“Good building science not only requires that all the parts and pieces of a house work together, but it also demands that they be figured out ahead of time.”

Kevin Ireton, “The Trouble with Building Science”, Fine Homebuilding Magazine

A complimentary chapter of The Home Comfort Book.

Buy the book at [NateTheHouseWhisperer.com.](NateTheHouseWhisperer.com)

Home Comfort 101

Are there things about your home that drive you crazy?

If you’re reading this, that answer is probably “Yes!” and you are serious about solving a problem that’s been bugging you.

Here are some typical problems people want help with:

Health I suspect my house is making me or my family sick with asthma, allergies, cold, or flu.

Hot Upstairs Second floor is 5-15 degrees warmer than downstairs in the summer.

Poor Sleep Bedrooms are too hot or cold, we have allergic reactions in them, or they feel stuffy.

Icicles I worry about water coming into the house.

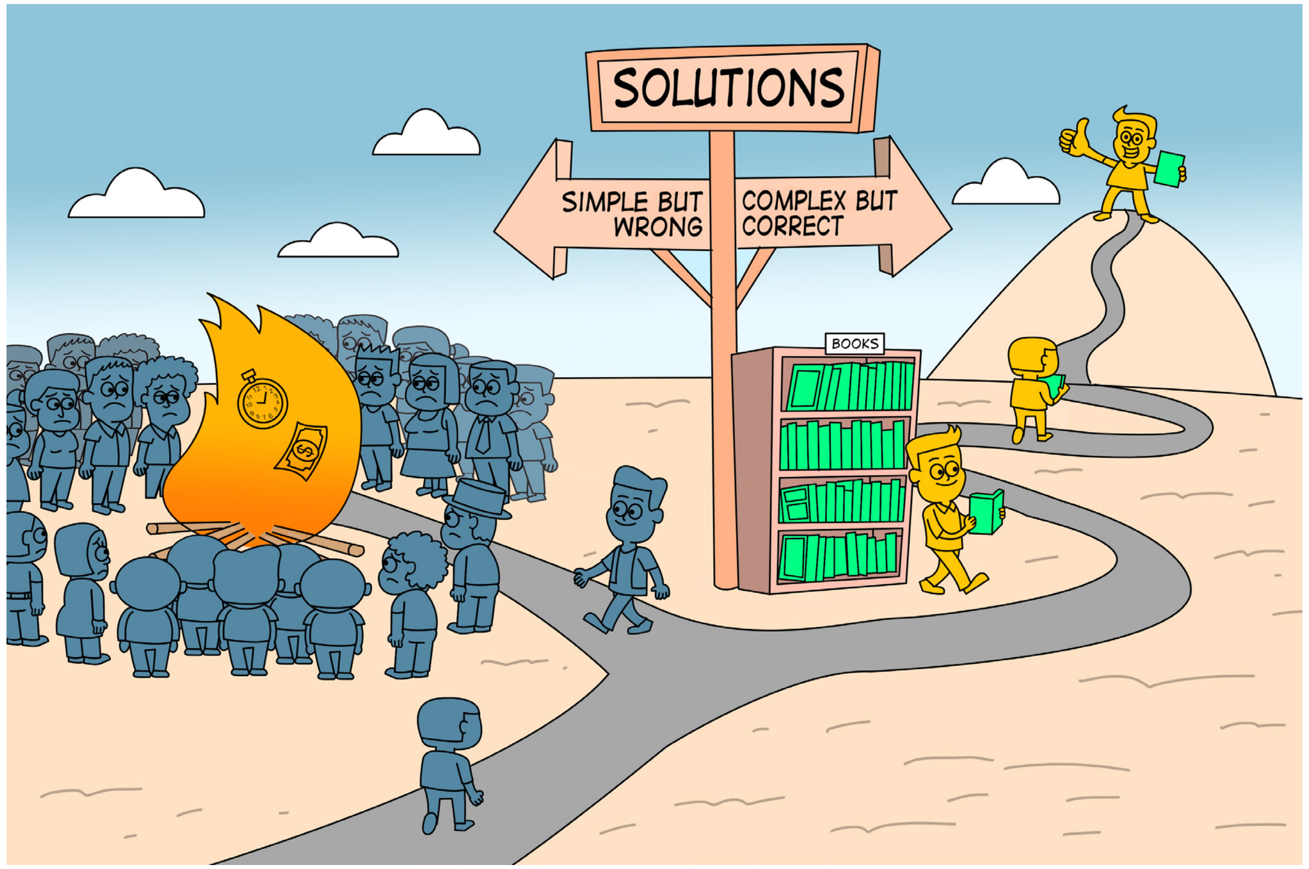
Damp Basement My basement smells musty and dank.

Mold There is questionable stuff growing in a few places. I may be allergic.

Stinky No matter how much I clean, the house sometimes stinks. I buy air fresheners or burn candles to cover nasty smells. I worry they’re unhealthy.

Sticky Even with the air conditioner on, floors, walls, and my skin feel sticky and clammy.

The goals of this chapter are to help you understand the Building Science behind these problems and to build a list of problems you would like to solve.



Let's get the hard stuff out of the way now. If you're expecting a silver bullet that solves all your woes, look elsewhere. We are in the business of complex, but correct. This book is written to break the complex down into digestible and actionable chunks.

Avoid Wasting Time and Money

A home is a complicated system of systems - heating, cooling, plumbing, electrical, roofing, siding, insulation, and many more. If you want to solve a problem, you often have to adjust several systems at the same time or bad things happen. Pests come, mold forms, roofs leak, houses stay uncomfortable. Bad results happen despite many thousands being spent to "solve" problems. The original work often has to be undone, repaired, and fixed correctly. It's frustrating. Neither doing nor redoing the work is cheap. We want to help you solve problems while avoiding that frustration and wasted money. The complex but correct path is heavy up front on education. Then it requires careful planning. This book will help with both, and this chapter is the beginning.

Some people have been told the "right" thing to do and heard so many conflicting opinions that they rightfully want to know not just what to do, but why. This book contradicts a lot of the common myths perpetuated by people who don't understand how the systems in your home are interconnected, and then explains why things need to be done. Much of it will be done with data and science. All of it will be done with a sense of humor. This rather dry subject doesn't need to be dry to read.

Definitions

Terms in my world tend to get mixed up, so here are the definitions I am using.

Home Performance The art and science of making your home more comfortable, healthier, longer lasting, and more efficient. 99% of the time it is multidisciplinary: multiple contractors are required. It is focused on solving homeowner problems within their budget. It requires measuring multiple characteristics to diagnose a problem, then planning to figure out how to solve root causes.

Building Science The physics of how your home works. Most importantly, it deals with the flows of heat, air, and moisture. Home Performance is built on a foundation of Building Science.

Building Scientist One who uses building science to solve problems in a building. There is not a certification program for it, so anyone can call themselves one. Multiple trades may use this term, particularly energy auditors, architects, insulation contractors, and various consultants.

Energy Auditor One who tests and inspects a home to find root causes to client problems in their homes. They almost always do a test in on a project, and sometimes do a test out. Often they are not heavily involved during a project (which is where mistakes can be best caught.)

Home Performance Specialist An individual or company that guides your project from start to finish. They use multiple measurements to help you not only diagnose a problem and figure out what to do, but also help you develop a budget, find contractors, get bids, and get the work done. Most importantly, they follow up to see if it worked, and why. (Or why not.)

A Home Performance Specialist is to your home like a doctor is to your body. They often tend to be generalists like a family doctor. Some will have different specialties, such as solving mold problems, Indoor Air Quality problems, icicle problems, etc.

Nothing is certain. Have you ever heard of a doctor saying, "this is 100% guaranteed to work?" Of course not. Bodies are very complex and we all treat them differently. Instead, doctors tend to think in odds. 50% odds of success isn't great. 80% is good. 90%+ is as good as you can expect. Home performance works the same way.

Separating Energy Auditors from Building Scientists from Home Performance Specialists

While Home Performance Specialists are often energy auditors, their work is far more than an energy audit. An energy audit is like an MRI test. It gives valuable information for the diagnosis, but it does not tell exactly what to do in order to solve the problem, nor does it actually solve a problem. Either one may also call themselves a Building Scientist (I do). That simply means their work is based on Building Science.

A Home Performance Specialist is much more than an energy auditor. Here are some key differences:

- Involved from start to finish with a Home Performance project.
- Make predictions. They predict budget, air leakage at completion, and energy usage one year post-project. Then they track to see how close they came.
- Accountable for results. While accountability is shared with homeowners because decisions are made jointly, their reputation is built on delivering results for clients.
- Rabidly look for feedback. We only know if something worked or didn't work from what clients tell us. While objective measurements give us a good idea if something worked, your subjective feedback is what we need to know.
- Very strong reviews. Average reviews should be at least 4.5 out of 5 stars with detailed feedback about the success of the projects, not just that they were nice and cleaned up after themselves.
- More likely to be individuals. Getting good results is hard, it takes intrinsic drive. Until their performance can be compared to others with a tool like a JD Power survey, which gives an extrinsic reward for excellence, individuals are likely to outperform larger companies.

Home Performance Specialists are pretty rare, it takes a rare mix of core competencies. One of the aims of this book is to educate consumers like you on what it takes to truly solve problems, thereby creating more demand for them.

Promises, Promises

I promise to do my best to teach you how your house really works and how to solve problems in it. Before you continue, I need you to make me a few promises, too:

- Promise to be open minded and thoughtful
- Promise to be open to challenging long-held beliefs
- And most importantly, promise not to take shortcuts. Half measures lead to quarter results. (Or worse.)

If you don't keep those promises, the responsibility for results, good or bad, rests on your shoulders. Is that fair? Promise? Great, let's go.

How to Solve Complex Problems

Solving complex problems takes a different thought process than buying a product like a TV or a light bulb. A slower, more thoughtful path is the best way to a solution that works the first time.

Think of it like being a doctor. Does a doctor throw a bottle of pills at you as you walk through the door? Of course not. They ask questions to find out what ails you. They take your height, weight, and blood pressure. They may run more tests. They diagnose first. There is a saying in medicine: "Prescription without diagnosis is malpractice."

Practicing Home Performance is similar to practicing medicine on your home. Home Performance is based on Building Science, which is the physics of how your home works. A high performance home is like a healthy body. We Home Performance Specialists need to diagnose before we can prescribe, or we are doing you harm. Please don't ask us to skip steps.

"Prescription without diagnosis is malpractice."

After diagnosis, a doctor will discuss the treatment plan with you. Together you finalize the treatment plan and she will help you execute it, following up to see if it works. Again, this same process is needed to solve complex problems in your home.

Break this process, and you're likely to get the equivalent of fen-phen pills causing heart attacks. A single pill can't make you lose weight. No single product can solve a complex problem. My industry has tried a lot of shortcuts, as have I. Shortcuts fail. This is the complex but correct path. Diagnose, prescribe, treat, follow up. Home Performance work gets the systems of your home back into balance, just as a good doctor does the same for your body's systems.

Design for People, Good Buildings Will Follow

That's the mantra of Robert Bean from HealthyHeating.com. We fully agree, in fact the next chapter, Home Comfort 102 (when complete), is based on his work. All of the problems listed at the beginning are about comfort. Even worrying about mold or ice dams is a comfort issue - it causes stress. Our homes should be our refuge. They should be comfortable, safe, and healthy. If a house is a comfortable refuge, typically most other problems were already solved, and the home is naturally efficient. It's a good building. Consequently, we focus heavily on comfort. Good comfort requires good balance of the many systems in your home.

The 5 Priorities for Creating Comfortable, Efficient Homes

Making your home a refuge has a similar path for all homes. This assumes that your home is watertight and doesn't have any roof, plumbing, or basement leaks. If you don't keep water out, you don't really have a building. After any water leaks are dealt with, the path will almost always follow the Five Priorities:

1. **Air seal the house to reduce air leakage.**
2. **Air seal the house more to reduce air leakage.**
3. **Keep air sealing the house to reduce air leakage.**
4. **Insulate better.**
5. **Install the right HVAC.**
   HVAC (heating, ventilation, and cooling system) that is properly sized, specified, installed, and optimized with sealed and right-sized duct work. This will allow you to really take control of your tighter and better insulated home.

Will I Save Millions of Dollars?

No. I need to burst your bubble here.

Typical savings are usually in the $200-700/year range, even for advanced projects. The math is simple. US homes use about $2000/year in utilities. Typically about half of that is for heating and cooling. That means we only have $1000/year we can affect, give or take. Typical energy savings from these projects are in the 20-70% range, so $200-700/year at best. Can it be more? Yep. But it's more likely to be less, unless you do a substantial project.

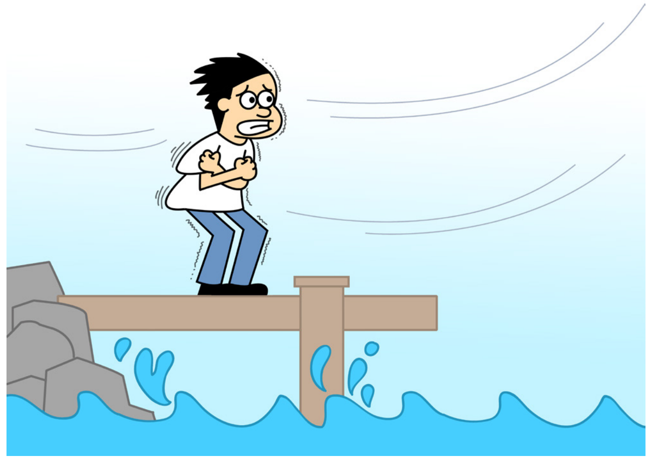
Sadly, my industry has focused on savings so much that consumers have come to expect this sales pitch. It's bunk. You are not sending your kids to college with energy savings. The math for the ~10% of US homes heating with fuel oil or propane may look better. Most homes heating with natural gas will see modest savings.

If you only want to save money, don't embark on this process. It's a waste of time and money. Only read this if you want to turn your home into a refuge and solve problems like uncomfortable rooms, mold, icicles, Indoor Air Quality, and so forth. Blunt enough for you?

