Study of Energy Storage & Supply Strategies for Advancing Resilience & Long-Term Comfort in Low-Income Communities During Texas Cold Snaps

Focus on: Guideline-Based Strategies for Protecting Occupants and Sustaining Thermal Comfort Throughout Storm Including Blackouts

History/Problem

Winter Storm URI 2021- A Case Study

Temperature: Below Freezing for 139-205 Hours

Outage: 350,000 Lost Power

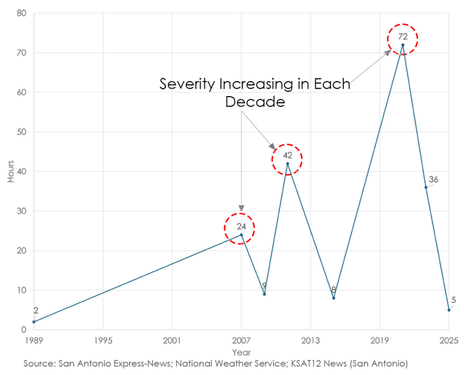
Deaths: 111+

Damages: $80–$195 Billion

Natural Gas Distribution Stations Failed

All Pipes Froze

Source: Austin Resource Recovery, A Case Study of the 2021 Winter Storm in Texas, Winter Storm Uri 2021- A Review of the Texas Economy.



Source: San Antonio Express-News; National Weather Service; KSAT12 News (San Antonio)

Figure 1: Number of Hours of Power Outage Over Years

Storm Effects

No Electricity or Backup: 3-5 days

No Heating

No Drinking Water

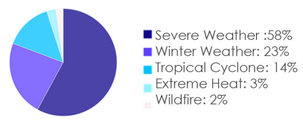
Snowfall: 5-6 Inches

Fire: Caused While People Using Gas Stove to Heat the Space

No Vacancy in Storm Shelter

Source: Austin Resource Recovery, A Case Study of the 2021 Winter Storm in Texas, Comptroller Texas gov.

State	Weather-related outages (2000-2023)
Texas	210
Michigan	157
California	145
North Carolina	111
Ohio	88
Louisiana	85
Virginia	83
Georgia	83
Pennsylvania	82
Florida	77
Alabama	76



Source: https://www.climatecentral.org/climate-matters/weather-related-power-outages-rising

Figure 2: Major US Power Outage

Figure 3: Located on the Southwest Side of San Antonio, Texas, this Area is Best Known for Housing the City's Oldest Home, and it is Primarily a **Low-Income** Residential Community, With Most Residents Earning Below **$50,000 Annually.**

Baseline

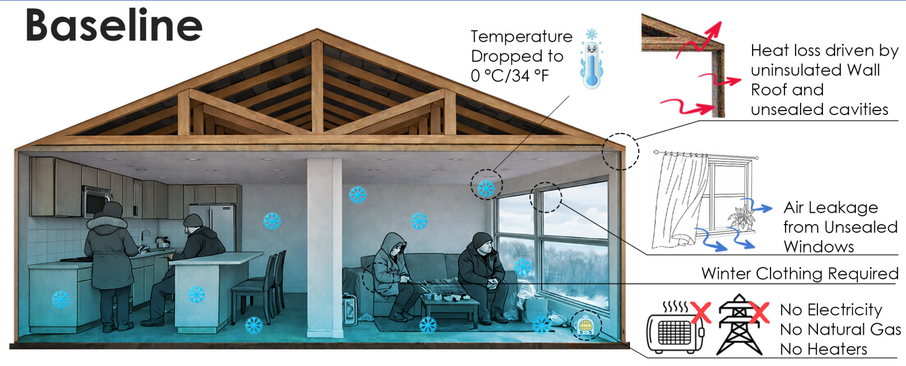
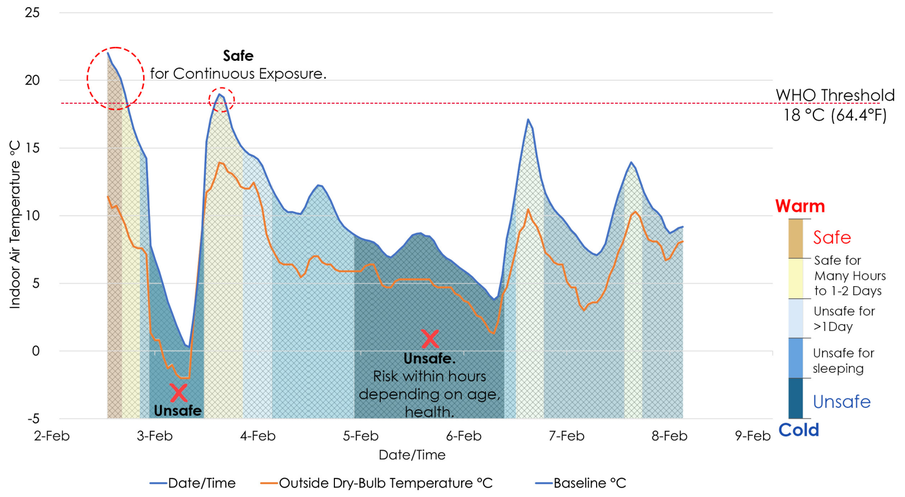


