load in extreme conditions.

- Central heat pumps in northern Colorado typically get installed with a gas furnace backup.
  - Pros: Meet load in almost all conditions; no added winter peak load.
  - Cons: Does not fully electrify.

- Ductless heat pump installations generally leave the existing heating equipment in place.
  - Pros: Meet load in almost all conditions, no added winter peak load.
  - Cons: Does not fully electrify.

Heat pumps in northern Colorado generally require a backup for health and safety.

- A fully electric new home with a ductless heat pump would require another source of backup heat to maintain comfort during the coldest temperatures.

- Other possible backup heat sources:
  - Propane/natural gas fireplace
  - Wood pellet stoves

Customers told us…

- Low awareness of heat pumps but were open to the idea
- View cities as taking lead role in addressing climate change
- Skepticism polarity: informed vs uninformed
- Replace on burnout (ROB):
  - Low consideration of heat pumps
  - Most people replace like for like
- Retrofit (RET)
  - Even fewer may consider early replacement of existing equipment

Contractors told us…

- High awareness and familiarity
  - but maybe "biased self-select" cohort
- Program requires commissioning
  - Contractors noted challenges and costs – need training on how to do commissioning
- Manufacturer technology sometimes has bugs/glitches.
  - Greater risk of callbacks
- Heat pump availability is sometimes poor/slow
  - Supply chain and labor shortages both short term issues

Contractors told us…

- Heat pumps in place of CAC with a furnace almost always makes sense
  - caveat: rentals, elderly
- Heat pump in place of CAC doesn't meet the full heating load
  - requires ductwork, panel work, etc., or additional ductless heat pumps
- Contractors may see conflict between electrification and previous efficiency messaging
  - TOD rates and gas equipment incentives
- Stressed important of customer education and contractor training!

Barriers to market adoption include….

- First cost – consistently first cost
- Lack of customer awareness/consideration – nobody even considers a heat pump, aesthetics also a concern – is a heat pump even cool?
- Programs don't cover outdoor unit only swapouts, may require new furnace and indoor unit to qualify
- System compatibility vs program requirements



V
S



Full Electrification gets EXPENSIVE once system approaches peak!

- Assume ~ $120 per kW in avoided demand costs in 2030
- Fully electrified SF home with backup strips = 10 kW new load
- 10 kW x $120/kW = $1,200 annual demand costs
- Lifetime winter demand costs of measure (16 years) = $17k – PER HOME !!!



Existing Fossil Fuel Space Heating: Furnace with AC

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	ROB	$ (380)	$ 1,236	$ 2,774	$ (90)	$ 12	$ 450	0	15.9	4
16 SEER CHP | Gas furnace | CAC | CAC ROF - HE | 50% Disp | Fort Collins	ROB	$ (196)	$ 1,111	$ 2,895	$ (93)	$ 29	$ 450	0	16.3	4

PCT (Customer):

- Positive net benefits: customer comes out ahead w/out rebates, negative needs rebate to offset.
- For IQ, negative net benefit needs to be offset with incentive.

RIM (Ratepayer):

- Positive net benefits: ratepayer comes out ahead, negative is red flag
- Difference between Ratepayer – Customer = Max Incentive

Community:

- Includes emissions and non-energy benefits
- Positive net benefits: community comes out ahead

CO2 Abatement Cost:

- (Community Test without GHG)/(tons of GHG)
- Lower is cheaper; compare to $76 in community test

Total Bill Savings; Incremental Cost

- Annual bill savings net of fossil and electric impacts; Positive is good;
- Upfront incremental cost to customer

Winter Peak Demand Impact

- Winter peak impact in kW
- $1700/kW cost not included in other tests

Lifetime GHG Impacts

- Tons of CO2e saved over life of measure
- Results for measure implemented in 2022 with dropping electricity GHG impacts

Composite Measure Score

- 4/5 are high priority
- 3/2 are low priority or no impact
- 1 is to be avoided

Existing Fossil Fuel Space Heating: Furnace with AC

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	ROB	$ (380)	$ 1,236	$ 2,774	$ (90)	$ 12	$ 450	0	15.9	4
16 SEER CHP | Gas furnace | CAC | CAC ROF - HE | 50% Disp | Fort Collins	ROB	$ (196)	$ 1,111	$ 2,895	$ (93)	$ 29	$ 450	0	16.3	4
16 SEER CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	ROB	$ (2,196)	$ 1,111	$ 1,095	$ 18	$ 29	$ 2,250	0	16.3	3
CC CHP | Gas furnace | CAC | CAC ROF | 50% Disp | Fort Collins	ROB	$ (5,140)	$ 1,071	$ (1,572)	$ 181	$ 35	$ 4,950	0	16.4	2
14 SEER CHP | Gas furnace | CAC | CAC ROF | 80% Disp | Fort Collins	ROB	$ (381)	$ 2,033	$ 4,738	$ (99)	$ 12	$ 450	0	25.8	4
16 SEER CHP | Gas furnace | CAC | CAC ROF - HE | 80% Disp | Fort Collins	ROB	$ 10	$ 1,777	$ 5,010	$ (103)	$ 49	$ 450	0	26.7	5
16 SEER CHP | Gas furnace | CAC | CAC ROF | 80% Disp | Fort Collins	ROB	$ (1,990)	$ 1,777	$ 3,210	$ (35)	$ 49	$ 2,250	0	26.7	4
CC CHP | Gas furnace | CAC | CAC ROF | 80% Disp | Fort Collins	ROB	$ (5,027)	$ 1,800	$ 482	$ 67	$ 46	$ 4,950	0	26.6	3
14 SEER CHP | Gas furnace | CAC | CAC ROF | 100% Disp | Fort Collins	ROB	$ (1,681)	$ 2,707	$ 4,814	$ (70)	$ (17)	$ 1,350	10	31.0	1
16 SEER CHP | Gas furnace | CAC | CAC ROF | 100% Disp | Fort Collins	ROB	$ (3,135)	$ 2,353	$ 3,399	$ (20)	$ 35	$ 3,150	10	32.3	1
CC CHP | Gas furnace | CAC | CAC ROF | 100% Disp | Fort Collins	ROB	$ (6,112)	$ 2,337	$ 713	$ 63	$ 38	$ 5,850	10	32.4	1
14 SEER CHP | Gas furnace | CAC | CAC ER | 80% Disp | Fort Collins	RET	$ (3,247)	$ 2,033	$ 2,159	$ 1	$ 12	$ 3,029	0	25.8	3
16 SEER CHP | Gas furnace | CAC | CAC ER | 80% Disp | Fort Collins	RET	$ (4,855)	$ 1,777	$ 631	$ 61	$ 49	$ 4,829	0	26.7	3
CC CHP | Gas furnace | CAC | CAC ER | 80% Disp | Fort Collins	RET	$ (7,895)	$ 1,802	$ (2,097)	$ 164	$ 46	$ 7,529	0	26.6	2
14 SEER CHP | Gas furnace | CAC | CAC/Furnace ER | 100% Disp | Fort Collins	RET	$ (5,692)	$ 2,707	$ 1,203	$ 46	$ (17)	$ 4,960	10	31.0	1
16 SEER CHP | Gas furnace | CAC | CAC/Furnace ER | 100% Disp | Fort Collins	RET	$ (7,146)	$ 2,353	$ (211)	$ 92	$ 35	$ 6,760	10	32.3	1
CC CHP | Gas furnace | CAC | CAC/Furnace ER | 100% Disp | Fort Collins	RET	$ (10,123)	$ 2,337	$ (2,898)	$ 174	$ 38	$ 9,460	10	32.4	1