Do you get the idea that air sealing is very, very important? It's critical. No, the mainstream still does not make a big deal about it (though things are changing). After watertightness, no other factor comes close to air sealing in importance for human comfort.

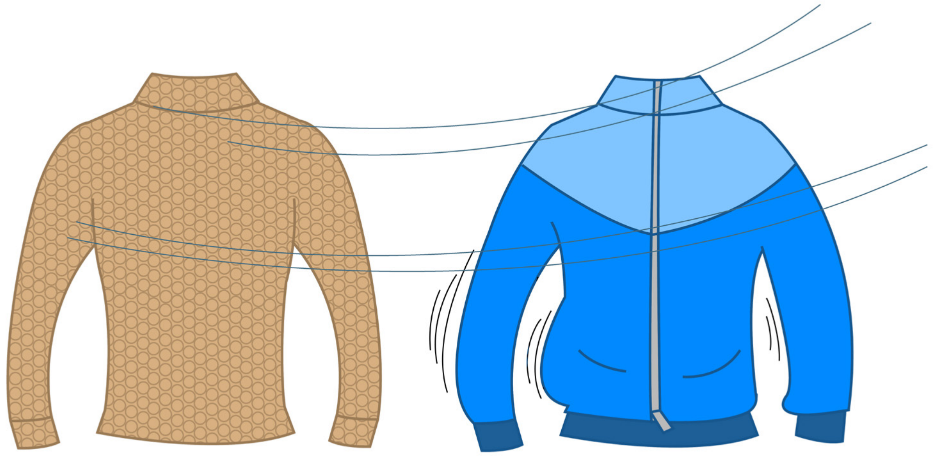
The Pier Analogy

Here's one way to picture air sealing: imagine you're standing on a pier in the middle of winter with a 30 mile per hour wind blowing.



You're only wearing a t-shirt and jeans, so the wind cuts right through you. Waves are crashing into the pier pilings and nearby rocks. The spray is hitting you. As you feel the wind blowing icily through your paper thin shirt, you're quickly frozen to the core.

Now imagine that I cruelly give you the choice between a windbreaker and a very loose knit sweater, the type with big gaps in the weaving of it. These two coverings are your only choices to wear out on that pier with the wind gusting and waves crashing. Which would you choose?



Of course you take the windbreaker! Since the wind and water will blow right through the sweater, you might as well have nothing on. Air sealing is the windbreaker, while most insulation is the loose knit sweater. Without air sealing, insulation is almost useless. This is how your house works too: air leaking through insulation makes the insulation almost useless.

I'm called to many older homes that have recently been "insulated", but because they're still very leaky, they remain drafty and cold. Even when the wind is not blowing those houses experience air-flow due to the house acting like a smokestack (more on that later). These homes are wearing a sweater on a cold pier.

Combine the windbreaker and the sweater, and the pairing is almost magical. They are Batman and Robin. The insulation is the sidekick, though. Air sealing does most of the butt kicking and gets to wear the cool suit.

I almost can't overemphasize the importance of reducing air leakage.

There are so many comfort and moisture problems in a house that can be traced back to air leakage. Much of the rest of this chapter (and book) will be about air leakage.

Do You Know Your Blower Door Number?

Me in a pink bunny suit with my blower door. (I lost a bet.)

I've already stressed how Home Performance revolves around comfort and that air sealing is the most important factor in delivering it. That means we need to measure leakage, since what gets measured gets managed.

If you don't measure air leakage, how can you have any idea of whether or not an upgrade worked, or is likely to work? The answer is you can't. Comfort and balance are likely to elude you.

A blower door is the tool Home Performance Specialists use to measure air leakage. The blower door number is by far the most important number I want to know about a house. Given the choice between square footage, year built, energy use, number of occupants, or blower door number, I want to know the blower door reading. Every. Single. Time.

That means it's an awfully good number for you to know, too. Think of it like the blood pressure reading for your home. Every time you go to the doctor, they take your blood pressure. It helps give them a basic understanding of your health. For a better understanding, they need to ask questions and do more tests. The same thing goes for Home Performance projects and blower door readings.

A blower door is a big fan that goes in the front door of your house. It can quite accurately measure how much air your home leaks. That number can be easily converted to the size of hole that is always open in your home, typically somewhere between a basketball sized hole and a window. Just divide your blower door number by 10, and that's approximately how many square inches it is. Every 1500 points is about a square foot.

It would be extremely difficult to do my job well without one. Imagine measuring blood pressure without a cuff. You can guess, but sooner or later those guesses are going to be wrong and hurt someone. Any competent Home Performance Specialist will test before, during, and after your project to gauge results and likelihood of success.

A red shroud replaces your door temporarily, while the large fan (in the bottom) blows air in or out of your home to measure leakage. The rectangular gauge hangs above the fan to one side.

Here's what a reading looks like on the blower door

The number on the left (50.0) is a pressure reading, which is measuring the difference between the pressure inside the house, and the pressure outside of the house.

The industry standard test pressure is 50 Pascals, which is the equivalent of a 15-20 mile-per-hour wind against all sides of your house at the same time. With something like that going on, you can find a lot of leaks in a house in a short amount of time.

The number on the right (2257) is the leakage reading or what I call the "blower door number.". It's measured in cfm50, or cubic feet per minute at 50 Pascals. The unit doesn't matter that much as long as you always compare the raw blower door reading in cfm50, which is our practice.

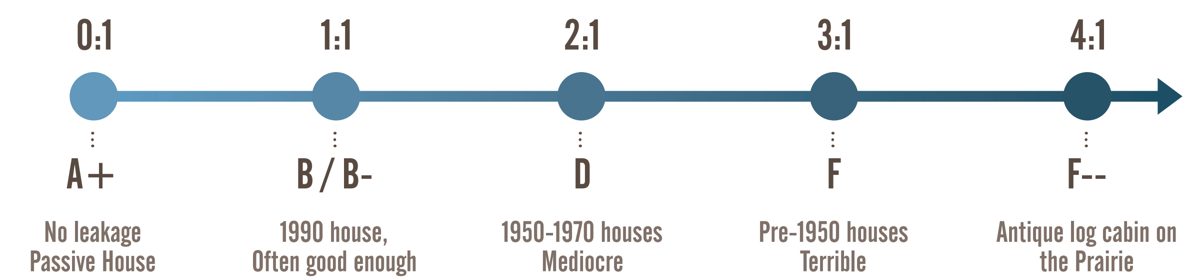
Every 10 points is roughly equal to a square inch hole. There are 144 square inches in a square foot, so every 1400-1500 on the blower door is equal to a square foot hole in your house that's open 24/7/365. A basketball sized hole is about 0.5 square feet, for reference.

The home from this reading is about 1700 square feet. ([It's the 1915 Case Study on the website.](#))

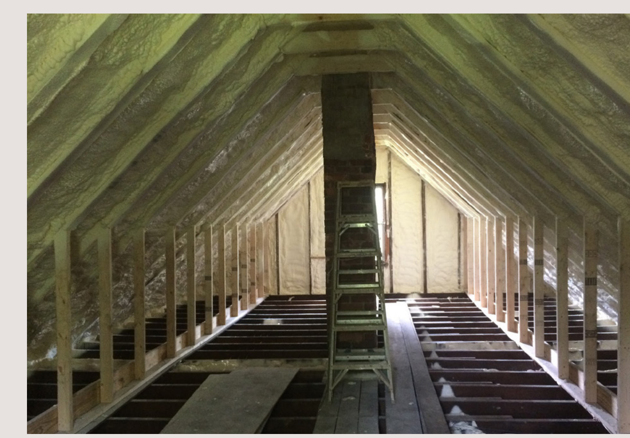
Before any work was done, the blower door number started out at almost 8000. That's over 5 square feet of leakage, 10 basketball sized holes, or one window being open all year. After air sealing work, it was down to 2257. We eventually got it under 1900. That's a little over a one square foot hole or two basketball sized holes.

What Does a Blower Door Reading Mean?

Leakage : Square Footage ratio



Real World Example



Here's the house from the blower door reading and the spray foamed attic that was a big part of the 6000 point leakage reduction. We installed 3.5" of closed cell spray foam on the roof deck, 2" on the walls.

Note the line of foam just to the right of the floorboards and the chimney, it's air sealing the tops of interior walls.

Let's think of a 2000 square foot home to make the math simple. If that house had a 1:1 leakage:square footage ratio, it would have a 2000 blower door number. That's decent; a B or B- grade. Often a one to one ratio like this is good enough to gain adequate control of the air/heat/moisture going into and out of the home. For a 1:1 home to work well, however, the top and bottom of those houses needs to be well air sealed.

Homes built in the last 20-30 years are usually in this 1:1 range, but often have to get tighter still because the tops and bottoms are still leaky. While the leaks aren't huge, they are still big enough to cause comfort problems. See the 1970s Two Story Colonial or 1996 Center Hall Colonial case studies as examples. They were still out of balance at the beginning of the projects. I'll expound on this as the chapter goes on.

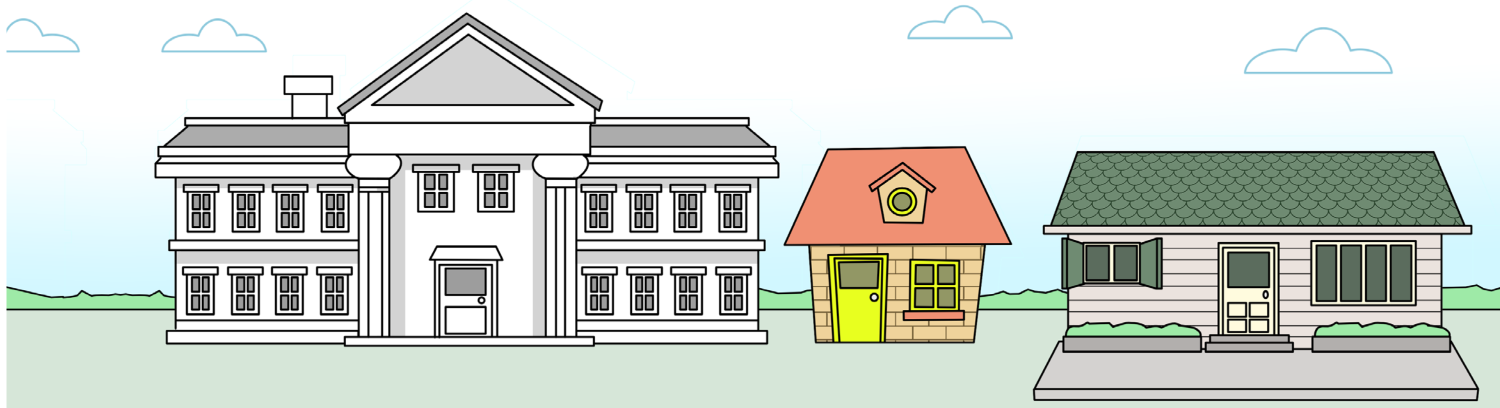
If that same home was built between 1950 and 1970, it might be in the 2:1 range, so it would have a 4000 blower door number to 2000 square feet. Delivering comfort in a home this leaky is often attempted with oversized brute force HVAC, and possibly a zoning system. HVAC stands for heating, ventilation, and air conditioning. Often the results of brute force HVAC still include 5-10 degree temperature differences between different parts of the house. Most homeowners remain unsatisfied in spite of having Herculean HVAC systems on the job. Finesse is needed to get comfort, not raw power. See the HVAC 101 and HVAC 102 chapters for more on this.

If that 2000 square foot house was built in 1910, it likely would be in the range of 3:1, or a 6000 blower door number. These homes are drafty and typically very difficult to control. They often experience massive temperature swings, where the basement may be 20 degrees different than the second or third floor. That was definitely the case in the 1915 Case Study home.

Once you know the blower door number, you can begin to make plans. What are the biggest problems to solve? What areas are most likely to affect those problems if they are air sealed? What can be sealed easily? What should be sealed but is more difficult? What is most likely to make the biggest difference to the blower door number?

These are the sorts of questions that help you and your Home Performance Specialist begin to design solutions that help address the problems you want to solve.

Be sure to set realistic targets for reductions and communicate them to the crews you work with. Setting multiple targets depending on what upgrades are planned is also important.



Quick and Dirty Has Weaknesses

Three caveats about the quick and dirty leakage ratio.

First, bigger houses need a handicap. To hit a tipping point, a 5000 square foot home may need to get to 0.7:1. That's around a 3400 blower door number to get to where it can be controlled. Think about a small box that has nothing inside of it but air. It has a lot of wall area compared to how much air it holds.

A big box has much less surface area compared to how much air it holds. Larger homes have more volume compared to their surface area, and air leakage happens where inside meets outside.

Big houses should naturally leak less than smaller ones, and often need to see low leakage:square footage ratios to be controllable.

Second, homes with knee wall attics often reach a tipping point above 1:1. Cape Cods, Bungalows, Victorians, and Arts and Crafts are examples of homes styles that often have knee wall attics. If you have sloped ceilings on your top floor, you probably have knee wall attics. They are sometimes known as 1.5 and 2.5 story homes. These homes often have tipping points in the 1.3:1 to 1.5:1 range.

Third, homes that are built on a slab need to be handicapped like large homes. Wherever two pieces of wood or other building materials come together, you have a potential for leakage. Homes built on slabs are missing a major joint: the top of the basement wall. That spot is typically a major leakage point in homes with basements or crawlspaces. Therefore homes built on slabs tend to be tighter. If you have a leaky slab home, say 2:1, it's really leaky. You may also need to get to 0.7:1 before your home is controllable. So a 1000 square foot ranch home on a slab would need to get to 700 points to have a good chance of solving comfort, mold, or other problems.

The Four Tenets of Home Performance

Before digging deeper, let's talk about the benefits of Home Performance and getting your home in balance. If you get your house sealed well, adequate insulation installed, and correctly install the right heating and cooling (HVAC) system, the benefits fall into four categories, or tenets.

1. Comfort

Few of us have ever truly experienced living in a consistently pleasant comfortable home, but it is possible. No room in your home should be more than 2-3 degrees different from another. It shouldn't have air that feels wet like a swamp or dry like a desert. The air shouldn't feel oppressive to your sinuses or give you headaches. Nor should it smell. It should be the most comfortable house you've ever lived in. It should be so comfortable you never think about your comfort. Sounds crazy, doesn't it?

