The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes

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What’s The Issue?

HOMES USE A LOT OF ENERGY

• New residential homes are pretty good and are only about 1% of homes in any given year
• Existing residential homes use (almost) all the energy

WE NEED TO FIX EXISTING HOMES

• Why aren’t all homes upgraded?
• What are the barriers to scaling upgrades?
• Can we make upgrade costs more manageable?

Switching from Energy Efficiency to Low Carbon:
We can’t efficiency our way to zero carbon homes
Emerging Changes in Residential Construction
100 percent clean policies by state as of April 2020

*Hover or click on states for more information.


BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Energy Technologies Area
Growth in Electric Heating

- Electrification of largest end-use has been increasing for years.
- We are just going to accelerate this trend.
- Most new-home growth in areas where homes are electrified for heating/cooling.
• >25% of homes are already all-electric.
• 40% of homes have electric primary heating.

Data from the American Community Survey (2016).
What are the main motivations of homeowners / building owners when seeking to perform an energy upgrade project?

- **Improve comfort**: 48
- **Save money on energy bill**: 42
- **Make home sustainable / green**: 32
- **Reduce carbon emissions**: 22
- **Reduce use of on-site fossil fuel**: 13
- **Upgrade for modern convenience (e.g., car charging)**: 7
- **Address existing moisture / mold problem**: 7
- **Increase home value**: 6
- **Increase resilience (e.g., hurricane, power outage)**: 5
- **Address existing odor / IAQ problem**: 5
- **Upgrade for lifestyle changes (e.g., aging in place)**: 4
- **Address home safety issues**: 3
- **Address existing noise problem**: 0

(n=70)
Aside from costs, what are the biggest barriers when performing DER projects?

- Lack of consumer demand (40)
- Lack of a reliable, trained home performance workforce (30)
- Unforeseen conditions in existing homes (23)
- Competition from companies performing non-DER work (23)
- Low customer conversion rate (14)
- Burden of designing DER work scope (8)
- Compliance with building code (7)
- Lack of proven retrofit strategies (6)
- Lack of advanced retrofit equipment / materials (3)
- Permitting atypical projects (2)
- Lack of simulation / design tools (1)

Total responses (n=68)
### Advanced Technologies and Approaches

**What contractors say will increase deep energy retrofits of homes**

<table>
<thead>
<tr>
<th>Description</th>
<th>Ratings</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>“One-stop shop” with energy audit, work scope, financing, permits, construction, testing</td>
<td>1 2 10 21 28</td>
<td>63</td>
</tr>
<tr>
<td>Energy plus healthy home retrofit</td>
<td>1 5 23 22 13</td>
<td>64</td>
</tr>
<tr>
<td>Standard weatherization combined with heat pump and PV</td>
<td>4 13 18 19 12</td>
<td>66</td>
</tr>
<tr>
<td>Over-time DER aligned with equipment replacement / upgrade</td>
<td>6 7 20 16 15</td>
<td>64</td>
</tr>
<tr>
<td>Home electrification retrofit</td>
<td>10 8 18 18 10</td>
<td>64</td>
</tr>
<tr>
<td>Exterior retrofit with minimal disturbance inside home</td>
<td>9 20 14 14 5</td>
<td>62</td>
</tr>
<tr>
<td>Pre-fabricated panelized envelope retrofits (e.g., EnergieSprong)</td>
<td>16 23 11 9 4</td>
<td>63</td>
</tr>
</tbody>
</table>
Why Electrification…?
What is Home Electrification...?

Replacing fossil fuels with electricity

Why Electrification…?

Need to STOP emitting CO₂

Need Low/Zero CO₂ energy – ELECTRICITY the only viable option.
  - Allows use of Low/Zero carbon renewable energy

“We can’t efficiency our way to zero carbon emissions”
  - Very limited efficiency gains remain for fossil-fuel heating and DHW

Gas leaks typically about 2-3% but higher GWP makes this a 20-30% increase in greenhouse gas emissions
  - 0.5% leakage inside homes
Why Electrification...?

Electricity is rapidly lowering its CO₂ content

Source: Prepared by CRS; data from EIA, Monthly Energy Review, net electricity generation from Table 7.2 and emissions from Table 12.6, http://www.eia.gov/totalenergy/data/monthly/.

Energy Impacts

• Significant site savings using Heat Pumps – typically factors of 3-4 compared to fossil fueled appliances and electric resistance heat and DHW.