- **Single most important opportunity for building electrification**
- Best measures for existing furnace/AC are SEER 14 and SEER 16 ROB Heat Pumps. Early retirements are not as good, but OK (higher costs).
- Cold climate central heat pump economics are borderline – high incremental cost is not justified by performance improvement at this time. This would change dramatically for 100% displacement case if they did not need electric resistance backup heat and price of carbon was very high.
- RIM test results are high, which pay for high rebates
- If rebates are high enough to make heat pumps the cheapest option for cooling, landlords may install

Existing Fossil Fuel Space Heating: Furnace without AC

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | No AC | RET | 50% Disp | Fort Collins	RET	$ (9,082)	$ 2,572	$ (1,839)	$ 217	$ (105)	$ 7,200	0	14.0	2
16 SEER CHP | Gas furnace | No AC | RET | 50% Disp | Fort Collins	RET	$ (10,932)	$ 2,405	$ (3,264)	$ 315	$ (90)	$ 9,000	0	14.2	2
CC CHP | Gas furnace | No AC | RET | 50% Disp | Fort Collins	RET	$ (13,542)	$ 2,073	$ (5,382)	$ 444	$ (52)	$ 11,700	0	15.0	2
14 SEER CHP | Gas furnace | No AC | RET | 80% Disp | Fort Collins	RET	$ (9,084)	$ 3,369	$ 124	$ 80	$ (105)	$ 7,200	0	23.9	3
16 SEER CHP | Gas furnace | No AC | RET | 80% Disp | Fort Collins	RET	$ (10,542)	$ 2,946	$ (1,029)	$ 126	$ (52)	$ 9,000	0	25.1	3
CC CHP | Gas furnace | No AC | RET | 80% Disp | Fort Collins	RET	$ (13,429)	$ 2,802	$ (3,327)	$ 217	$ (42)	$ 11,700	0	25.2	2
14 SEER CHP | Gas furnace | No AC | RET | 100% Disp | Fort Collins	RET	$ (8,383)	$ 4,043	$ 2,000	$ 17	$ (134)	$ 6,300	10	29.1	1
16 SEER CHP | Gas furnace | No AC | RET | 100% Disp | Fort Collins	RET	$ (9,687)	$ 3,523	$ 961	$ 54	$ (67)	$ 8,100	10	30.7	1
CC CHP | Gas furnace | No AC | RET | 100% Disp | Fort Collins	RET	$ (12,514)	$ 3,339	$ (1,297)	$ 127	$ (50)	$ 10,800	10	31.0	1

- Adding heat pumps to homes without AC generally has poor customer and community economics.
- RIM tests support high rebates.
- It would generally be better/easier to focus on influencing people already adding AC to homes; getting them to put in a HP instead of CAC has similar economics to CAC ROB measures

Existing Fossil Fuel Space Heating: Boilers with no AC

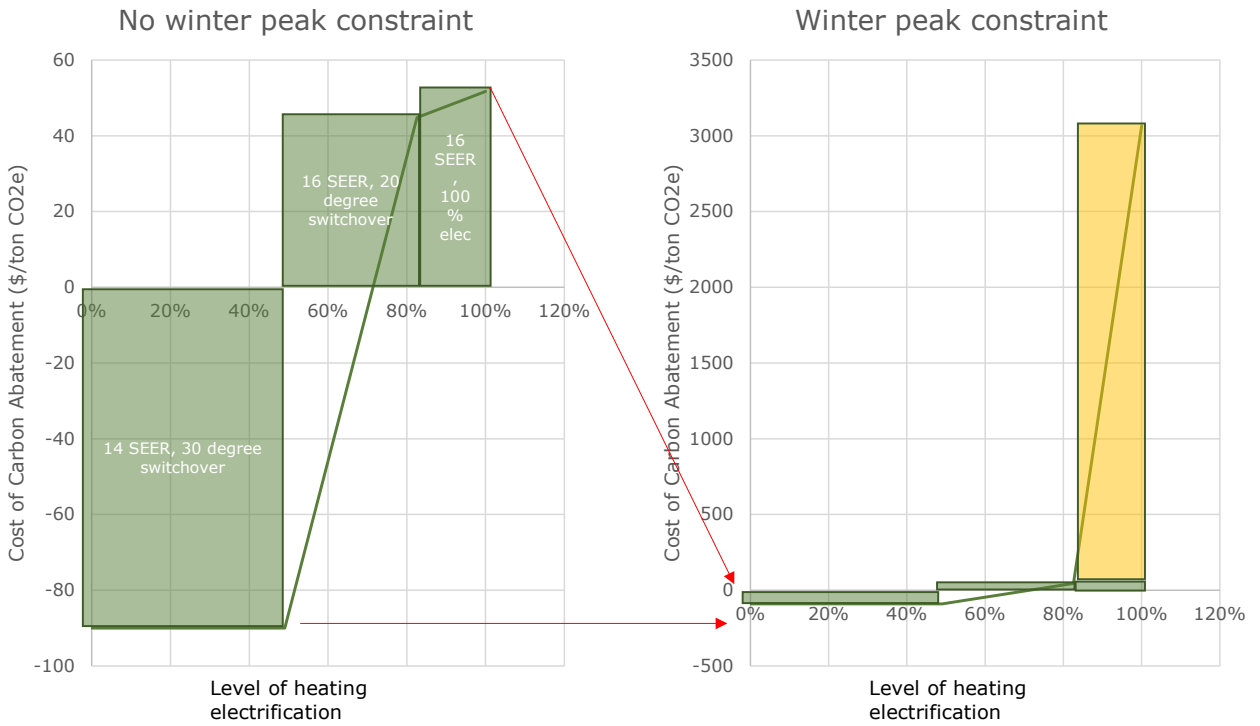
Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
CC DHP | Gas boiler | Cooling blend | RET | 50% Disp | Fort Collins	RET	$(13,391)	$ 1,906	$ (5,487)	$ 446	$ (38)	$ 11,700	0	15.2	3
CC DHP | Gas boiler | Cooling blend | RET | 80% Partial Disp | Fort Collins	RET	$(13,279)	$ 2,635	$ (3,432)	$ 220	$ (27)	$ 11,700	0	25.4	3
CC DHP | Gas boiler | Cooling blend | RET | 100% Full Disp | Fort Collins	RET	$(15,363)	$ 3,172	$ (4,102)	$ 216	$ (35)	$ 13,500	10	31.2	1
CC DHP | Gas boiler | Cooling blend | ROF/New Central Cooling | CC DHP | 100%	ROB	$(10,363)	$ 3,172	$ 398	$ 72	$ (35)	$ 9,000	10	31.2	1
CC DHP | Propane boiler | Cooling blend | RET | 50% Disp | Fort Collins	RET	$ (9,725)	$ 1,906	$ (395)	$ 104	$ 312	$ 11,700	0	20.4	3
CC DHP | Propane boiler | Cooling blend | RET | 80% Partial Disp | Fort Collins	RET	$ (7,185)	$ 2,635	$ 5,030	$ (63)	$ 555	$ 11,700	0	34.0	4
CC DHP | Propane boiler | Cooling blend | RET | 100% Full Disp | Fort Collins	RET	$ (7,803)	$ 3,172	$ 6,397	$ (68)	$ 687	$ 13,500	10	41.8	1
CC DHP | Propane boiler | Cooling blend | ROF/New Central Cooling | CC DHP |	ROB	$ (2,803)	$ 3,172	$ 10,897	$ (175)	$ 687	$ 9,000	10	41.8	1