2. Health and Safety

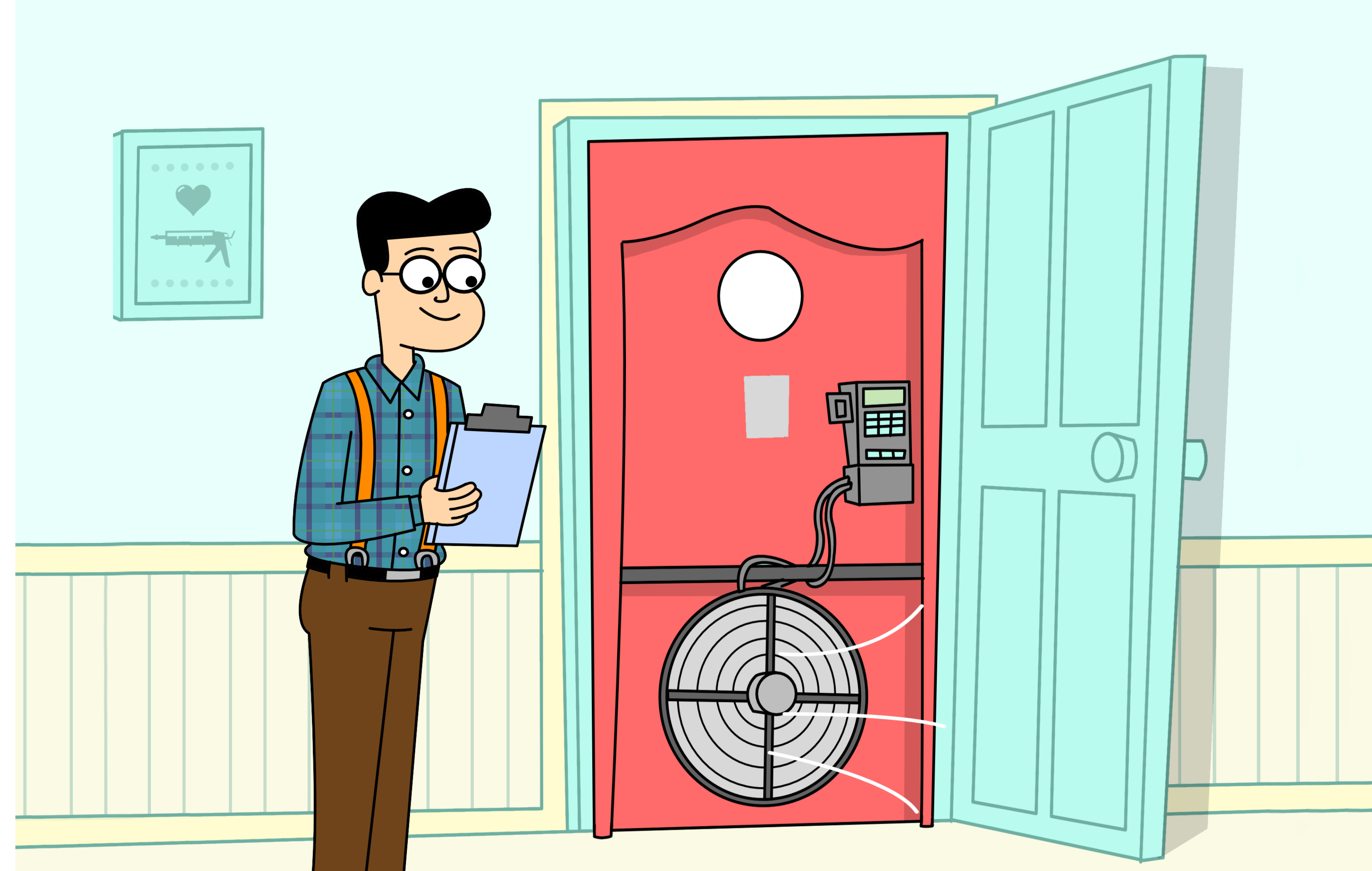
It's a bit unsettling to hear, but studies and new measurement tools tell us our homes are often very unhealthy. High humidity levels can lead to dust mites and mold. Humidity also causes volatile organic chemicals in furniture and cleaners to release faster. These can lead to respiratory illness, allergies, asthma, etc. Appliances like gas water heaters and gas stoves emit bad things like carbon monoxide, particulates, and nitrous oxides. The air leaking into the house likely crept in through nasty places like the attic, garage, basement, crawlspace, or walls. In my work I have found all of these spaces are usually full of animal excrement and/or mold. Pretty gross! A high performing home will also have a dry, clean, healthy fresh air supply coming in from a known location.

3. Durability

There are three major things that kill buildings: water, water, and water. Liquid does the most damage, but water vapor is hard on things, too. The more moisture problems a house has, the more likely you are to need expensive repairs. If you design moisture management into your home, it is likely to be longer lasting, healthier, more comfortable, and less expensive to operate or repair. Crawl spaces won't contribute to asthma issues. Termites won't have wet wood to burrow into. Mold likely won't develop or need to be treated.

4. Efficiency

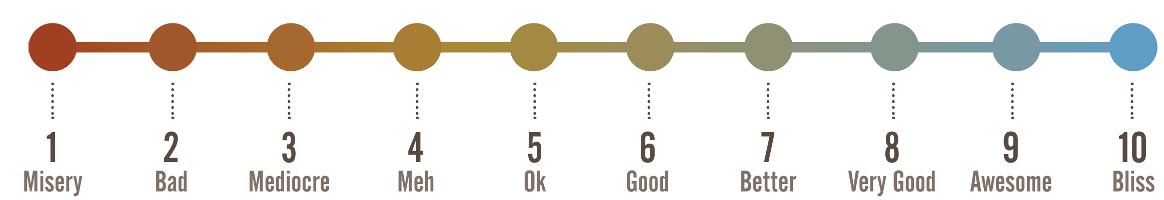
This is generally what clients think of first. Good news and bad news here. The bad news is that efficiency makes a lousy goal. We find that when we focus on it, the problems we are there to solve get forgotten, and little is accomplished. The good news is that if you make a building really comfortable, healthy, and long-lasting, efficiency just follows. It's important to repeat Robert Bean's mantra here: design for humans and good buildings will follow. Efficiency is part of a good building.



A friendly Home Performance Specialist can deliver results.

Depending on your priorities and budget, you can achieve all four tenets simultaneously. Don't expect perfection unless you have a very high budget, though. Results arrive on a spectrum. On a scale of 1-10, outcomes for some problems may score a 6, others a 9. Budget and the type of work you opt for determines which benefits are most likely to show up.

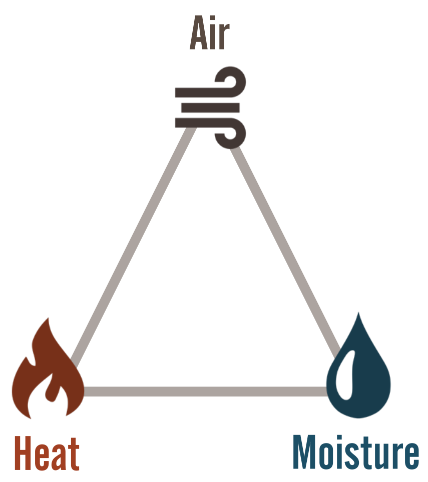
Results Spectrum



Budget Determines What is Possible

A qualified Home Performance Specialist can help you prioritize your problems, develop an affordable budget, and design a solution package that balances achieving as many of your goals as possible while sticking to your budget.

Getting Control



It's time for some light physics. If you want Comfort, Health and Safety, Durability, and Efficiency, they will show up once you gain adequate control.

Control over heat, air, and moisture flows in and out of your home, as well as inside it. Control doesn't have to be perfect, but it does have to be adequate. What that means varies from home to home.

If you adequately control the air, heat, and moisture flows, magic happens. Air flow is the most important one to control, because heat and moisture often travel in air. If you stop the air, you stop much of the heat and most of the moisture as well.

Heat moving on air is easy to understand as most of us have lived in or visited a drafty place where cold air blows through a crack of a door, window, or wall into the house. What you may not realize is that in and out are always balanced. That cold air leaking in is matched by warm air leaking out somewhere else in the house. Moisture is a touch trickier. Water vapor is often called humidity, and you've probably heard the phrase "it's not the heat, it's the humidity." Moisture in the air can carry a lot of energy. It's called "latent" heat. [Latent heat] is the energy it takes to make a material change phase. In the case of dehumidification, the phase change is from water vapor to liquid water. If you live in a humid climate, it's part of what your air conditioner or dehumidifier must work to remove from the air.

It's a lot of work, too. Did you know that it takes three times as much energy to turn waterr into water vapor as it does to take it from freezing to boiling temperature to freezing temperature (32 to 212 degrees)? That's why controlling humidity is so important: it takes a ton of energy to deal with it. Use your bath fan to pull shower and bath steam out of the house. Use your range hood to pull cooking steam out. Air seal your house to let less humid air in. Simple in theory, trickier in execution.

Latent heat (aka humidity) makes us pretty uncomfortable because our bodies cool themselves by sweating. If there is a lot of moisture in the air, our sweat.

Air Sealing to Control Air, Heat and Moisture Movement

Air sealing is also very important to make insulation work properly. Insulation controls heat moving in and out of the house. It works mostly by trapping air. If air blows through insulation, not much air gets trapped. This is particularly true for fiberglass and mineral wool insulation. See the Insulation Types chapter for more.

In case you think your new home is safe from air leakage, about 20% of Energy Smart's work is done on homes built after 1990. In many parts of the country, builders seldom test leakage with blower doors. Without measuring leakage you have no way of managing build quality around this critical metric.

The importance of solving air leakage is often unrecognized or underemphasized. Understanding and solving air leakage is the most critical piece of Home Performance. Do I sound like a broken record yet?

Control Within Your Home

Once you get control of the air, heat, and moisture going in and out of your house with air sealing and insulation, then you want to control their levels inside the house. Each room needs the Goldilocks amount of heat or cool – not too much, not too little.

This is tricky because HVAC needs inside your home are constantly changing:

Rooms
Every room needs a different amount of heating or cooling.

People
Every person has different comfort preferences.

Sun
Conditions change during the day as the sun shines on different parts of the house.

Wind
Heating and cooling load changes when its windy.

Temperature
Outdoor temperatures go up and down which mean more or less heating or cooling is needed.

Humidity
Humidity levels change, also affecting how much it takes to heat and cool your home.

Weather
It could be sunny, or rainy, or snowy. That's often what spring is like in Cleveland, where I live.

Fresh Air
With new inexpensive monitoring tools we are beginning to measure fresh air in a lot of homes. The results are terrifying...

Real World Example: Replacing new furnaces is expensive and painful. Air seal first!

This 1989 home had substantial comfort issues and a very humid basement that were largely solved with air sealing and a smaller furnace. It was relatively tight, a 3300 blower door on a 3300 square foot home. It wasn't tight enough for comfort, though. We brought it down to 2300. The dehumidifier in the basement ran much less because the air sealing reduced humid air leaking into the house in summer. The project also required ripping out the 3 year old furnace pictured below left. The new system is on the right.

The old furnace on the left was an expensive, fairly high end one. The new furnace is of similar quality, only smaller. It really was a waste of money, and an avoidable one with a little planning.

Ripping out nearly new furnaces and air conditioners is frustrating for homeowners, and it's frustrating for me to break the bad news. Sadly, we do it a lot. It's inelegant and often futile to try to solve a leaking energy problem with brute force HVAC. Seal the house up first. Insulate. Then put in the smallest furnace and/or heat pump you can. There's a reason the Five Priorities are in the order that they are.

Once you air seal and insulate, suddenly that new HVAC system you were looking at is very likely to be too large. If you want comfort and control, it will need to be replaced.

The replacement for the furnace above made the second floor of that home heat well. A $5000 lesson that I hope to help you avoid. More about this in the HVAC 101 and HVAC 102 chapters.

So, how do you get control of air, heat, and moisture inside your home?

Tighten it! Once the house is as tight as possible, the outdoors has less influence on the indoors. Then install the right HVAC system. HVAC has to be carefully designed so it can control all of these factors. It must be sized aggressively small, meaning very close to the actual amount needed to heat and cool the house on cold nights or hot days. Yes, smaller is much better than bigger. (Sorry Texas!) The system should have multiple speeds so it's not just on and off. Good filtration, dehumidification, and humidification capabilities are often needed. Then it needs to be installed carefully so all the systems actually work (heat pump, humidifier, dehumidifier, filter, fresh air system.) Often they don't play well together because they were never optimized together.

Once installed it may need some optimization to make it operate in balance with the duct work and the home. Sometimes optimizing an existing system can fix a lot of problems, but don't pin your hopes on it working in most cases. Most home HVAC systems are woefully inadequate for this Herculean task. They're usually single speed, which means they're either on or off. They're also typically far too large which creates a whole slew of other comfort and control problems. This is discussed in depth in the HVAC 101 and HVAC 102 chapters.

Find Help. I Do.

You might have noticed by now, that Home Performance can be pretty complicated. It's not something to do alone. I don't. My business partner and I work through every project together. Often 3-5 hours per home between the two of us, just on discussion. Sometimes our disagreements are very pointed, and we almost always catch things the other one missed. Collaboration is critical to good outcomes. Our clients almost always make suggestions during the process where we say "why didn't we think of that?" and we adjust course. The same goes for contractors we work with. No one can think of everything, no one is perfect. In a game of inches, collaboration increases your chances of success.

To repeat, I highly recommend you consider working with a Home Performance Specialist to help you with the diagnostics, planning, and execution processes. You'll hear this refrain throughout the book.

