A Simple Screening Formula for Estimating the Energy-Cost Effect of an Undersized Residential HVAC System

A practical field approximation using national-average household HVAC spending

Purpose. This short paper proposes a deliberately simple screening equation for estimating the possible annual energy-cost penalty associated with an HVAC system whose nominal capacity is below the calculated design load. It is intended for preliminary field communication and comparison - not as a substitute for ACCA Manual J/Manual S, hourly building simulation, or utility-bill regression.

1. Background

Proper HVAC sizing begins with a building heating and cooling load calculation. U.S. Department of Energy guidance identifies ACCA Manual J as a recognized method for determining residential loads and notes that undersized equipment may fail to heat or cool a home properly. ENERGY STAR likewise emphasizes proper sizing for comfort and performance.

ENERGY STAR currently states that a typical U.S. household spends about $1,900 per year on energy, with almost half going to heating and cooling. That implies a convenient national screening baseline of approximately $900-$950 per year in HVAC-related energy spending. This is an average only; actual costs vary substantially with climate, fuel, utility rates, envelope quality, equipment efficiency, and occupant behavior.

2. Proposed Screening Model

Define the fractional capacity deficit as:

$$U = \max(0, L/C - 1)$$

where **L** is the home's design heating or cooling load (Btu/h), **C** is the installed equipment capacity at the relevant design condition (Btu/h), and **U** is the fractional undersizing. For example, U = 0.20 represents a 20% capacity deficit relative to the installed capacity.

The proposed cost-screening equation is:

$$\text{Delta Cost} = H \times U \times P$$

where **H** is annual HVAC energy cost and **P** is an empirical screening penalty coefficient. For a deliberately conservative first-pass estimate, this paper uses **P = 0.35**. The 0.35 coefficient is not a published national engineering constant; it is an explicit modeling assumption introduced to prevent the capacity deficit from being incorrectly treated as a one-for-one energy penalty.

Variable	Meaning	Suggested screening input
L	Calculated design load	Manual J or equivalent (Btu/h)
C	Available installed capacity	Rated/selected capacity at design condition (Btu/h)
H	Annual HVAC energy cost	Actual bills preferred; ~ $950/yr national screen

Variable	Meaning	Suggested screening input
P	Penalty coefficient	0.35 default screening assumption

3. National-Average Simplification

If actual HVAC spending is unavailable, set H approximately equal to $950/year. The equation becomes:

Estimated Extra Annual Cost ~= $950 x U x 0.35

Capacity deficit	Approx. annual penalty*
10%	$33/year
20%	$66/year
30%	$100/year
40%	$133/year
50%	$166/year

*Using H = $950/year and P = 0.35. These values are screening assumptions, not guaranteed savings or measured national undersizing penalties.

4. Worked Example

Assume a home has a calculated cooling load of 42,000 Btu/h and an installed system with 36,000 Btu/h of available capacity.

$$U = 42{,}000 / 36{,}000 - 1 = 0.1667\ (16.7\%)$$

Using $1,000/year of known HVAC energy spending:

Delta Cost = $1,000 x 0.1667 x 0.35 ~= $58/year

This result should be described as an estimated screening penalty, not as a prediction that the homeowner's bill will necessarily increase by $58. The principal consequence of undersizing may instead be extended runtime and inability to maintain setpoint during peak design conditions.

5. Interpretation and Limitations

Capacity deficit and energy consumption are not linearly interchangeable. A system that is 20% undersized does not automatically consume 20% more energy. Compressor and blower efficiency, part-load behavior, indoor and outdoor temperature, humidity, duct leakage, insulation, thermostat settings, equipment staging, and supplemental heat can materially change the outcome. Heat pumps are especially important to model separately when capacity shortfall causes electric resistance backup heat to operate.

The formula is therefore best used as a communication and triage tool: determine the load, determine available equipment capacity, estimate the deficit, and translate that deficit into a modest dollar range. For engineering-grade predictions, replace the national baseline with actual utility data and use climate-specific load/runtime modeling.

6. Recommended Field Formula

Extra Annual HVAC Cost ~= Annual HVAC Cost x max(0, Design Load / Installed Capacity - 1) x 0.35

For customer-facing use, label the output **Estimated undersizing-related energy-cost impact** and disclose that the 0.35 coefficient is a screening assumption. A future calibrated version could estimate P from measured runtime, local weather, equipment efficiency, and utility-bill data.

Sources

1. U.S. Department of Energy, Building Science Education: *HVAC Proper Sizing of HVAC Systems*. Describes load-based sizing and ACCA Manual J.

2. U.S. Department of Energy: *Right-Sizing Equipment vs. Wrong-Sizing - How Not to Waste Energy*. Notes that undersized equipment may fail to heat or cool properly.

3. ENERGY STAR: *Clean Heating and Cooling* and *Air-Source Heat Pumps*. Reports typical household energy spending around $1,900/year, with almost half devoted to heating and cooling, and emphasizes proper equipment sizing.

Technical note: This paper introduces a simplified screening model. No national study located for this paper establishes P = 0.35 as a universal measured undersizing penalty. It is intentionally identified as a tunable assumption rather than an empirical constant.