• Primary or source energy less clear due to electric distribution system losses. Minimize primary energy by:
  • On-site generation: Mainly PV but could include solar hot water
  • On-site storage: Limits peak power, allows shifting energy use to time of greatest renewable generation

• (Utilities willing) Electrification allows homes to operate at minimum power using their own generation/storage – big increase in resiliency.

• Not just electrification: energy efficiency will help the transition and keep costs down.
We have to fix all the homes in the country and electrification is easier than other retrofit approaches:

- Less home disturbance
- Better cost control
- Easier financing
- Easier work for contractors c/w envelope/window upgrades
- Easier to sell – give people what they want

Think about it as the completion of the electrification program begun in the US 100 years ago
Resiliency

• On-site storage and generation allows basic home operation during emergencies.

• About half of natural gas processing is along the gulf coast and highly vulnerable to hurricanes and storm surges.
EV-Ready Homes

- Current poor public charging infrastructure:
  - Need to be able to charge at home
- All new homes should have a circuit ready for a charger install
- Trickier in existing home – need a space circuit or new panel/rewiring
- EV is easily be the biggest home load: 7.2 kW up to 50 kW
- Car battery may become the house battery
Health Reasons to Eliminate Fossil Fuels

- **Burning fossil fuels:** emit several contaminants of concern:
  - PM$_{2.5}$, NO$_2$, CO, aldehydes and leaking unburned CH$_4$

- **In the home:**
  - Field studies show key health-related contaminants related to bring fossil fuels: cooking and poor appliance venting
  - Electrification removes need for combustion safety testing, CO alarms
  - EPRI study: Electrification results in more than 12,000 avoided deaths and a monetized health benefit of $108B per year…. *Just for California plus additional benefits from cleaner outdoor air*

- **Outside air:** PM$_{2.5}$ & NO$_2$
  - Environmental Justice Issue – often worse in disadvantaged communities
Key safety issues are:

- **Carbon monoxide** – No concerns if home is all-electric
- **Fire safety** – No naked flames
- **Kitchen safety** - No naked flames
  (Induction cooking inherently safer – cooler surfaces for induction cooktops, no flames)
- **No gas explosions**
  A key risk factor for utilities – see, for example, PG&E’s bad reputation from occasional home explosions
- **Earthquake safety**
  Post-earthquake fires usually a bigger hazard than the earthquake itself
Removing poor appliances: e.g. Wall Furnaces
- Wall furnaces are chronically poor at venting
- Causes moisture problems and high levels of combustion contaminants
- Even worse if kitchen of bath exhausts are used

Their low capacity serving small spaces makes them ideal candidates for low-cost replacement with a Heat Pump – possibly even a 120V Heat Pump

This would serve Low-Income households the most
- More likely to have wall furnaces
- Smaller dwellings have higher contaminant concentrations
- Low income dwellings less likely to have ventilation systems

Eliminate use of GAS cooking appliances as supplemental heat
- Need to provide good low operating cost options for low income households
Reducing the Cost of Decarbonization / Electrification
Data Solicitation

GET PAID to help break down the costs of Deep Energy Retrofits in homes!

Berkeley Lab is gathering information to better understand the costs and challenges of deep energy retrofit (DER) projects in homes. Your contribution will help guide the future research agenda on this topic. We need your help!

TWO WAYS TO CONTRIBUTE:

1. Anonymously share detailed DER project cost and work scope data with our team. The first 30 participants can each receive $300 for providing cost data if they submit a minimum of 5 projects.
2. Respond to a survey of the DER market drivers, opportunities and challenges.

For more information, visit: https://homes.lbl.gov/projects/costs-deep-energy-retrofits
Or email us at ProjectDERCosts@lbl.gov.

BERKELEY LAB
Bringing Science Solutions to the World
Database Summary

12 Programs  1,739 Projects  10,512 Measures  3,294,946 ft²  $24,689,213
Clustering Project Types

Unsupervised Machine Learning approach that groups similar objects such that the objects in the same group are more similar to each other than to objects in the other groups.
Clustering Project Types

- BASIC
- HVAC
- ADVANCED HVAC
- LARGE HOME GEOTHERMAL
- SUPERINSULATION
- ELECTRIFICATION WITH PV
Clustering Project Types

- BASIC
- HVAC
- ADVANCED HVAC
- LARGE HOME GEOTHERMAL
- SUPERINSULATION
- ELECTRIFICATION WITH PV

$ - Total Cost
\%
- CO₂e reduction

![Bar chart showing total costs for different project types.]