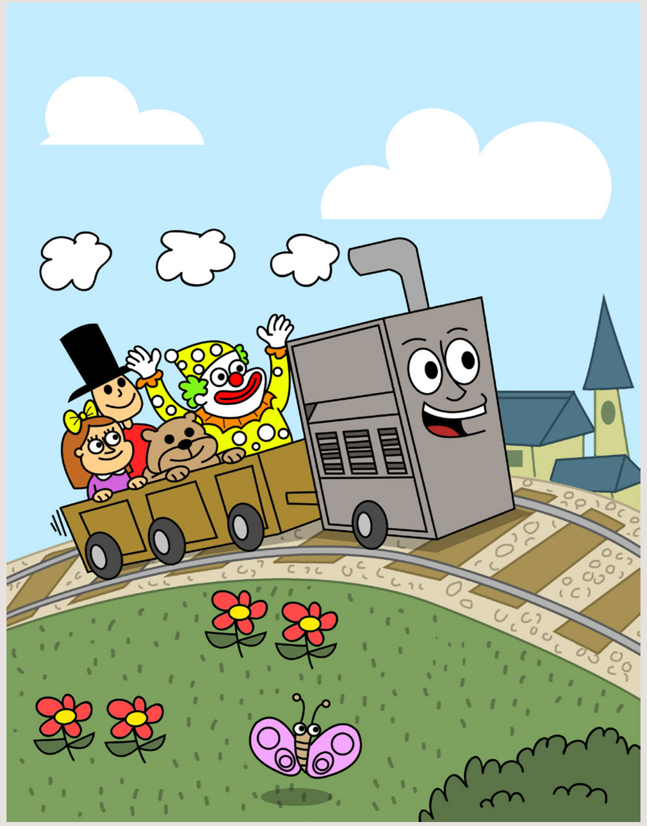
An entire section is dedicated to helping you find good people to work with and how to execute projects well. It's how you avoid snake oil and get real results.

Don't get too bewildered, though, as it almost all comes down to air sealing, insulation, and the right HVAC. Those three things help us balance your home and use physics to our advantage.

In the future we plan to create a nation-wide list of quality Home Performance Specialists and Contractors ranking them on various metrics. It will be called TrustBridge.

For now, there is a checklist at the end of this chapter to help you find a good Home Performance Specialist. Or click here to sign up to hear when the chapter on finding a HPS is ready.

Why Aren't More HVAC Systems Sized Right?



For more on HVAC Sizing, see our chapter on the topic.

You may be wondering why good HVAC systems are the exception, not the rule. It's actually pretty simple: market forces. As a society, we have gotten used to free quotes. Except they're not free. We pay for them with lower quality.

Think about it, if you had to give 3-6 bids to get a job, would you put hours of unpaid work into each bid? Not if you intended to stay in business! They could charge more for design services, but since most consumers don't see the value in the extra time to design an HVAC solution and size the equipment properly, that contractor will lose even more bids and also go out of business. It's a Catch-22. A race to the bottom in price and quality.

If you really want a comfortable home, it's likely to take a combination of a bit more work and a bit more money on your part. It also requires team players who understand the Home Performance principles discussed in this book.

Once your home is balanced and optimized, it doesn't take much to keep it in control. Once your home is in control, comfort is usually a matter of a few tweaks.

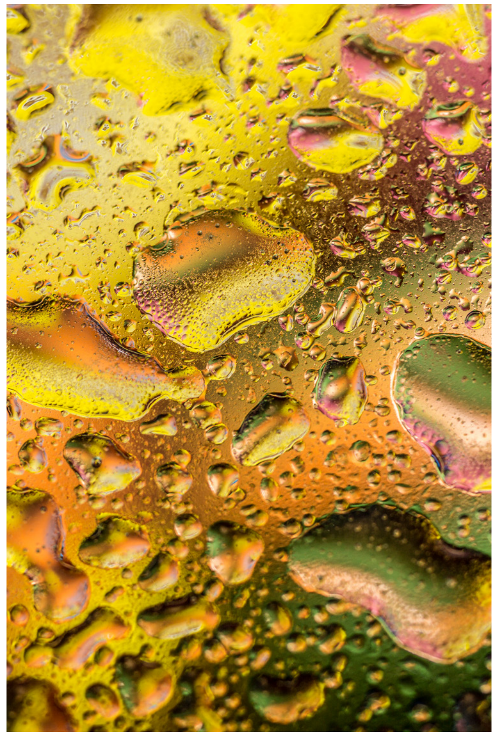
Avoid the free quote trap! Pay a Home Performance Specialist to make you a plan. They'll run a blower door test at a minimum, tell you what size and type of equipment to buy, review bids, verify it was installed correctly, and help you make those final tweaks. There are no shortcuts, except to disappointment. The Project Management section of this book will help you find a good Home Performance Specialist to help you solve problems, not create more.

In time, I hope to see the market demand more transparency about results. Currently, if a contractor doesn't get a callback, they assume it was a job well done. They miss out on a lot of feedback to improve, and "the way we've always done it" continues. Energy Smart does "warts and all" case studies to help jumpstart this practice in the market. We learn a lot from feedback on our projects.

If contractors' results were published publicly and transparently, they would become much more focused on delivering results. We are already publishing our results as case studies. See them here.

The Rules Part 1 Heat and Moisture Transfer

It's time to put on my Bill Nye the Science Guy hat! Most of the physics[1] behind how your home works are really quite simple:



Hot goes to cold. Heat wants to go anyplace cooler until it equalizes, like your coffee cup releasing heat into the air and surfaces around it until the coffee is cold. It's a more powerful force than warm air rising.

Wet goes to dry. Moisture wants to equalize, like a damp towel drying into drier air.

Air and moisture go from a higher pressure to a lower pressure via the easiest path. They are lazy, they look for the biggest and easiest holes or paths.

Gravity acts down.

And then one weird one:

Wet goes to cold.

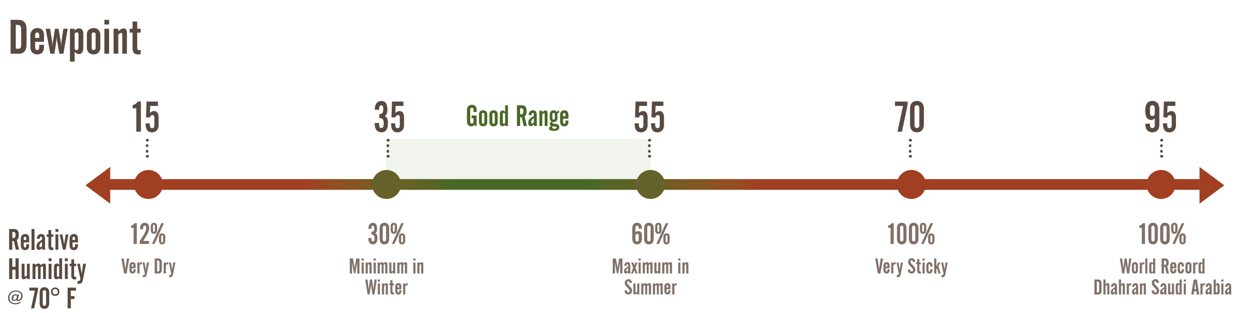
The first four are pretty obvious. The last one needs a little explanation.

Wet Goes to Cold

In general, moisture in air is drawn to cold surfaces. If those surfaces are below dew point, moisture vapor will turn to liquid. Dew point sounds tricky, but you already know what it is. Dew point is the temperature at which air can't hold any more moisture. A cold beer can or lemonade glass gets condensation droplets on it because the liquid inside is below dew point. If you cook pasta in the winter you may notice condensation inside the cold windows, especially with single pane glass. The surface of the can, glass, or window is so cold that the moisture in the air condenses on it. It's below dew point. See, you knew it already!

Ideal indoor dew points range between 35 and 55 degrees. When you get above a 70 degree dew point, it feels like you can cut the air with a knife.

High humidity leads to bad things like mold.



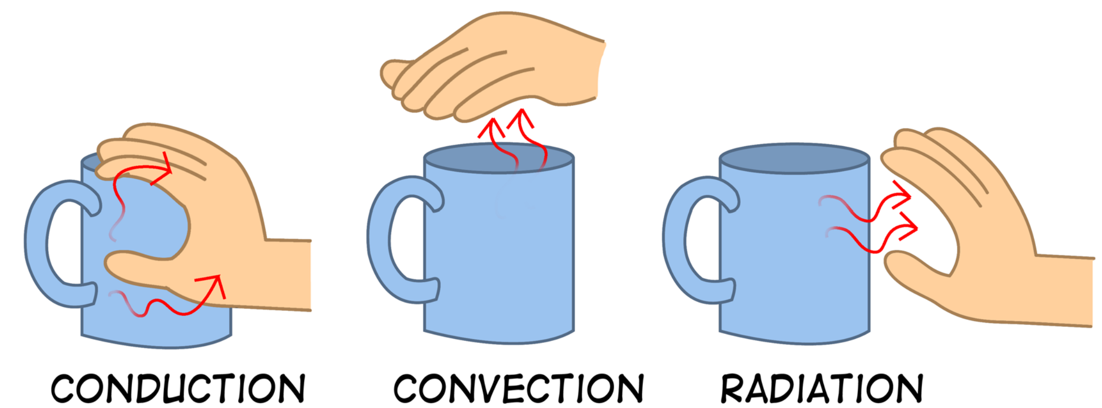
This brings us to the next important point: things are going to get wet. That's ok. It's not ok if those things don't get dry. It's very important to note that wet and dry are not absolutes. It's a spectrum. Think about a towel that's almost dry. It's not wet, but it's not dry. We need to pay attention to keeping things dry, even when they don't appear wet. Even slightly wet building materials can cause big problems like rot, pests, and mold.

Wet goes to cold is frequently why basements are damp and musty. If it's hot and humid outside and that air gets into the basement through air leaks or open windows, that humid air is likely to condense on cold basement walls. The walls are often only somewhat wet, but they can still smell musty, which is potentially a health problem. Presto! Yuckiness.

Careful air sealing and HVAC design can tackle many moisture problems. Kitchen and bath fans, good gutter systems, and landscaping can tackle most of the others. Control moisture levels in your home, and wet goes to cold won't be a substantial problem. See the Mold and Moisture chapter for more.

The Rules Part 2 – Heat Transfer

If you want a comfortable and efficient home, you need to control how quickly heat gets in and out. Heat transfers in three ways:



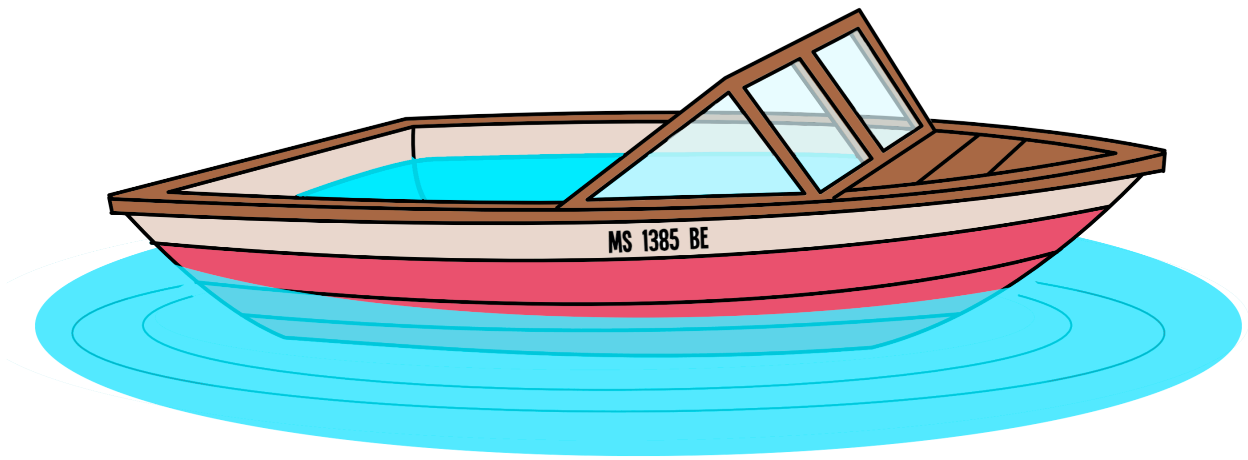
1. **Conduction**
   Through one solid to another. If you put your hand on a hot coffee cup, the heat goes from the coffee through the cup and into your hand.

2. **Convection**
   Through fluids, which can be air or liquid. Holding your hand over a coffee cup transfers heat to your hand through the steam and rising heated air.

3. **Radiation**
   Through space in one direction. Holding your hand 1" from the hot coffee cup, you'll feel radiant heat. Sunlight and fire are other examples of radiant heat.

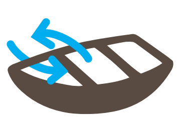
All three of these are important. Which one is most important varies by the situation. The more control you can exert over all three, the more comfortable your home will be.

Control: A Leaky Boat is Like a Leaky House



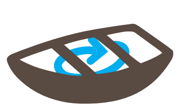
Now that we've covered some basics, it's time to go a bit deeper and talk about how your home actually works. One of the best ways to think about it is imagining your home as a leaky boat with a foot of water in the bottom of it all the time. We'll tie problems in a leaky boat back to the Four Tenets: Comfort, Health, Durability, and Efficiency. In a leaky boat, you would expect some typical problems:

In & Out of the Boat



A leaky boat requires a large bilge pump to constantly pump water out, which is an efficiency problem thanks to the bilge pump using a lot of power. Because the boat constantly has water in it, it smells musty, which is a health problem. That water is likely rotting the boat out, reducing its lifespan, which is a durability problem. If the bilge pump ever fails, the boat will sink, another durability problem, but also a health issue if you drown on the boat!

Inside the Boat



If there is constantly water in the bottom of your boat, it's not going to handle very well as it sloshes around, a comfort problem. It will also be a slow boat from not only the weight of the water, but because it leaks faster as you go faster. Those are both comfort and efficiency problems. Basically, a leaky boat stinks. And the first thing to do is to plug the leaks. Everything gets better after that.

It's not too tricky to see how all of those apply to your home:

In & Out of the House

Most homes leak a lot of air, just like the leaky boat leaks water. Moisture and heat travel on air, so leaking air has stowaway heat and moisture in it. On a hot, muggy summer day, heat and humidity are sneaking into your house. During the winter cold air is dry, so heat and moisture leak out of your home. Air leakage almost always works the opposite of what you want inside your home. That leads to an uncomfortable home.