- Adding heat pumps to homes without AC generally has poor customer and community economics.
- Propane displacements look good, but very few homes have propane.
- RIM tests support high rebates.
- It would generally be better/easier to focus on people adding central cooling to homes, which has similar economics to CAC ROB measures

With winter peak constraint included, last 17% of space heating GHG reductions costs $17,000/house for capacity

APEX ANALYTICS

First ~50% saves community money, next 33% costs ~$500/house, last 17% costs $17,000/house



Heat Pump Potential additional costs of installation

- Control wiring upgrade:
  - Need to add thermostat sensor to outdoor unit
  - May require different wire from outdoor unit to furnace
  - OR may require thermostat upgrade and new thermostat control wire
  - **Analysis included extra $300 in installation costs above AC** for heat pump control wiring upgrade – this could be higher or lower than this amount depending on application, difficulty of changing control wire
- Full electrification will require additional 50 or 60A 240V circuit and may require panel or service upgrade – not included
- Change in outdoor unit stance – may require mounting outdoor unit higher to avoid deep snow, depending on heat pump outdoor unit location – not included

Key selling points for heat pumps in existing homes

- Be part of the climate change solution for our community – we're decarbonizing our electric grid, so you should use electricity when you can
- Hybrid systems allow you to deal with electricity or gas price spikes
- Take advantage of the Fort Collins TOU heating rate to save money on your heating bill
- Air sealing and adding HP leads to healthier homes (close windows during wildfire smoke, provide relief during extreme heat)

Existing Fossil-Fueled Space Heating Near-term Recommendations

APEX ANALYTICS

Focus on partial displacement heat pumps, water heating.

- No requirement for full electrification
- No extra rebates for full electrification

Change heat pump/CAC rebates to promote heat pumps.

- Stop incenting central AC; require heat pumps for central cooling efficiency rebates.
- Remove cold climate requirement for central heat pumps.
- Keep ductless rebates.
- Offer new base rebate (e.g. $500-1000) for ANY heat pump installed, regardless of efficiency or commissioning.
- Offer additional high efficiency rebate (e.g. $1000 more) for high efficiency heat pump with controls commissioning.

Increase education and support

- Provide customer education/support focused on key benefits, payback, and set expectations
- Provide contractor training/support focused on promoting use of lower switchover temps
- Provide customer education/support focused on heat pump operations (scheduling, maintenance, differences vs gas furnace)

Existing Fossil-Fueled Space Heating Medium- and Long-term Recommendations

Medium-term:

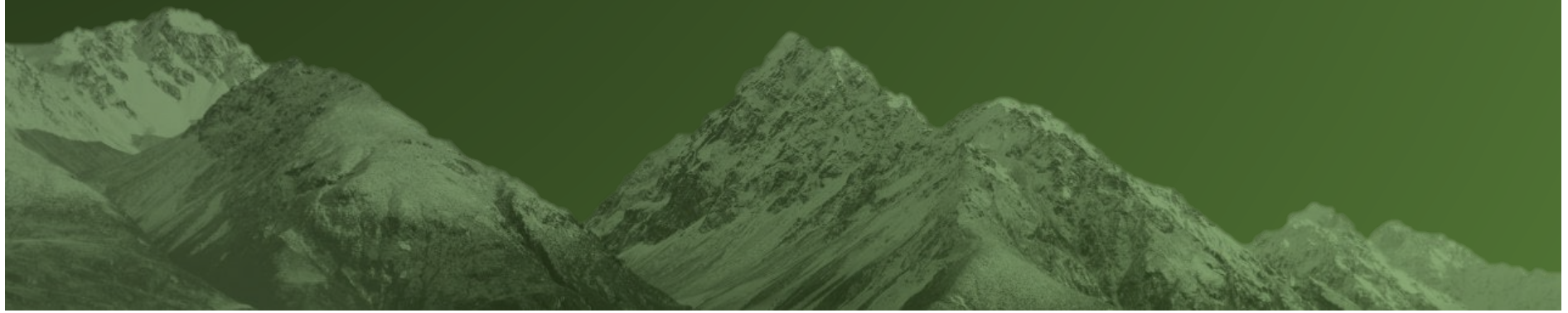
- Consider extra rebate incentives for early retirements of existing fossil equipment.
- Develop low income heating program.
- Develop measures to incent use of proper controls to increase usage at colder temperatures (adding lockouts, lower switchover temps, etc.)