- Envelope
- Equipment
- PV

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Total Cost ($)</th>
<th>% CO₂e reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic, n=671</td>
<td>$3,849 (18%)</td>
<td></td>
</tr>
<tr>
<td>HVAC, n=557</td>
<td>$10,105 (31%)</td>
<td></td>
</tr>
<tr>
<td>Advanced HVAC, n=136</td>
<td>$26,228 (25%)</td>
<td></td>
</tr>
<tr>
<td>Large Home Geothermal, n=14</td>
<td>$120,802 (39%)</td>
<td></td>
</tr>
<tr>
<td>Superinsulation, n=15</td>
<td>$109,059 (51%)</td>
<td></td>
</tr>
<tr>
<td>Electrification with PV, n=43</td>
<td>$54,098 (68%)</td>
<td></td>
</tr>
</tbody>
</table>
Clustering Project Types

BASIC

HVAC

ADVANCED

HVAC

LARGE HOME

GEOTHERMAL

SUPERINSULATION

ELECTRIFICATION

WITH PV

$150,000
$125,000
$100,000
$75,000
$50,000
$25,000
$0

Total Cost ($)  

- Envelope
- Equipment
- PV

Basic: $3,849 (18%)
HVAC: $10,105 (31%)
Advanced HVAC: $26,228 (25%)
Large Home Geothermal: $120,802 (39%)
Superinsulation: $109,059 (51%)
Electrification with PV: $54,098 (68%)

$ - Total Cost
% - CO₂e reduction
Affordability and Cost Compression
Affordability and Cost Compression

Utility Bill Savings ($)

$33
Affordability and Cost Compression

Utility Bill Savings ($)

Loan Payment ($)
Affordability and Cost Compression

- Utility Bill Savings ($)
- Loan Payment ($)
- Loan Supported by Savings ($)

Loan Terms
(Period and interest rate)
Affordability and Cost Compression

- Utility Bill Savings ($)
- Loan Payment ($)
- Loan Supported by Savings ($)
- Actual Project Cost ($)

Loan Terms (Period and interest rate)
Affordability and Cost Compression

- Utility Bill Savings ($)
- Loan Payment ($)
- Loan Supported by Savings ($)
- Actual Project Cost ($)

Required Cost Compression ($)

Loan Terms (Period and interest rate)
Clustered Projects Cost Compression

Terms: 30-year, 3% interest
Cost Compression - Pathways

- Rebates and Incentives
- Technology Innovation
- Soft Cost Reductions

- New Metrics
- No- and Low-Cost Methods
Cost Compression - Rebates
Cost Compression – Technology Innovations
Cost Compression – Ductless Heat Pumps

Ductless Heat Pump Cost Compression

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Amount ($USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Cost</td>
<td>$4,397</td>
</tr>
<tr>
<td>Automated HVAC sizing calculations</td>
<td>$250</td>
</tr>
<tr>
<td>Bundled measures soft cost savings</td>
<td>$220</td>
</tr>
<tr>
<td>Volume purchasing discount</td>
<td>$220</td>
</tr>
<tr>
<td>Automated fault detection and commissioning</td>
<td>$250</td>
</tr>
<tr>
<td>Electrical savings from 120V plug-in tech</td>
<td>$350</td>
</tr>
<tr>
<td><strong>Target Cost</strong></td>
<td><strong>$3,107</strong></td>
</tr>
</tbody>
</table>
Cost Compression - Heat Pump Water Heater, 50-Gal

Heat Pump Water Heater Cost Compression

- Current Cost: $2,242
- Bundled measures soft cost savings: $112
- Volume purchasing discount: $112
- Electrical savings from 120V plug-in tech: $700
- Target Cost: $1,318
Cost Compression - Heat Pump Water Heater, 50-Gal

80-Gal HPWH

Heat Pump Water Heater Cost Compression

Current Cost: $3,828

- Bundled measures soft cost savings: $2,242
- Volume purchasing discount: $112
- Electrical savings from 120V plug-in tech: $700
- Target Cost: $1,318

80-Gal HPWH Installed Cost (2019 $USD): $3,828
Cost Compression - Heat Pump Water Heater, 50-Gal