In your home the bilge pump is your HVAC system: your furnace and air conditioner. If your home is leaky, it has to work harder to keep up, particularly on hot or cold days. That means the house is less efficient, less comfortable, and may have rot problems if moisture is able to come inside too quickly.

When the furnace or air conditioner dies, it gets uncomfortable fast. If it's particularly cold your pipes may freeze. If your house isn't leaky, you can live without heat or air conditioning for a while, no big deal. One client home went from losing 20 degrees in 6 hours to losing 10 degrees in 26 hours.

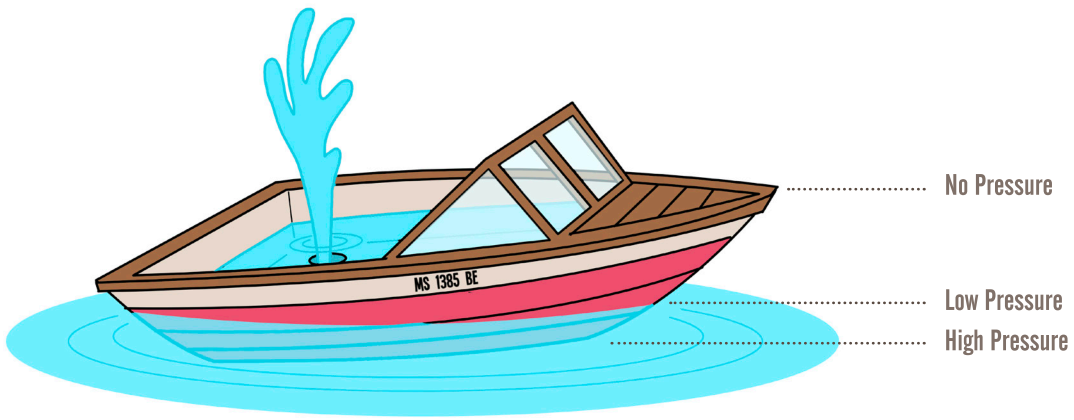
Just like a boat, your house will get wet, musty, and moldy when it stays wet too long. It's generally ok if things get wet, but they must be able to dry out fairly quickly. If you have a damp basement or crawlspace, or water pools against the house after a rain storm, these are problems that should be resolved. Otherwise you could have health issues or the house may rot out and require expensive repairs. Just like a leaky boat, the first thing to tackle is to plug the leaks.

Inside the House

Like water leaking and sloshing in a boat, a leaky house will make your furnace and air conditioner work much harder to keep you comfortable. On very hot or cold days, they may lose the battle and the house won't stay at the temperature you want. In a tight home, it takes far less energy to keep a home comfortable, and they will ride out the hot and cold periods more easily and comfortably.

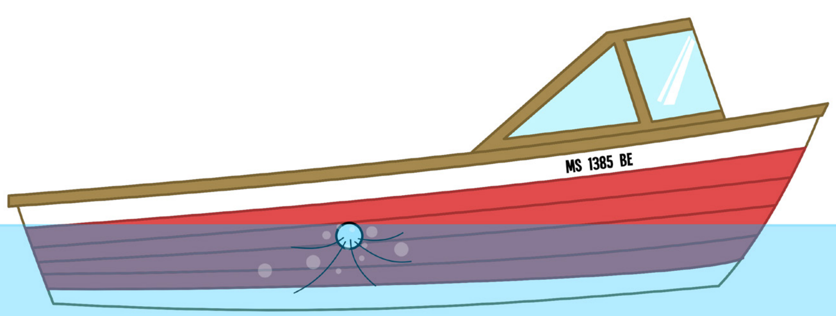
Once again, start by sealing leaks, not by buying a larger furnace or air conditioner, which will likely make things worse. If you buy a larger HVAC system and then seal your home, you probably made comfort in a tighter home impossible. Always start with air sealing.

Stack Effect – Leakage & Pressure



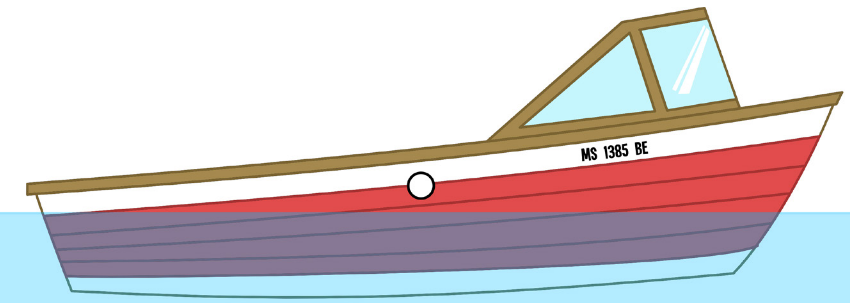
As a boat goes faster, it leaks more. As the weather gets hotter or colder, your house leaks more too. In a mixed metaphor you're unlikely to see anywhere else, I'm about to connect a leaky boat and a smoke stack.

Think about a leaky boat. Does it matter where the leak is? Of course. A hole near the bottom of the boat is going to be a real problem.



That hole in the bottom is going to be very leaky because there is a lot of pressure acting on it, and that pressure is always there if the boat is in the water. It's much more likely to sink that boat quickly than a leak near the waterline.

A hole at the waterline doesn't have much pressure acting on it. As waves go by the hole, a little bit of water will leak in each time, but the odds are the bilge pump can handle it.

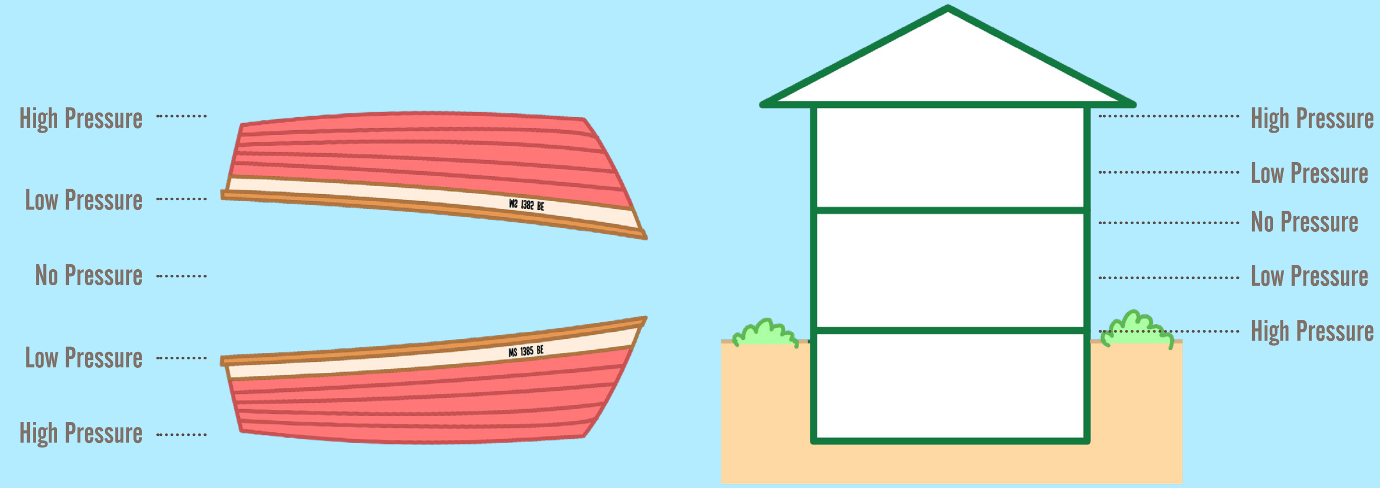


A hole above the waterline is only a problem in big storms when the water either gets that high on the boat or even sloshes over the side.

Leakage = Pressure x Hole Size

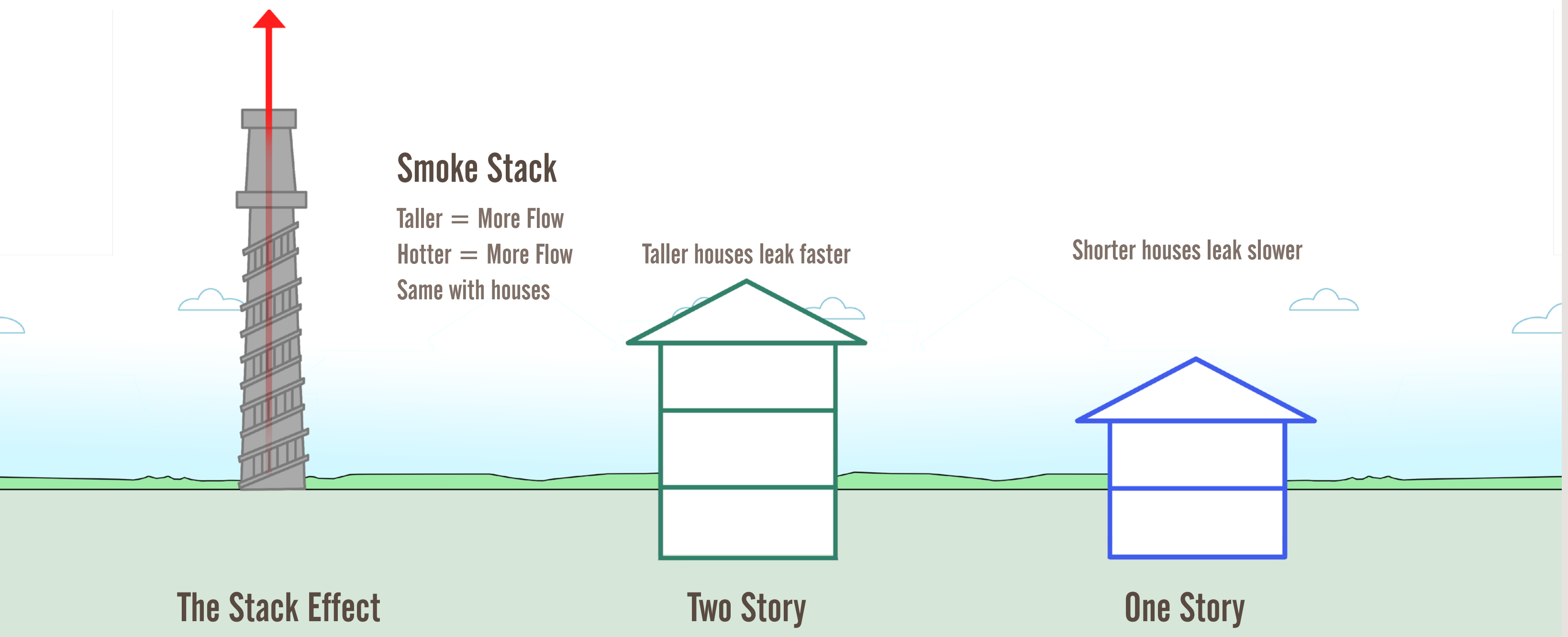
This illustrates a very important point that relates back to one of the Rules: pressure goes from high to low. If you have a hole, but there isn't any pressure pushing on it, it won't leak. If you have a hole where a lot of pressure is pushing on it, it's a big deal. (Even if it's small.)

This applies very directly to your home. Your home essentially acts like two boats on top of each other, like this:



In the winter, warm air rises through your home, due to it being less dense than colder air. It sneaks out any hole in the ceiling or walls that it can. That air has to get replaced, and it's pulled in from outdoors through the bottom of your house, usually through the top of the basement wall, or where the bottom of the first floor walls rest on the slab foundation, or on a floor over a crawl space.

Just like smoke stacks, taller homes leak faster than shorter ones.



It's time to bring in the smoke stack. If you think of the smokestacks of any factory, the taller they are the faster they flow. Also, the more heat in a smokestack, the faster they flow. Ironically, this is why using the fireplace in your house is a terrible idea if you are actually trying to heat it. Fires burn hot in the tallest part of your house, so they flow really well. They actually pull about four times as much heat out as they contribute to the house.

You've probably noticed this if you have one: other parts of the house get really cold when a fire is burning.

Different houses flow at different rates too. Many homes built from 1900-1950 have three stories, with the top story being a "finished attic" complete with quaint sloped ceilings. These houses tend to be quite leaky. They often have steam heat which makes very hot heat, plus they're tall. The stack effect is strong in them. Consequently heating them efficiently and comfortably is quite a challenge.

Conversely, single story ranch homes tend to be pretty tight. Most were built in the era of forced air, which isn't as hot compared to steam heat The house height is short when compared to older multi-story homes, too. The stack effect has much less sway in these homes, but is still a force to be reckoned with.

Breaking the Energy Model

Regardless of how tall your house is, air sealing the top and bottom thoroughly is key. One client had a very good air sealing and insulation job done on their 1952 two story home. This was one of the first retrofit jobs completed without a home performance expert's guidance where I was impressed by the air sealing work.

That house "broke" the energy model because the top and bottom were so tight.

An energy model is a computer program that creates a virtual version of your home. We can change various things in the model, like air sealing, insulation levels, and HVAC types.

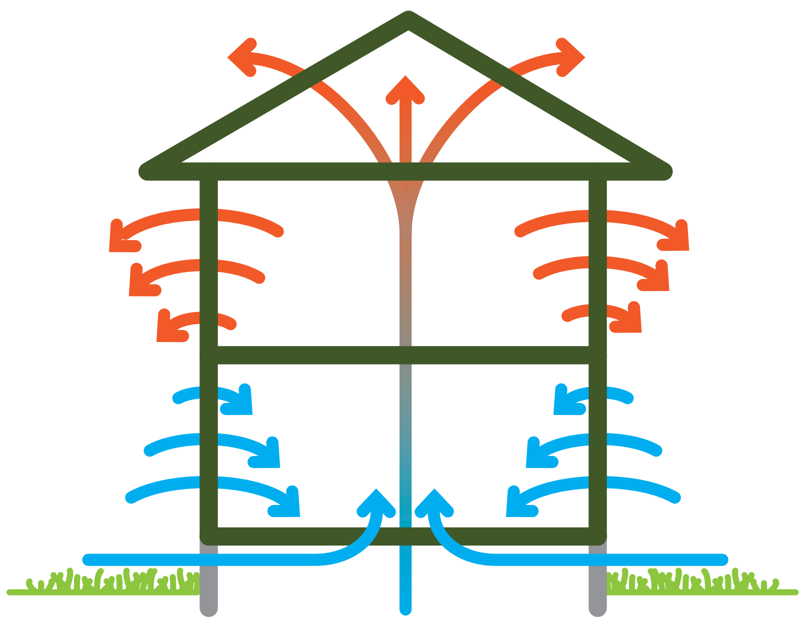
The model predicts how much energy a house will use, but often the predictions are incorrect to begin with. We have to adjust them to match reality.