Long-term:

- For 2028 code implementation cycle, require all CAC installations be heat pumps.
- Develop additional offerings focused on full-electrification based on improving technologies of various kinds

APEX ANALYTICS

Existing Fossil-fueled Water heating



Existing Fossil Water Heating

Baseline Equipment	Fraction of Homes	Electrification Solution	ROB	Early Retirement
Existing Gas Water Heater	76% (Longmont) 70% (Fort Collins)	Heat Pump Water Heater	Convince people replacing their water heater to install heat pump water heater	Convince people to early retire water heater in favor of heat pump water heater

How do heat pump water heaters work?

- Heat pumps moves heat from one place to another place, against the direction that it wants to flow, just like a water pump moves water against the direction that it wants to flow

- Key characteristics:
  - Heat pump water heater removes heat and moisture from wherever heat pump is located
  - In summer, this provides a cooling/dehumidification benefit
  - In winter, this creates a heating penalty

New developments in heat pump water heaters

- Higher efficiency – heat pump water heaters have gotten much more efficient over last 10 years

- Communication-enabled – "smart" water heaters allow for preheating of tank to shift demand via a thermal virtual battery (50 gallons * 25 degrees at COP of 3 ~ 1 kWh shifted)

- Development of products requiring only 120V circuit
  - Makes retrofit easier, frequently no need for an electrician
  - Reduces size of potential maximum peak impact

Existing Fossil Fuel Water Heating

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
3.5 UEF HPWH | Gas | | ROF | | Fort Collins	ROB	$ (731)	$ 328	$ 515	$ 14	$ 13	$ 770	0.5	7.4	3
3.5 UEF HPWH | Propane | | ROF | | Fort Collins	ROB	$ 922	$ 328	$ 2,772	$ (202)	$ 178	$ 770	0.5	9.7	5
Smart Electric Water Heater | Gas | | ROF | | Fort Collins	ROB	$ (2,431)	$ 1,069	$ (1,003)	$ 348	$ (160)	$ 770	1	3.8	2
Smart Electric Water Heater | Propane | | ROF | | Fort Collins	ROB	$ (777)	$ 1,069	$ 1,255	$ (120)	$ 6	$ 770	1	6.1	5

- Heat pump water heaters provide mixed economics
  - RIM test is positive, but relatively low, not enabling large incentives by itself
  - Community test is solid
  - PCT (participant) test is not very good. Hard to make the rebates large enough to make this a winner for participants.
  - Assumptions did NOT take advantage of Fort Collins heating rate OR load shifting benefits, which could improve PCT and

- Propane always looks better

Heat Pump Potential additional costs of installation

- May require new 240V circuit and may require panel or service upgrade; 120V options avoid this – not included
- Heat pump water heater is likely taller than existing water heater, which may or may not require plumbing modifications to accommodate – not included
- Heat pump water heater replacing water heater installed in closet may require modification of closet door to increase free airflow – not included

Key selling points for heat pump water heaters in existing homes

- Greening our community: Be part of the climate change solution for our community – we're decarbonizing our electric grid, so you should use electricity when you can
- Healthy Home: Get rid of your unsealed combustion appliance
- Smart economics: Smart water heaters allow you to take advantage of TOU rate

Existing Fossil-Fueled Water Heating Recommendations

APEX ANALYTICS

Near-term:

- Keep heat pump water heater rebates
- Promote 120V heat pumps with installers as an easier retrofit

Medium-term:

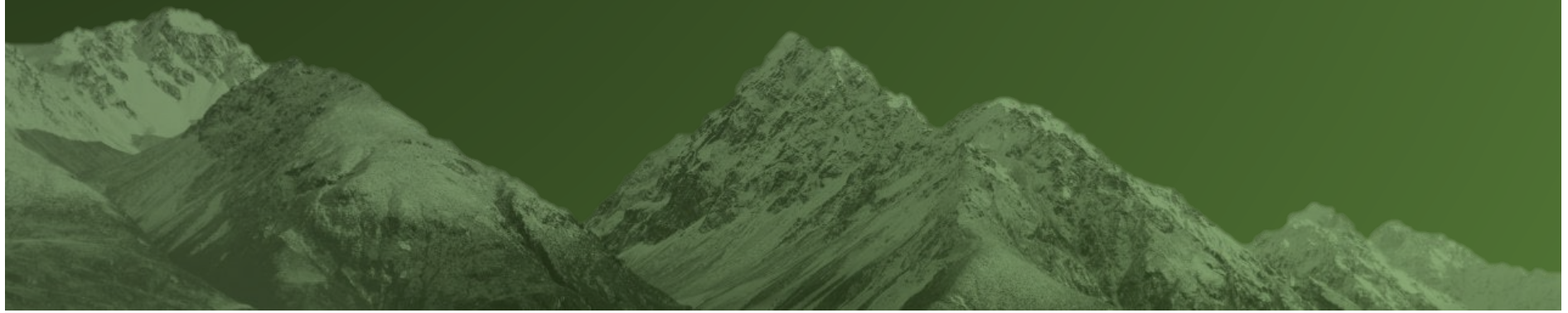
- Consider midstream rebate in partnership with other entities; work with gas utility on combined clean heat offering

Long-term:

- Require heat pump water heaters in all water heating applications in 2028 code cycle update.

APEX ANALYTICS

New construction



New Construction

Baseline Equipment	Fraction of New Homes	Electrification Solution	New Construction
Gas Furnace and AC	Nearly 100%	Central Heat Pump	Convince builders to install heat pumps instead of air conditioners in new homes.
Gas water heater		Heat Pump Water Heater	Convince builders to install heat pump water heaters instead of gas water heaters in new homes.
Gas Range		Electric (or induction) Range	Convince builders to install electric range
Gas Home switch to All-Electric Home		Heat pump, heat pump water heater, electric (or induction range)	Convince builders to only connect to electricity, not gas