Figure 4: Baseline Behaviour of a House during a Storm and Grid Breakdown



Graph 1: Outdoor and Indoor Air Temperatures During a Five-Day Winter Grid Outage

METHODOLOGY

Survival-Owner Driven Interventions

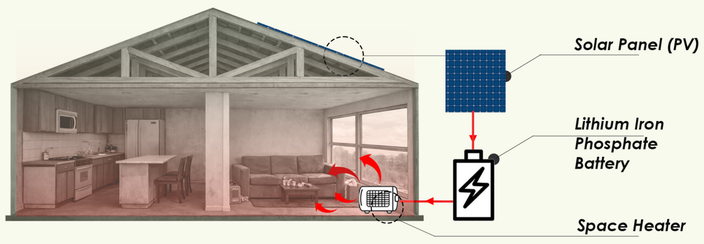
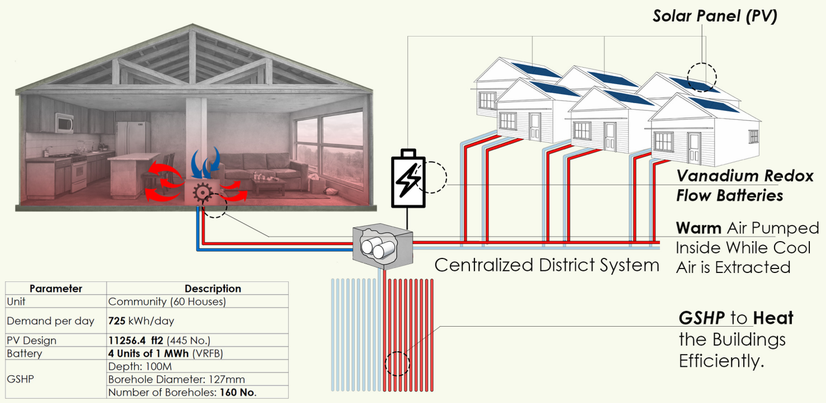


Figure 5: Single Stand Alone Home Powered by PV and Batteries

Parameter	Description
Unit	Single Unit – 1367.02ft2
Demand per day	27 kWh/day
PV Design	613.54 ft2 (25 No. of Monolithic panels) Roof and Façade) 45%
Battery	4 Units of 40 kWh $LiFePO_4$ battery
Construction	No Retrofit (No changes made to the building)

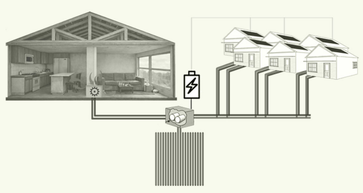
Survival-City- Driven Interventions



Parameter	Description
Unit	Community (60 Houses)
Demand per day	**725** kWh/day
PV Design	**11256.4 ft2** (445 No.)
Battery	**4 Units of 1 MWh** (VRFB)
GSHP	Depth: 100M Borehole Diameter: 127mm Number of Boreholes: **160 No.**

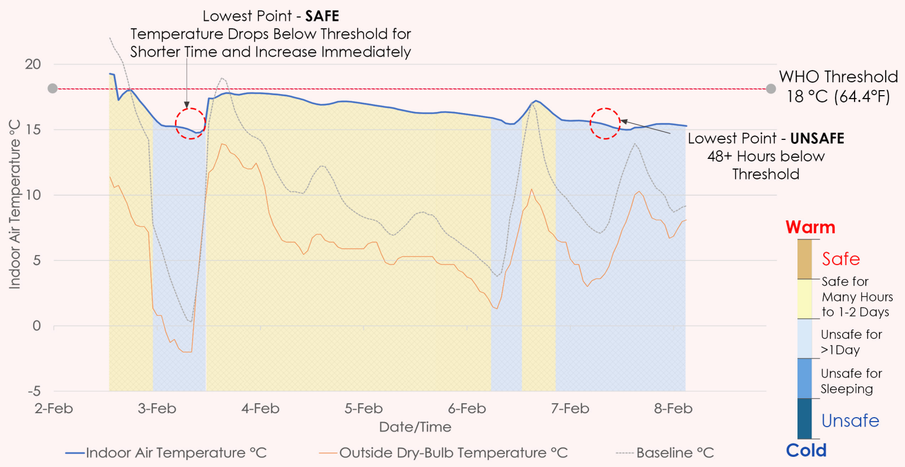
Figure 6: Centralized District System - Ground Source Heat Pump (GSHP)