Although it was two stories tall, the stack effect was arrested so much that when we built the computerized energy model we couldn't match what the house actually used to the model! Many models (including the one we use) assume that leakage is pretty evenly distributed throughout the home. When the top and bottom are extra tight, there is no way to adjust for that.

Even though the walls were empty, we had to energy model that home like the walls were insulated. We also modeled it 20% tighter than it actually was to get modeled natural gas consumption to line up with actual! This was because the stack effect was already under tight control.

It would be like a car being rated for 20 MPG that got 30 MPG and you couldn't figure out why. We believe the biggest part of it is that stack effect was largely stopped. Consequently, that home only needed HVAC measures, whereas we normally start with air sealing and insulation.

Stack Effect (Winter)



Cold air enters the bottom of the house and rises through air leaks.
The top and the bottom of the house have the highest pressures and are most important to seal.

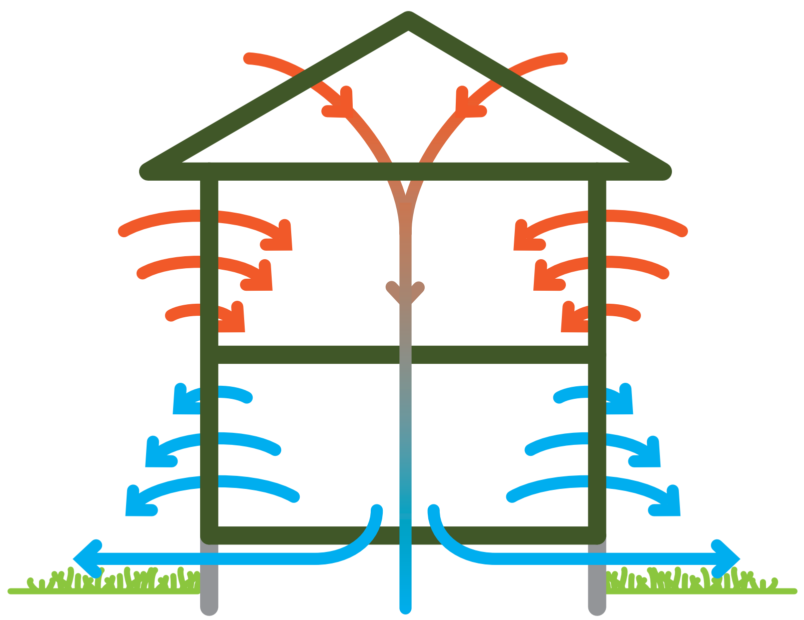
Winter is easy to understand because we're used to thinking about warm air rising.

Summer, on the other hand, is a bit mind blowing. This is where the rule about hot going to cold comes into play. On a 90 degree day an attic might hit 140-150 degrees F. (Attic ventilation isn't as big of a deal as you think here, as shingle color and type is usually the biggest driver of attic temperature. [See this Florida Solar Energy Center study on attic ventilation] for more.)

That 140 degree hot air in the attic wants to go somewhere cooler. Your air conditioned house right below it is around 75 degrees. Heat moves faster with larger temperature and pressure differences, so it's in a real hurry to get into your house through any gaps or cracks. If you look at these diagrams, you understand why the upstairs is more comfortable in winter and the basement is more comfortable in summer. In this video, Larry Janesky of Dr. Energy Saver does a great job demonstrating the stack effect with his blower door gauge.

If there is a spot in your attic where insulation is missing, perhaps at

Stack Effect (Summer)

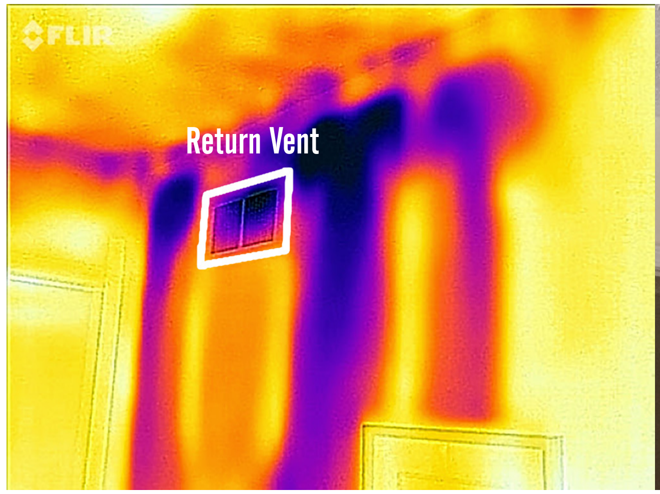


Hot attic air pushes into the top of the house and cools as it goes down.

your attic hatch, heat rushes down through the drywall (radiation and conduction) and through the leaks around the edges of the hatch (convection.) Try standing under your attic hatch on a hot day, you'll probably notice that your head feels hot. That's radiant energy coming down through the attic hatch. That hot hatch may be enough to increase the Mean Radiant Temperature in that room to make the room feel much hotter, even if the air temperature is the same as other rooms.

Air also leaks into your living space through any air leaks in the attic. Some leaks are very small, such as at the "top plates". Top plates are the boards that make up the top of a wall. They usually have drywall screwed to each side, but the top of the board is exposed. You can see them in the attic in most homes, and they tend to be leaky. Because they're at the top of your house, they have a lot of pressure on them, so even small leaks matter. I'll illustrate with a client home.

Real World Example – Leaky Top Plates

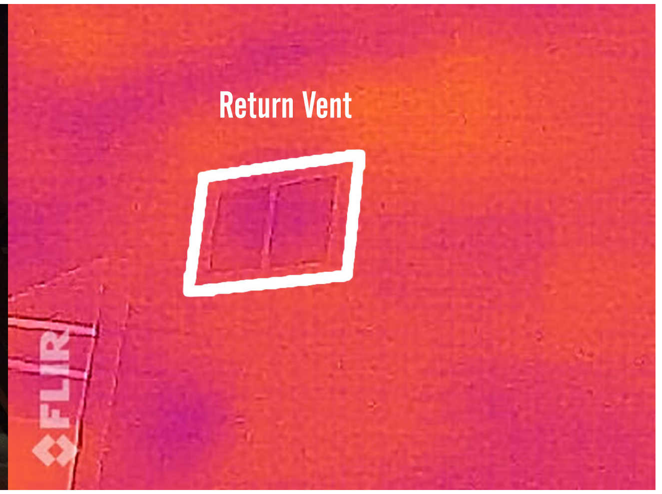


Leaky top plates.

In normal light, it doesn't look like a problem!

Blue is cold (and bad) in this case because this photo was taken in cold weather. This interior wall was wildly leaky. You can see the cold blue air rushing downwards as the blower door (which is on) sucks it into the house.

Air sealed top plates.



After air sealing.

This is the same spot after being air sealed. It's a very boring infrared picture, just what we want. There are no warm or cold spots. You can see from how even the temperatures are that we licked that problem with air sealing. The client reports comfort levels in his office going from a 3 out of 10 to a 9 out of 10. To diagnose this problem you really need a blower door running on a fairly hot or cold day, and an infrared camera. Everything else is just guesswork.

In summer, pressure pushes from the attic into the house, so just like in a boat a small leak at the bottom of a boat is a big deal. Same thing with your house at both the top and bottom. Typical leaks at the top and bottom of your house are around chimneys, plumbing stacks, dropped ceilings in bathrooms, basement rim joists, and so forth are also important to find and fix. See the Air Sealing chapter for more.

The warmth then travels downwards towards the bottom of the house. In homes with basements or crawlspaces, the air coming into the house from the attic leaks back outside through any gap it can find in the basement or crawlspace wall. In slab homes, the colder air seeks any path it can find where the wall touches the floor, then escapes to the great outdoors.

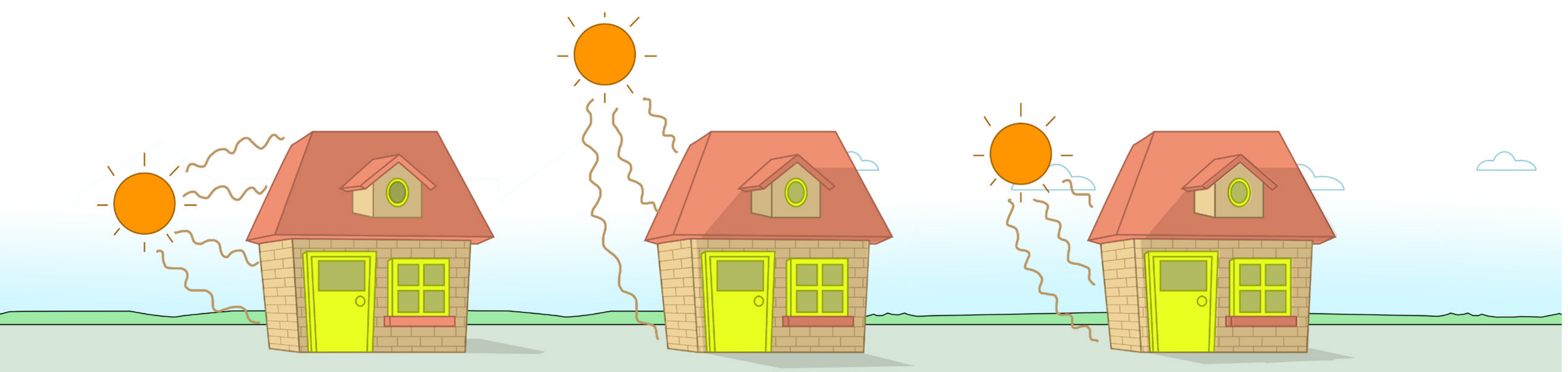
If your air conditioner won't keep up or keep the house comfortable in the summer, the first thing to tackle is usually air sealing and insulating the attic. Unfortunately, we find this often leads to unsatisfactory results because now the air conditioner is wildly oversized. It cools the first floor just fine (where the thermostat is.) The thermostat reaches the temperature you set it at, which is known as being "satisfied", and shuts off the AC.

The AC didn't run long enough to push cool air all the way upstairs, leaving the second floor cooking. Because of this, true comfort often requires new HVAC equipment. This is why it's a good idea to figure out your air sealing and insulation plan before buying a new air conditioner or furnace. Otherwise you may be buying new HVAC again. We rip out quite a few furnaces and air conditioners that are less than five years old. Plan first so you avoid that expensive mistake.

To reiterate, the better you can air seal a house, particularly at the top and bottom, the more you can reduce the stack effect. The more you can reduce the stack effect, the easier your house is to control. The easier the house is to control, the easier it is to make it comfortable. And when your home is comfortable, everyone is happy. Everything is interrelated. You'll find that theme throughout this book.

Next, it's time to show how reducing the stack effect and having the right HVAC system are interrelated.

It's a Brick! House.



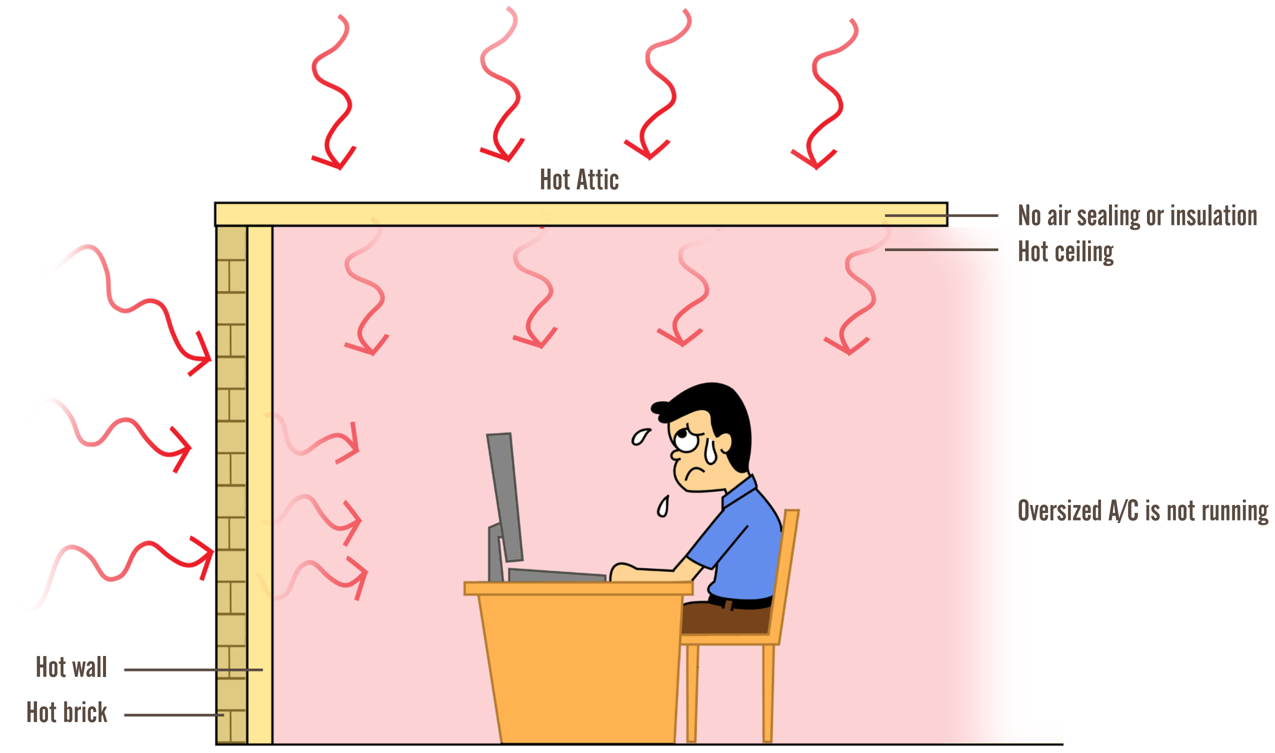
Morning	Afternoon	Evening
Brick 70 F	Brick 85 F	Brick 95 F
Roof 70 F	Roof 125 F	Roof 140 F

Think about a brick house with uninsulated walls on a hot, sunny summer day. The sun beats on the brick (radiation) and warms it up.