New Construction

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
14 SEER CHP | Gas furnace | CAC | NC | 50% Disp | Fort Collins	New	$ (80)	$ 1,236	$ 3,044	$ (107)	$ 12	$ 180	0	15.9	5
16 SEER CHP | Gas furnace | CAC | NC | 50% Disp | Fort Collins	New	$ (1,896)	$ 1,111	$ 1,365	$ 1	$ 29	$ 1,980	0	16.3	4
CC CHP | Gas furnace | CAC | NC | 50% Disp | Fort Collins	New	$ (4,840)	$ 1,071	$ (1,302)	$ 164	$ 35	$ 4,680	0	16.4	2
14 SEER CHP | Gas furnace | CAC | NC | 80% Disp | Fort Collins	New	$ (81)	$ 2,033	$ 5,008	$ (109)	$ 12	$ 180	0	25.8	5
16 SEER CHP | Gas furnace | CAC | NC | 80% Disp | Fort Collins	New	$ (1,690)	$ 1,777	$ 3,480	$ (45)	$ 49	$ 1,980	0	26.7	4
CC CHP | Gas furnace | CAC | NC | 80% Disp | Fort Collins	New	$ (4,729)	$ 1,802	$ 752	$ 57	$ 46	$ 4,680	0	26.6	3
14 SEER CHP | Gas furnace | CAC | NC | 100% Disp | Fort Collins	New	$ 1,619	$ 2,707	$ 7,784	$ (166)	$ (17)	$ (1,620)	9	31.0	1
16 SEER CHP | Gas furnace | CAC | NC | 100% Disp | Fort Collins	New	$ 165	$ 2,353	$ 6,369	$ (112)	$ 35	$ 180	9	32.3	1
CC CHP | Gas furnace | CAC | NC | 100% Disp | Fort Collins	New	$ (2,812)	$ 2,337	$ 3,683	$ (29)	$ 38	$ 2,880	9	32.4	1
14 SEER CHP | Gas furnace | CAC | HE NC | 50% Disp | Fort Collins	New	$ (110)	$ 927	$ 2,238	$ (103)	$ 9	$ 180	0	11.9	5
16 SEER CHP | Gas furnace | CAC | HE NC | 50% Disp | Fort Collins	New	$ (1,972)	$ 834	$ 529	$ 42	$ 22	$ 1,980	0	12.2	3
CC CHP | Gas furnace | CAC | HE NC | 50% Disp | Fort Collins	New	$ (4,930)	$ 803	$ (2,147)	$ 260	$ 26	$ 4,680	0	12.3	2
14 SEER CHP | Gas furnace | CAC | HE NC | 100% Disp | Fort Collins	New	$ 1,665	$ 2,030	$ 6,243	$ (183)	$ (13)	$ (1,620)	8	23.2	1
16 SEER CHP | Gas furnace | CAC | HE NC | 100% Disp | Fort Collins	New	$ 74	$ 1,765	$ 4,732	$ (110)	$ 27	$ 180	8	24.3	1
CC CHP | Gas furnace | CAC | HE NC | 100% Disp | Fort Collins	New	$ (2,909)	$ 1,753	$ 2,042	$ 1	$ 28	$ 2,880	8	24.3	1
3.5 UEF HPWH | Gas | | ROF | | Fort Collins	New	$ (731)	$ 328	$ 515	$ 14	$ 13	$ 770	0.5	7.4	3
All Electric, 16 SEER HP, 3.5 UEF HPWH | IECC 2021, base gas cooking, furnace, hot water | (		$ 1,143	$ 875	$ 6,714	$ (84)	$ 157	$ 612	9	39.8	2
All Electric, CC HP, 3.5 UEF HPWH, 6 kW heat strips | HE envelope, gas furnace, hot water, c		$ 235	$ 518	$ 3,618	$ (63)	$ 76	$ 676	6	24.5	2

- New construction encouraging heat pumps looks great. RIM test enables high rebates without ratepayer impacts.
- 100% electric new homes looks great until you consider winter peak impacts
- Add $1700/winter peak kW for winter peak-constrained results
- Opportunity for MF also exist, but weren't separately screened

Other End Use Potential changes to costs of installation

- Dropping all gas creates additional savings associated with not installing gas line – operating costs are included, but gas connection fee and trenching costs are not included. This would slightly improve results for all electric homes.

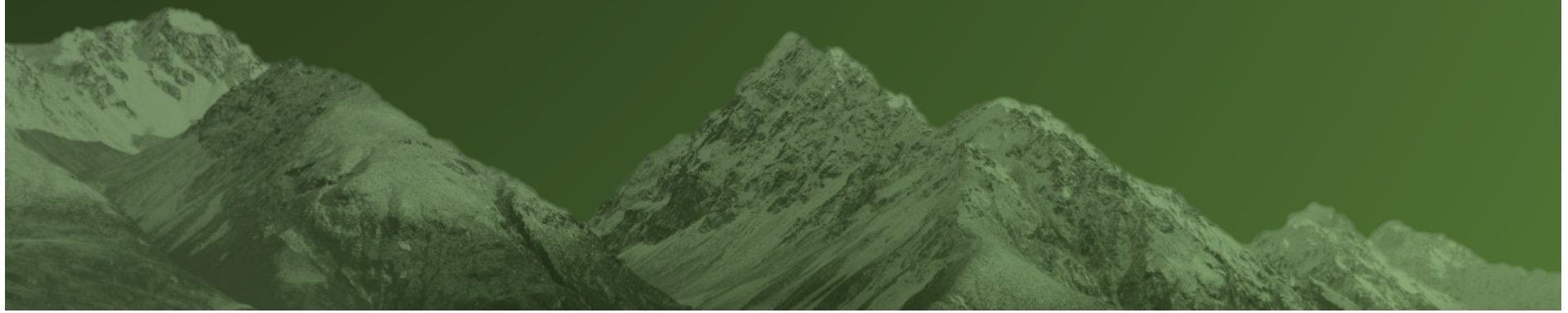
- Slightly more expensive thermostat may be required – not included

New Construction Recommendations

APEX ANALYTICS

Near-term:	Medium-term:	Long-term:
• Offer same rebates for heat pumps and heat pump water heaters. • Promote health and environment benefits of mostly electric home.	• Require heat pumps and heat pump water heaters in new construction in 2025 code update. • Develop all-electric super-efficient home offering with limited electric resistance heat size. • Explore other technologies in new construction that include better storage, lower peak impacts.	• Around 2030, change code to require all electric homes with limited electric resistance heat size.

Existing Other Fossil-fueled end Uses



Existing Fossil Water Heating

Baseline Equipment	Fraction of Homes	Electrification Solution	ROB	Early Retirement
Gas Clothes Dryer	5% both cities	Electric Clothes Dryer	Convince people replacing their clothes dryer to switch to electric	Convince people to early retire gas clothes dryer in favor of electric clothes dryer
Gas Range	24% both cities	Electric (or induction) Range	Convince people replacing their range to switch to electric	Convince people to early retire gas range in favor of electric range
Gasoline lawn equipment (not screened)		Electric corded or cordless lawn mower	Convince people replacing their lawn mower to switch to electric	Convince people to early retire lawn mower in favor of electric or cordless lawn mower

Existing Fossil Fuel Other End Uses

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composit Measure Score
Electric Dryer | Gas | | ROF | | Fort Collins	ROB	$ (123)	$ 108	$ 9	$ 76	$ (35)	$ (216)	0.2	0.8	
Electric Range | Gas | | ROF | | Fort Collins	ROB	$ (306)	$ 11	$ (255)	$ 1,343	$ (9)	$ 225	0.1	0.2	
Electric Range | Propane | | ROF | | Fort Collins	ROB	$ (231)	$ 11	$ (165)	$ 626	$ 3	$ 225	0.1	0.3	