80-Gallon 120F = 50-Gallon 140F + Mixing Valve
Cost Compression – Low Power Electrification
Cost Compression – Low Power Electrification

INNOVATIONS FOR EASIER HOME ELECTRIFICATION

Avoiding panel upgrade/new service/home rewiring costs

Watt Diet Calculator

Source - Sean Armstrong, Redwood Energy (2020)

56homes.lbl.gov
Cost Compression – Low Power Electrification

INNOVATIONS FOR EASIER HOME ELECTRIFICATION
Avoiding panel upgrade/new service/home rewiring costs

Smart Circuit Splitters and Sharing

Programmable Subpanels

Power-efficient Appliances (120V)

<table>
<thead>
<tr>
<th>Device</th>
<th>Device</th>
<th>120</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>10A, 1200W</td>
<td>8.3A, 1000W</td>
<td>6.3-15A, ~1400W</td>
<td></td>
</tr>
<tr>
<td>LG WM3999HBA</td>
<td>GE GeoSpring</td>
<td>Innova HPAC 2.0</td>
<td></td>
</tr>
</tbody>
</table>

Watt Diet Calculator

All Electric 100 Amp Home (2,000 square feet)
Ducted heat pump, medium power heat pump water heater, hybrid heat pump dryer

<table>
<thead>
<tr>
<th>Device</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>240</td>
</tr>
<tr>
<td>12</td>
<td>240</td>
</tr>
</tbody>
</table>

Eaton®
Energy Management Circuit Breaker (EMCB)

Source - Sean Armstrong, Redwood Energy (2020)

57homes.lbl.gov
Cost Compression – Soft Costs
Cost Compression – Soft Costs

Need to reduce Soft Costs:

- Customer acquisition
- Testing
- Program participation
- Load calculations
- Project design
<table>
<thead>
<tr>
<th>Cost Compression – Soft Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outsource customer acquisition to programs with marketing and sales expertise</strong></td>
</tr>
<tr>
<td>CURRENT</td>
</tr>
<tr>
<td>$1,000-2,500 per project</td>
</tr>
<tr>
<td>COMPRESSED</td>
</tr>
<tr>
<td>$700</td>
</tr>
</tbody>
</table>

| **Reduce diagnostic testing and commissioning** |
| CURRENT                      |
| Combustion: $387              |
| COMPRESSED                   |
| $0                           |

| **Remote approaches to customer acquisition, management and sales** |
| CURRENT                      |
| Remote audits: 40% cost savings for individual projects |
| COMPRESSED                   |
| 60% savings for executed projects |
| $564                         |

| **Automated, rapid HVAC equipment sizing** |
| $100                                      |
Cost Compression – New Metrics
Using Electric Heat Pumps Instead Of Gas Furnaces
Cost Compression – New Metrics
Using Electric Heat Pumps Instead Of Gas Furnaces

Emissions Neutrality

Cost Neutrality

80 AFUE

95 AFUE
Cost Compression – New Metrics
Using Electric Heat Pumps Instead Of Gas Furnaces
Cost Compression – New Metrics
Using Electric Heat Pumps Instead Of Gas Furnaces
Cost Compression – No- and Low-Cost
Automated emission reductions
Cost Compression – No- and Low-Cost
Automated emission reductions

FIGURE ES1
Emissions-optimized EV Charging Waterfall
Average Mileage Scenario - SPP Night

What’s Next?

• Cost Compression
  - Technology, Soft Costs, Behavior, New Metrics
  - Streamlining/Reducing code and permitting requirements

• Standardized packages of upgrades to simplify decision-making process

• Electrification for Low-Income households
  • Drop-in/Plug-in/DIY approaches
  • Transportable technologies

• Over-come market fears about heat pump performance, higher energy costs, induction cooking

• Document health and IAQ outcomes of electrification

• How to overcome emergency equipment replacement

• Homeowner electrification ambassador programs

• Contractor networks
Resources

- For electrification big picture: **Rewiring America** and **Rewiring Communities**
- For power-restricted homes: **Redwood Energy Pocket Guide**
- Check with your contractor or utility for rebates

**Rewiring Communities:**
A Plan to Accelerate Climate Action and Environmental Justice
By Investing in Household Electrification at the Local Level

1. Adam Zurofsky,
2. Jeffrey Schub,
3. John Rhodes,
4. Tony Carnes,
5. and Sam Gelb**
Thank You...!

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References