The brick gradually transfers that heat through the wall until the inside wall is warm (conduction.) The heat gain into the house is at its worst level in the late afternoon and early evening because the sun has been beating on the house all day. It's bad timing because it happens just as you get home from work a bit tired.

Right before dinner you sit down at your desk to pay bills against a south wall that the sun has been beating on all day. The wall is warm because heat from the brick conducted through. Even sitting two feet away from the wall, you feel slightly uncomfortable, but you don't know why. The reason is there are hot spots on the wall that are pushing interior surface temperatures to 90+ degrees (radiation) even though the air in the air conditioned room is at 70 degrees (convection removing heat.) The warm wall may make you feel hot and tired, even though your home is air conditioned.

Mean Radiant Temperature (MRT)



70 degrees F, 70% humidity

The problem with where you're sitting to pay bills is one of Mean Radiant Temperature (MRT). Mean Radiant Temperature is the average temperature of all the surfaces around us. If there are any hot spots on the walls or ceiling during a hot day, we're likely to be uncomfortable. Our bodies like average temperatures to be around 70-75 with low to moderate humidity. (There's moisture again!) When surface temperatures get above 80 degrees or so, we start to feel hot. Our bodies can't give off heat quickly enough to stay cool. Warm walls may be nice in winter, but not on a hot day while paying bills.

In this example, the walls and attic are leaky and uninsulated, so the heat just comes right through. Especially in the evening after the sun has been beating on them all day. When the air conditioner is running, it blows cool air against the walls and ceilings and cools them off.

The problem is, when the AC is too big, it doesn't run much. It's called short cycling, and means it doesn't cool surfaces well.

Hot spots remain, Mean Radiant Temperature stays high, and you feel hot, even though the thermostat says 72. Also, an AC has to run for a while before it begins dehumidifying. If it short cycles, it doesn't dehumidify well, and that leaves you feeling clammy. If your AC is right sized, it will run a lot longer. Then it will constantly wash the walls, ceilings, and floors of your home with cool air. That leads to better MRT. It also does a lot more dehumidification. Both lead to better comfort. Oversized is bad, mmmk? Still not convinced? See the HVAC 102 chapter for more.

MRT and Controlled Cooling

The reason Mean Radiant Temperature is so key to comfort is that your body is always trying to get rid of heat. It makes more than it needs. Human comfort is all about how fast the body dumps heat. Too quickly and we say we're cold. Too slowly and we say we're hot. Just right and we don't even think about it. Human comfort is all about controlled cooling 24/7/365.

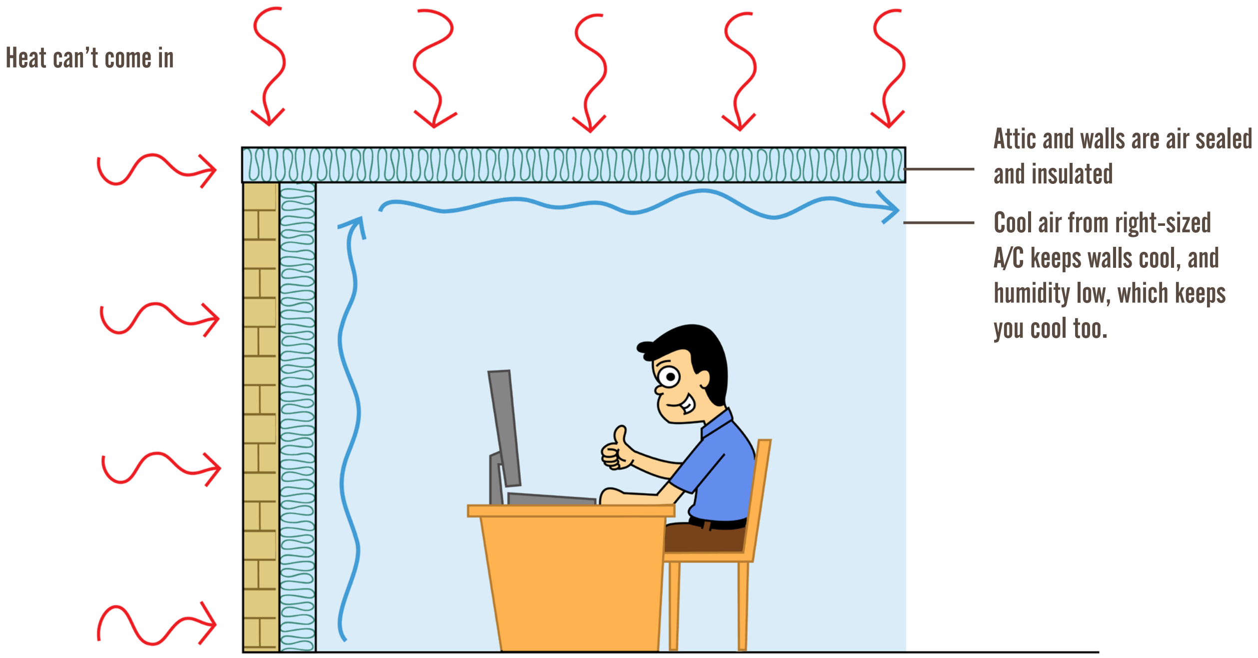
Cool surfaces actually suck radiant energy out of us. Think about a plate glass window on a cold day, you don't want to sit next to it! It literally sucks the heat out of you.

60% of heat transfer from our bodies is radiant, so MRT is the most important comfort factor.

When surfaces are warm, they don't pull radiant heat from us as quickly. If they're warm enough, they push heat back at us. If the house is at all humid, your sweat also can't evaporate quickly enough and cool you. If surfaces get too warm and humidity gets too high, you end up overheating since your body can't cool fast enough. Thermostat wars ensue.

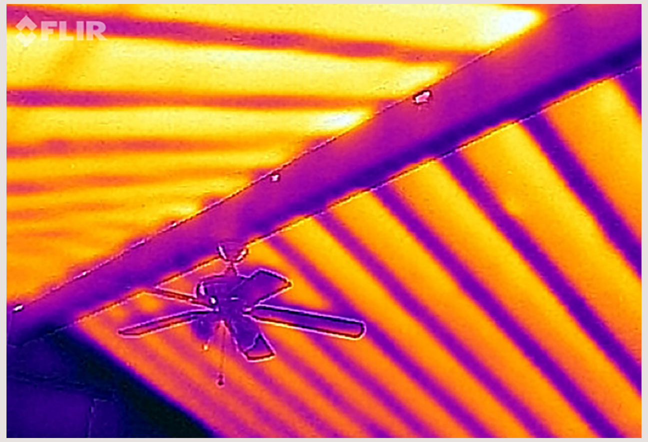
If all walls, ceilings, and floors in your home have similar temperatures, you're likely to be much more comfortable than if there are hot spots. A few hot spots probably won't kill you, but the fewer the better. It's not just the average of the temperatures, it's also about how extreme the highs and lows are. Even surface temperatures in the mid 70s equals good Mean Radiant Temperatures. Here is what good Mean Radiant Temperature looks like. The wall and ceiling are well air sealed and insulated, so heat doesn't come into the house quickly. The right-sized air conditioner is running and cooling all the room surfaces, evening out temperature differences and reducing humidity.

You are almost happy paying bills!

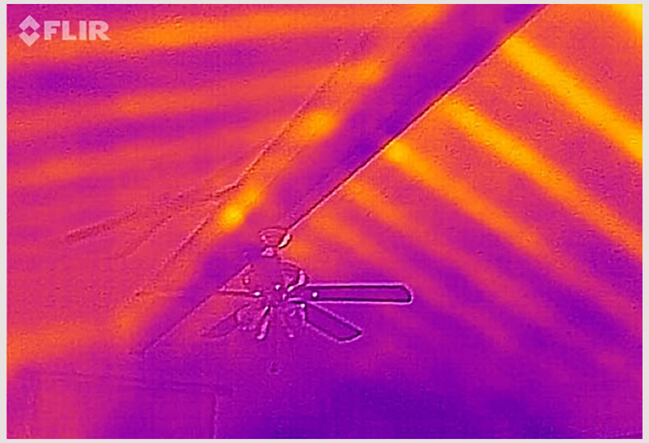


76 degrees F, 45% humidity

Real World Example



This is a cathedral ceiling that was completely uninsulated during a renovation project. It was a warm day when this infrared photo was taken. Yellow in the image is warm, cool is blue. Since the studs are cooler, it shows there is no insulation over the ceiling. With all that yellow, the average surface temperature, or MRT, is very high. Comfort was miserable at this moment. It felt like the sun was shining on my head, which in effect it was.



This is the same space after insulation and air sealing. Note that the studs are the warm part now, which means there is more insulation on the ceiling. There's one small air sealing miss above the fan. Misses can happen, particularly in a rushed project. The roof on this house was torn off, spray foam was applied between the rafters, and the roof then reinstalled, all on the same day. Misses like the one shown here are why I like to come back the next day to test for leaks and fix them. In this case the miss was small enough it won't badly affect MRT. The MRT in this room is now far better. The clients report a massive improvement in how comfortable the room is. Want to read more? It's the 1970s Two Story Case Study.

MRT in Winter

In the winter the opposite applies. One hot spot can make us pretty comfortable. Think about how nice it is to be next to a bonfire on a cold day. That single (radiant) heat source is enough to take the edge off the cold. In an older house with uninsulated walls, the wall surfaces tend to be cold (radiant heat being sucked out of your body) even if the air temperature is warm (convection). Because of MRT problems, older homes usually need to run higher air temperature set points on the thermostat to feel comfortable. My in-laws' tight 2008 house is comfortable at 71-72, but my own 1835 home needs to be at 74 to feel good. The higher air temperature raises the Mean Radiant Temperature of the room, but even there, uneven surface temperatures may make some rooms feel uncomfortable.

The Home Comfort 102 chapter dives deeper into this subject, and there are a bunch more factors that affect comfort beyond MRT, although MRT is probably the single most important factor.

How to Improve MRT

I already touched on it, but improving MRT has the same formula as almost everything else: it's the Five Priorities. Air sealing times three, insulation, and the right HVAC. Air sealing reduces hot or cold outside air from getting into the house and warming or cooling indoor surfaces. Insulation slows heat down as it moves in or out through the walls, ceiling, and floors.

Finally, a multiple stage, carefully sized and optimized HVAC system with sealed and right-sized ductwork slowly moves cool air around in summer (convection controlling radiation) to reduce those hot spots and even out the average surface temperature. In winter the furnace or heat pump slowly moves warm air around in just the right amount to warm up the walls, floors, furnishings, and ceilings of your home.

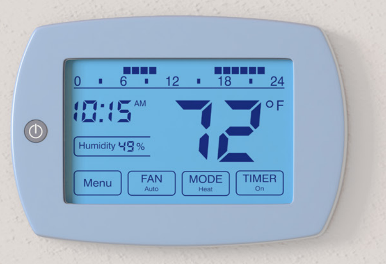
A really important note here, if your house feels cold, turn it up! 68 is cold for almost everyone. Bump the temperature a degree at a time. 69 may be comfy. Or 70, or even 72. Figure out what is comfortable, live with it for a month, and see what your energy bill does. If you have a reasonably efficient home, it may not cost much. If you have a leaky home, it may come with a bigger cost penalty. See what the cost difference is, and decide if it's worth paying. Or if it's time to upgrade your home.

Multiple stage HVAC has at least two stages (low/high) and may have over 100 stages for "modulating" equipment. They are like having a gas pedal in your car vs. an on/off switch. See the HVAC 101 chapter for more.

It's important to note that a blast of heat or cold doesn't work well. Think how pleasant a shower is for getting wet vs. having a bucket of water thrown at you. One is a steady, gentle wash of water at a temperature you've set, while the other is a sharp blast to the face and body. The Ice Bucket Challenge was not about comfort. Furnaces and air conditioners that are oversized are also not about comfort. Particularly when they are single speed.

Gradual heating or cooling is key for comfort, but only after fixing the air sealing and insulation. Otherwise the HVAC may not be able to fully control MRT. Several of our clients had awesome HVAC systems, but their homes were still cold in winter because their homes were leaky. You can learn more in the the HVAC 101 and HVAC 102 chapters.

With some upfront planning, you can substantially increase the chances of having a really comfortable home by controlling all of the conduction, convection, and radiation forms of heat movement. At the same time the house will likely get healthier because there are fewer cold surfaces for mold to grow on, it will last longer because the air sealing reduced where humidity can creep in or out, and it will probably cost less to heat or cool because it leaks less and has a smaller sized HVAC system that uses less energy. Everything is interrelated.