- Other end uses have very small impacts
  - Electric clothes dryers look OK, because they are cheaper than gas clothes dryers
  - Electric ranges don't look good
  - Propane always looks better, but it still doesn't look good
- Clothes dryers assumed not to take advantage of TOU or heating rate; economics would improve
- In theory, a smart clothes dryer also introduces load shifting opportunity to delay clothes drying (about 2-3 kWh/load)

Other End Use Potential additional costs of installation

- Clothes dryer and range may require new 240V circuits and may require panel or service upgrade, some (as yet unproven) heat pump dryers use 120V, would not require upgrade – not included
- Range (if induction) may also require new compatible cookware – not included

Existing Fossil-Fueled Water Heating Recommendations

APEX ANALYTICS

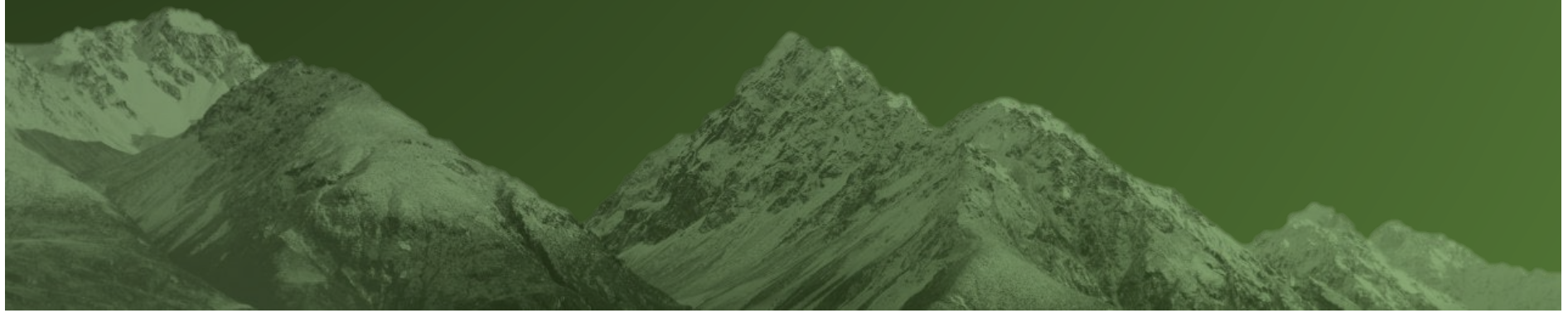
Near-term:

- No rebates for other existing equipment.
- Promote health and environment benefits of mostly electric home.

Medium-term:

- Explore possibility of new lawn equipment measure, partnering with air board to capture ozone benefits
- Develop combined offering with bonus for installing electric clothes dryer or electric range along with electric heat pump and heat pump water heater

Existing Electric end uses



Existing Electric End Uses

Baseline Equipment	Fraction of New Homes	Electrification Solution	New Construction
Electric Furnace and AC	< 1% both cities	Central Heat Pump	Convince builders to install heat pumps instead of air conditioners in new homes.
Electric Furnace and No AC	2% Longmont 5% Fort Collins	Heat Pump Water Heater	Convince builders to install heat pump water heaters instead of gas water heaters in new homes.
Electric Baseboard and No AC	2% Longmont 5% Fort Collins	Electric (or induction) Range	Convince builders to install electric range
Electric Water Heater	24% Longmont 30% Fort Collins	Heat pump, heat pump water heater, electric (or induction range)	Convince builders to only connect to electricity, not gas

Existing Electric End Uses

Measure	Type	PCT	RIM	Community	CO2 Abatement Cost	Total Bill Savings	Incremental Cost	Winter Peak Demand Impact (kW)	Lifetime GHG impacts (tons CO2e)	Composite Measure Score
CC DHP | Electric Baseboard | Cooling Blend | RET | Full Disp | Fort Collins	RET	$ (4,271)	$ (2,749)	$ (173)	$ 97	$ 458	$ 8,100	0	12.1	3
14 SEER CHP | Electric furnace | No AC | RET | 100% Disp | Fort Collins	RET	$ (1,954)	$ (3,407)	$ (30)	$ 85	$ 586	$ 7,200	0	15.7	3
16 SEER CHP | Electric furnace | No AC | RET | 100% Disp | Fort Collins	RET	$ (3,248)	$ (3,933)	$ (1,064)	$ 144	$ 654	$ 9,000	0	17.3	3
CC CHP | Electric furnace | No AC | RET | 100% Disp | Fort Collins	RET	$ (6,072)	$ (4,118)	$ (3,319)	$ 272	$ 671	$ 11,700	0	17.6	2
14 SEER CHP | Electric furnace | CAC | CAC ROF | 100% Disp | Fort Collins	ROB	$ 6,749	$ (4,743)	$ 4,583	$ (178)	$ 702	$ 450	0	17.6	3
16 SEER CHP | Electric furnace | CAC | CAC ROF | 100% Disp | Fort Collins	ROB	$ 5,304	$ (5,102)	$ 3,174	$ (85)	$ 756	$ 2,250	0	18.9	3
CC CHP | Electric furnace | CAC | CAC ROF | 100% Disp | Fort Collins	ROB	$ 2,330	$ (5,120)	$ 490	$ 57	$ 758	$ 4,950	0	19.0	3
HPWH | Electric | | ROF | | Fort Collins	ROB	$ (192)	$ (1,127)	$ (964)	$ 593	$ 91	$ 981	0	1.9	2

- Electric end uses will have GHG emissions reduced by grid decarbonization, without additional action
- Adding heat pumps for folks with electric furnace and AC have great economics, but opportunities are rare
- Weatherization may offer better economics than heat pumps in electrically-heated homes
- Note that NEIs ARE included in community test.

Existing electric potential changes to costs of installation

- No additional costs have been noted.

Existing Electric Recommendations

Near-term:	Medium-term:	Long-term:
• Offer same rebates for heat pumps and heat pump water heaters.	• Develop new electric resistance to heat pump measure focused on income-qualified.	• Develop new winter peak demand response/load shifting measures.


APEX
ANALYTICS
Strategy / Roadmap

Phased approach

Phase 1: Build market awareness, customer education, and contractor capability with training and downstream rebates.	• *What would it take for you to almost always install a heat pump instead of an air conditioner?* • Offer rebates for ALL heat pumps
Phase 2: Widespread adoption in most cost-effective applications.	• Start code requirements; Consider midstream offerings; Broaden offerings. • Improve heat pump economics through rate design.
Phase 3: Pushing towards zero carbon.	• Change codes to require heat pumps and heat pump water heaters in all new installations. • All-electric new homes.