Annual Comfort- City- Driven Interventions



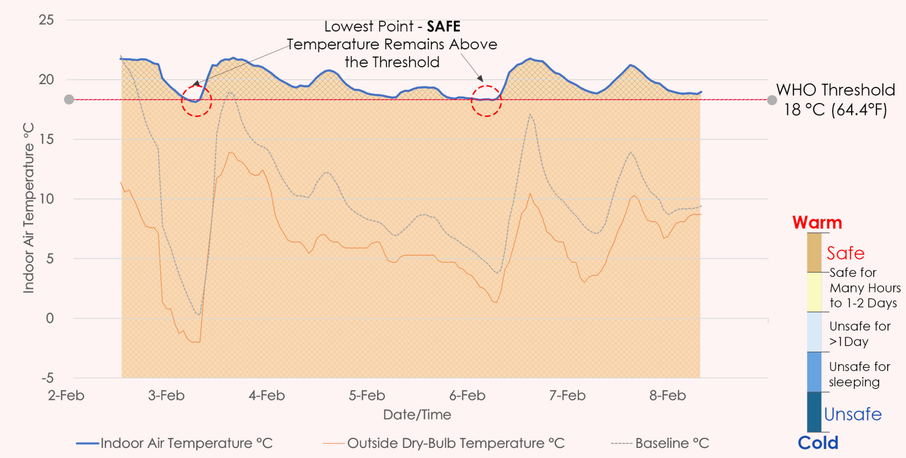
RESULTS

The Energy Stored Keeps Indoor Temperatures Within 14–17 °C (57-63 °F) During the Five-Day Outage but Falls Below 18 °C (64.4°F) for 19 Hours Per Day on Average, Also Increasing owner's Maintaince Resposibilities.



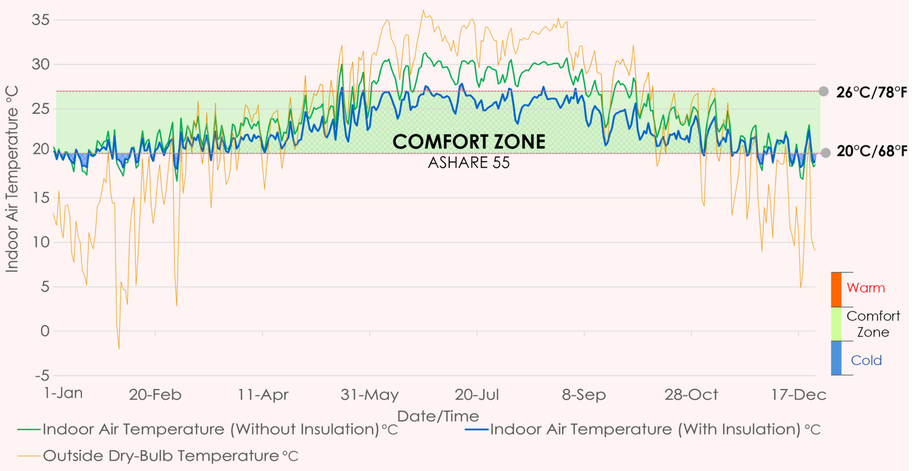
Graph 2: **Stand Alone Homes-** Extreme Winter Storm Survival Guided by **World Health Organization**

Indoor Air Temperatures Remain Nearly Constant ~18–22 °C (64.4 - 71.6°F) for 22 Hours Per Day on Average During a Five-Day Winter Outage Despite Large Fluctuations in Outside Temperature.



Graph 3: **Community Scale-** Extreme Winter Storm Survival Guided by **World Health Organization**