Phase 1: Build market awareness and contractor capability. Through early-to-mid-2020s.

APEX ANALYTICS

Customers:

- Rebates
- General awareness marketing campaign
- Webinars for early adopters
- Guides on how to maximize performance of heat pumps, e.g. set and forget
- Setting expectations (will they really see bill savings?)

Contractors:

- Trainings: How to limit risk. How to deal with different kinds of installs, figure out what works in Fort Collins/Longmont.
- Marketing materials
- Get more contractors up the heat pump curve: trainings, outreach
- Leverage and expand preferred contractor network
- Offer simpler/more streamlined participation model
- Customer training materials for contractors to provide

Engage distributors

- Make sure they know that we're promoting products, increasing demand, need to increase orders, increase stocking
- Partner with distributors to offer trainings

Phase 2: Widespread adoption in most cost-effective applications. Mid-Late 2020s

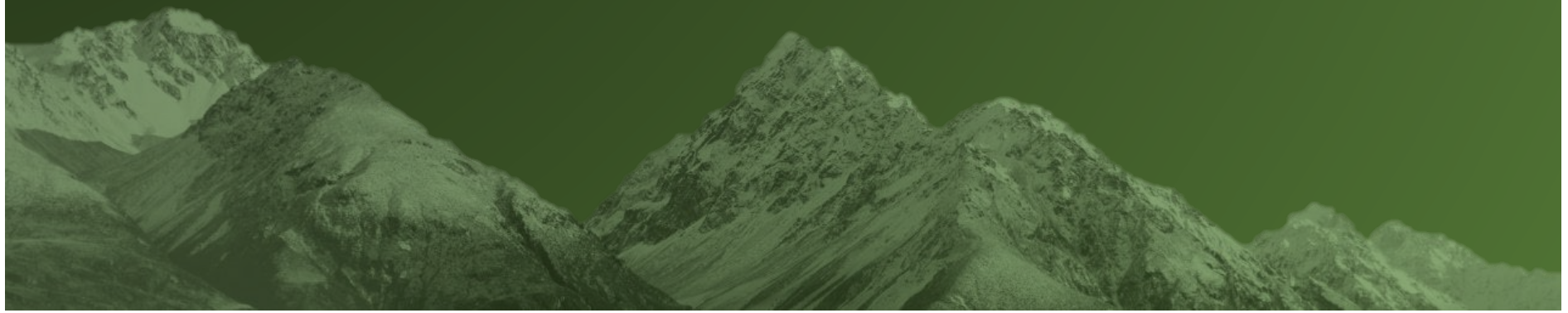
- Midstream incentives: explore partnerships with other utilities to go midstream – midstream doesn't work as well without whole region included.
- Code requirements: Make every CAC be a heat pump, first in NC, then in replacements
- Offer additional incentives for new thermostats and wiring required with heat pumps, after heat pump is required
- Broaden offerings
  - Explore other technologies
  - Offer more incentives to other, more marginal measures
- Improve heat pump economics through rate design
  - Make desirable consumption less expensive
  - Make undesirable consumption more expensive

Phase 3: Reduce GHG emissions to zero (2030s-2040s)

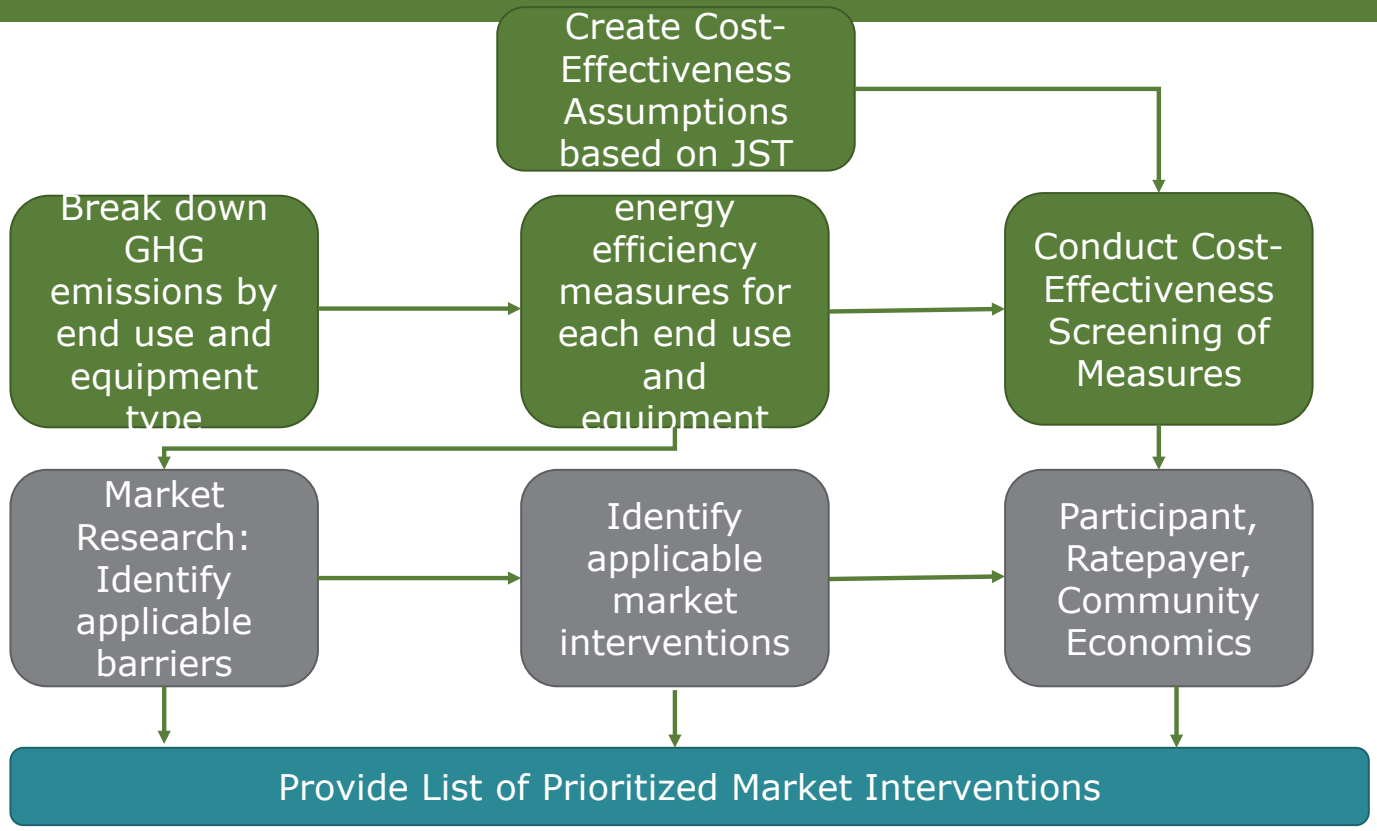
- Currently, no clear answers.
- Full electrification will lead to winter peak problems without action being taken to reduce winter peak
- Code requires all CACs be heat pumps and all water heaters be heat pump water heaters
- Code requires extreme efficiency all electric new homes, limit on electric resistance heat sizing, keeping backup electric heat loads down
- Deploy widespread weatherization/envelope improvements
- Go full electric in conjunction with deep energy retrofits
- Deploy new technology under development
  - Even colder climate heat pumps
  - Ground source and other long term thermal storage heat pump variants
- Decarbonized gas?? Pellet stoves??

APEX ANALYTICS

Methods / Assumptions



Overall Approach

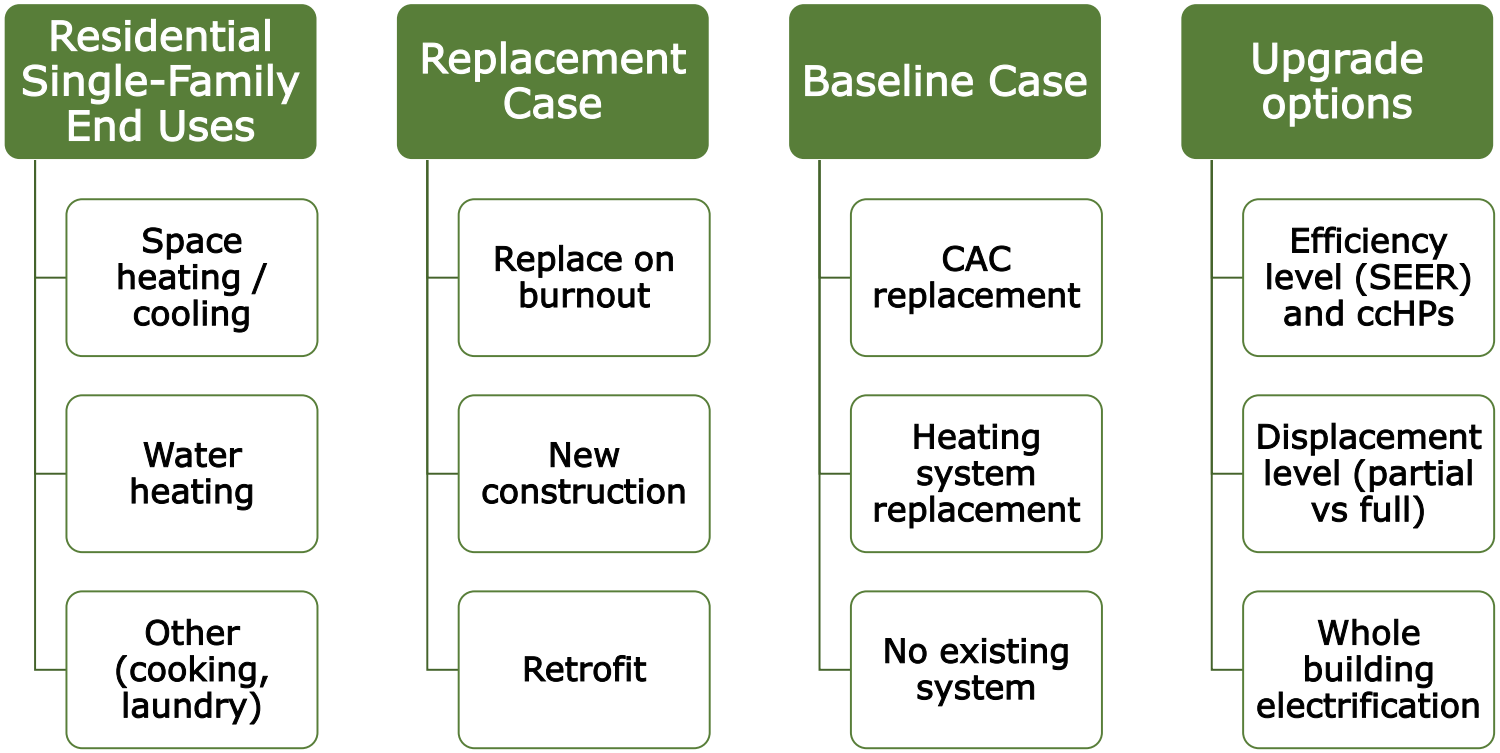


Break down GHG emissions by end use and equipment type

- Start with Xcel Energy billing data for residential accounts in Fort Collins and Longmont
- Use monthly disaggregation to estimate heating and non-heating
- Apply national data to estimate remainder that is hot water vs cooking vs clothes drying
- Further break out results by equipment type using tax assessor data for Fort Collins and Longmont
- Assume propane shares same breakdown, but increases total slightly

Measure Development: Use Cases

Ordered by opportunity



Cost-Effectiveness: Develop Jurisdiction Specific Test

APEX ANALYTICS

- Series of stakeholder meetings
- Grouped by key inputs
  - Establish community goals
  - Decide on key metrics: $/CO2, overall community net benefit
  - Entities inclusion w/in community test
  - Direct costs and benefits
  - Indirect costs and benefits



Cost-Effectiveness: Develop Custom JST Model

- flexCE (Lumina Systems)
  - Developed custom model in coordination with James Milford and Dan Violette
  - Built from ground up using JST decision making
  - Includes scenario and tornado (sensitivity) analysis
  - Assignment of non energy benefits to cost tests
  - Include new metric: cost of avoided carbon ($/eCO2)
    - Includes avoided methane as well

CE Input Assumptions

- Measure Life
  - Xcel and Illinois TRM
- Measure Savings
  - Apex analysis, TRM, lit review
- Measure Costs
  - Manufacturer pricing, Apex analysis, lit review
- Emissions rates and costs
  - PRPA
- Avoided energy and demand costs
  - PRPA
- Program Costs
  - Set to zero, assume integrated into existing programs
- Incentives
  - Blank slate: allow output of cost tests to determine ceilings
- Non-energy impacts:
  - Comfort, health, jobs

Market Research

- In prior phase of work, collected data from customers and local contractors
- Pull insights from contractors and customers into final analysis of barriers and interventions
- Add insights gleaned from around the country
- Identify potential interventions