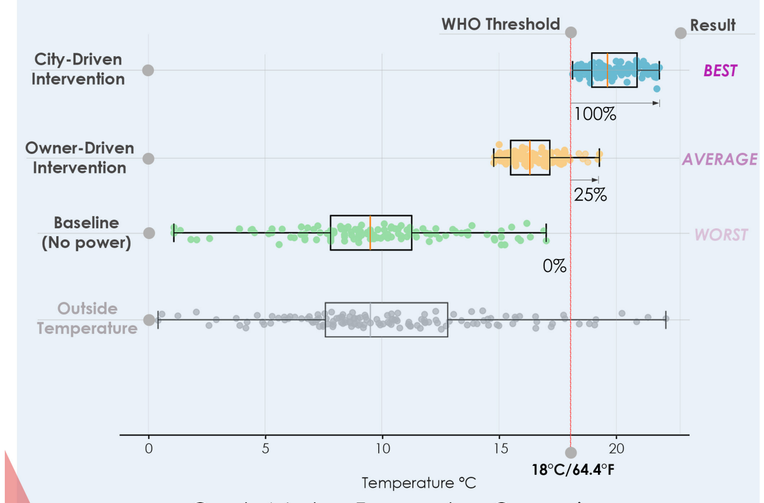
The District GSHP + Microgrid + Insulation Maintains Indoor Air Temperatures Consistently Between 18 - 27 °C (64.4 - 78.8 °F) Year-Round, While Only District GSHP + Microgrid Maintances Temperature between 17.5 - 31 °C (63.5 - 87.8°F), Within the ASHRAE Standard 55 Comfort Band



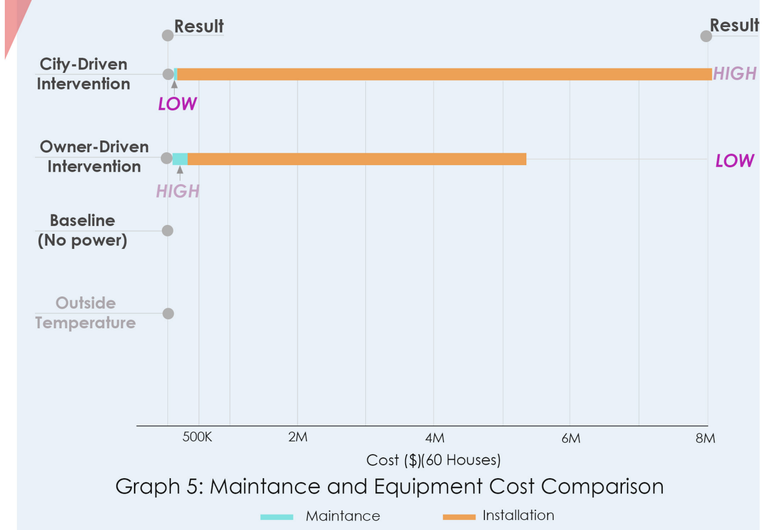
Graph 6: Representing Annual Comfort Guided by **ASHARE 55**

COMPARISION

Decentralized PV + Battery **VS** District-Scale GSHP + Microgrid **VS** Baseline



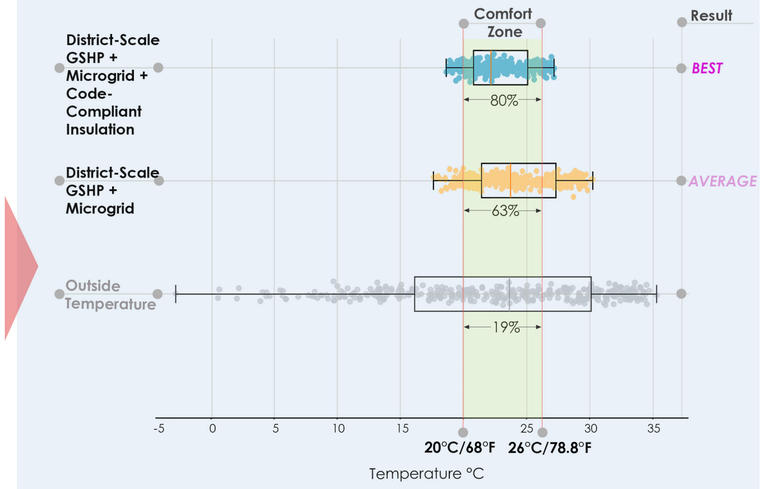
Graph 4: Indoor Temperature Comparison



Graph 5: Maintance and Equipment Cost Comparison

City- Driven Interventions Solution Maintains Temperatures Above the Threshold During Grid Breakdown, Although the Initial Investment is Higher, it Provides Long-Term Resilience for With Lower Maintenance & Improved Reliability.

District-Scale GSHP + Microgrid + Code-Compliant Insulation **VS.** District-Scale GSHP + Microgrid



Graph 7: Indoor Temperature and Comfort Comparison

Incentive ✓

Tax Credits ✓

Utility Payback ✓

PAYBACK PERIOD

Long-Term Comfort (District-Scale GSHP + Microgrid + Code-Compliant Insulation)

Approx

~20 Years

District-Scale GSHP + Microgrid + Insulation
Added Insulation Cost
Reduced Cost & Size- GSHP, Batteries & PV

COST ≈

District-Scale GSHP + Microgrid

The ***District-Scale GSHP*** with Added ***Insulation*** helps Improving Annual Comfort and Providing Stable Comfort Across Extremes Winters Events.

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