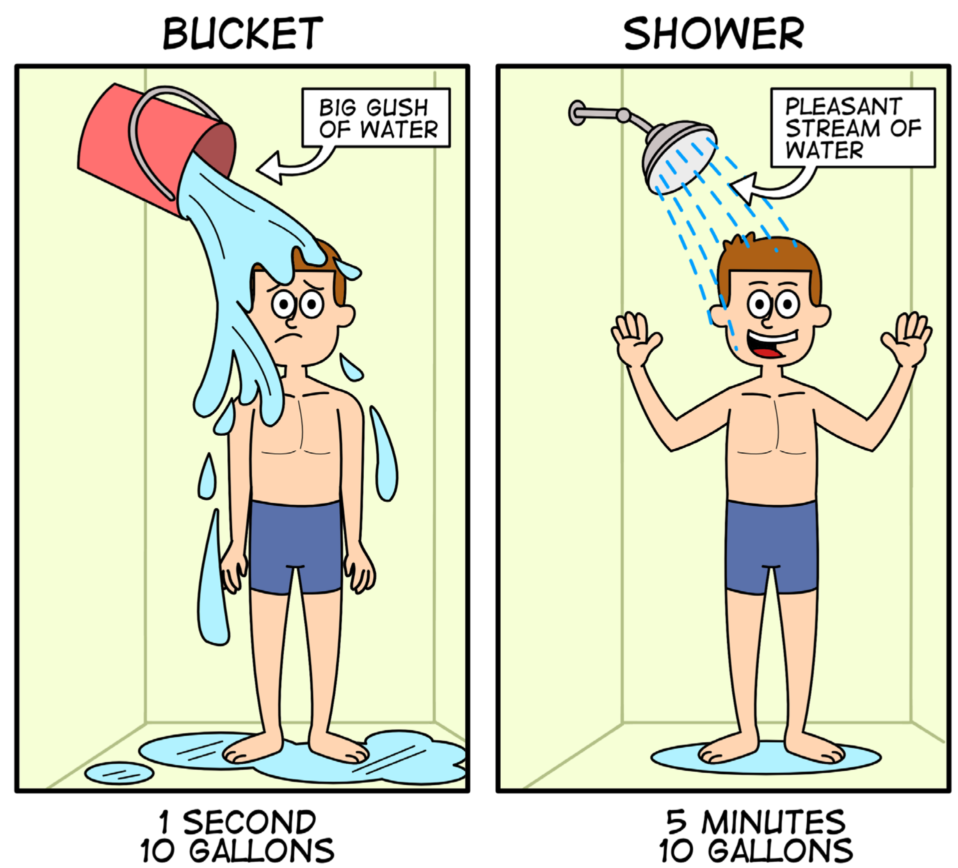


Thermostats Are Lousy Comfort Indicators

Thermostats measure "sensible" heat. Sensible heat is basically the temperature of the air. It's frankly a pretty poor indicator of comfort, because it ignores latent heat (humidity) and the 165,000 sensors in your body that detect Mean Radiant Temperature. All of these must be in balance before you will be comfortable.

There is typically only one thermostat in your home. Only a home that is in balance can effectively use a thermostat as a comfort indicator.

If your home is out of balance, the thermostat will not be good at measuring your comfort. See the Home Comfort 102 chapter for a much deeper dive on what truly leads to a comfortable home.



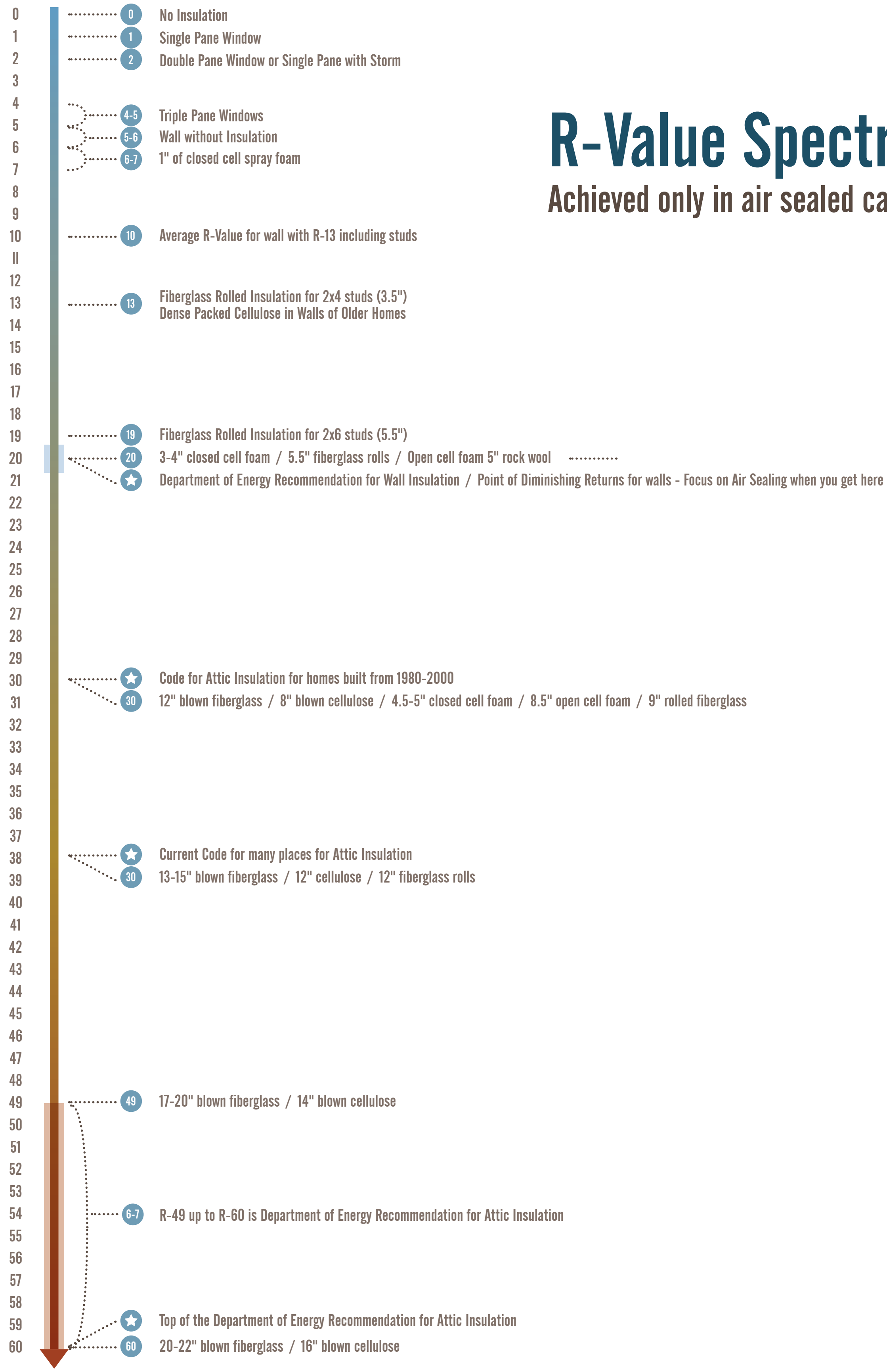
Insulation and R-Value

While air sealing is most important, it's still important to have effective insulation. Insulation is rated in R-Value, which is a measure of its resistance to heat. Note that insulation does not stop heat moving through it, it just slows it down.

It's a linear scale, so R-40 is twice as high as R-20. R-40 is not twice as effective, though. How much insulation is effective? Often less than you think.

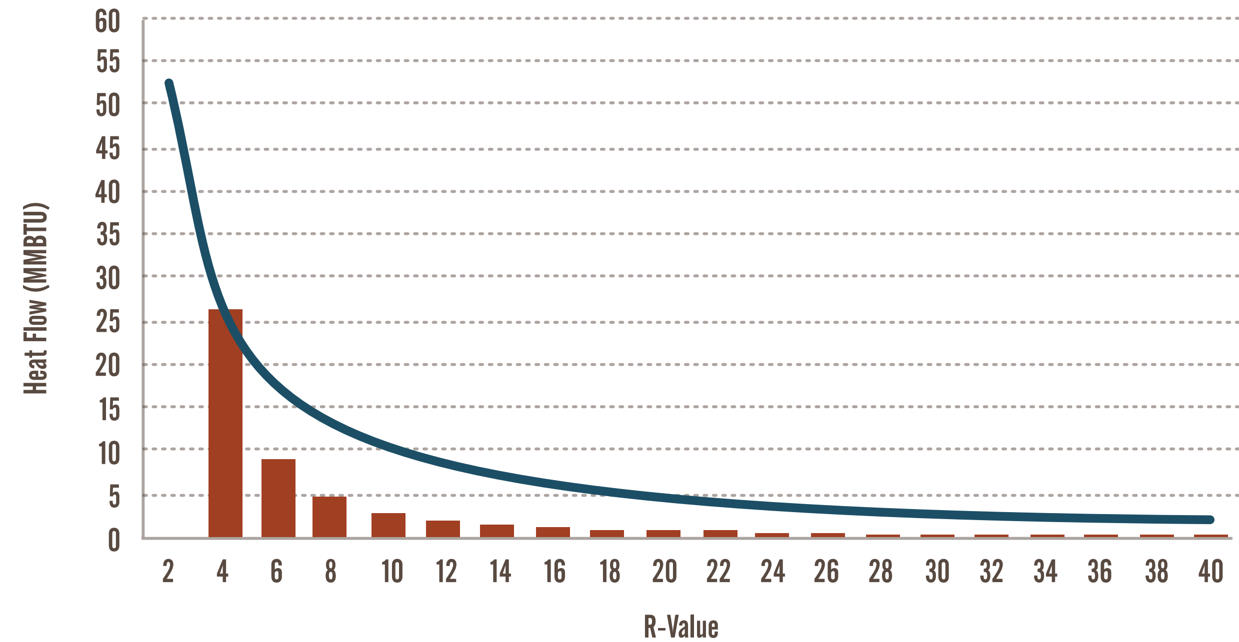
R-Value Spectrum

Achieved only in air sealed cavities



The Diminishing Returns of More Insulation

Adapted from Energy Vanguard. The effect of more insulation (measured in Atlanta, GA.)



Allison Bailes is a fellow Building Scientist who writes the excellent Energy Vanguard blog and specializes in new construction. This chart is adapted from his article The Diminishing Returns of Adding More Insulation.

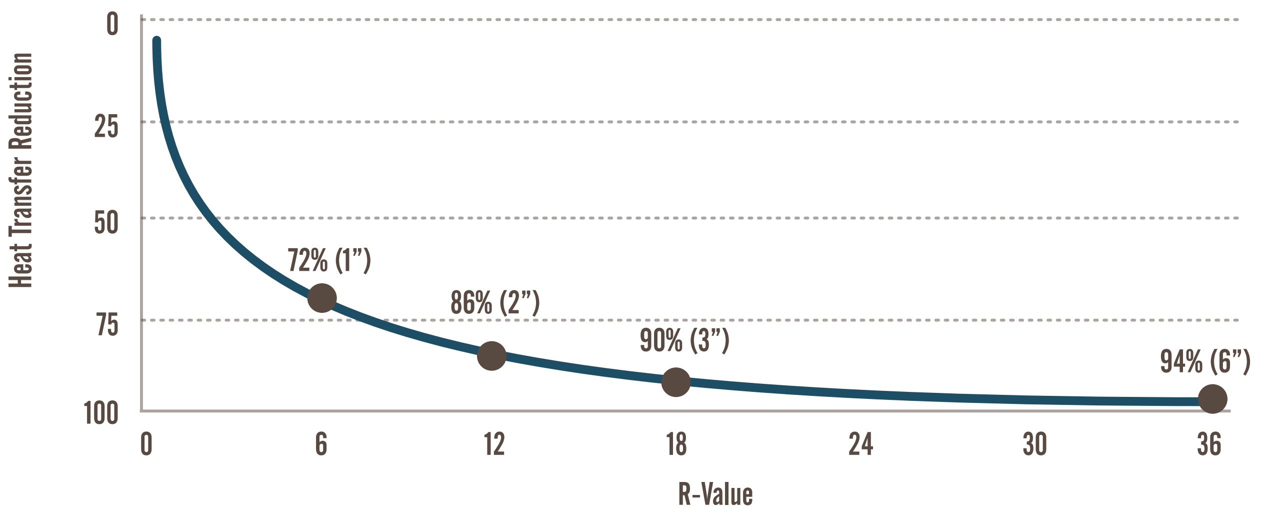
Note how after R-8 or R-10 very little energy is saved for each step up in R-Value. Past R-20 the improvements are difficult to see.

This makes intuitive sense if you think about it. Having a t-shirt and shorts on during a cold day is considerably warmer than being naked, but would have a low R-value. Stepping up to jeans and a sweater helps a bit more. Snowpants, gloves, hat, a parka, and boots will suffice in most cold weather. How often do you wear a second winter coat over the first? It sounds pretty silly. Pretty quickly you hit the point of diminishing returns.

The same thing goes for insulating your home. This is good news for existing homes because adding lots of R-Value can be difficult and expensive. After filling up wall cavities, going further may be extremely expensive. This is where planning comes in – what are your goals and budget? What best meets both of them? More is not necessarily better.

Thickness of Closed Cell Spray Foam vs. Thermal Losses

Adapted from Mike Jag of Jag Construction in Rochester, New York



Closed cell spray foam only needs to be about 3" thick (R-18 to R-21) to do a good job in many homes.

Habitat for Humanity Retrofit in Ravenna, Ohio

Closed cell spray foam is a great technology to use for existing homes, and [it's covered in the Insulation Types chapter.] At only 1", it reduces 72% of heat transfer, which is R-6 to R-7 depending on the manufacturer. At 3" it stops about 90% of heat loss (R-18 to R-21.) We specify 3.5" closed cell spray foam in many of our projects (installers are allowed +/- 1", and we want to stay over 2.5".) Spray foam continually shocks me at how well it performs at only a few inches thick. One client recently told me that there were no icicles at all around a spray foamed section of his attic that used to develop very large icicles. All that said, spray foam is not a very nice product from a chemical perspective, proper safety gear needs to be used, ventilation needs to be provided, and installers need to be well trained.

The point is that air leakage is still most important. More R-Value is often a good idea, especially if you are considering inexpensive blown attic insulation, but please don't get too hung up on high R-Values. Insulation can effectively deliver results with R-13 to R-20 in many climates. That may be all that fits in your home.

Your Home Performance Specialist can help you do the math to see what is likely to get your home to the tipping point where you can solve problems and achieve a good result.

Real World Example

This is the inside of a Habitat for Humanity of Portage County home retrofit. The platform is a sleeping loft to maximize space usage like in a Tiny House.This home has no more than 3.5" of insulation anywhere, ranging from R-15 to R-25. We did this partly to break the "rules", and partly because we knew it would work.

At the time of this picture, it's 720 square feet with a blower door reading of just over 400, resulting in a 0.6:1 CFM to square foot ratio. That's not much leakage. The whole home could be cooled with one small window air conditioner or heated with two space heaters if necessary. The home is all electric using a heat pump (in Cleveland!) and has continuous filtration, fresh air, and dehumidification systems. This type of work can even be done on a Habitat for Humanity budget with some creativity. You can read the whole series about this project starting here.

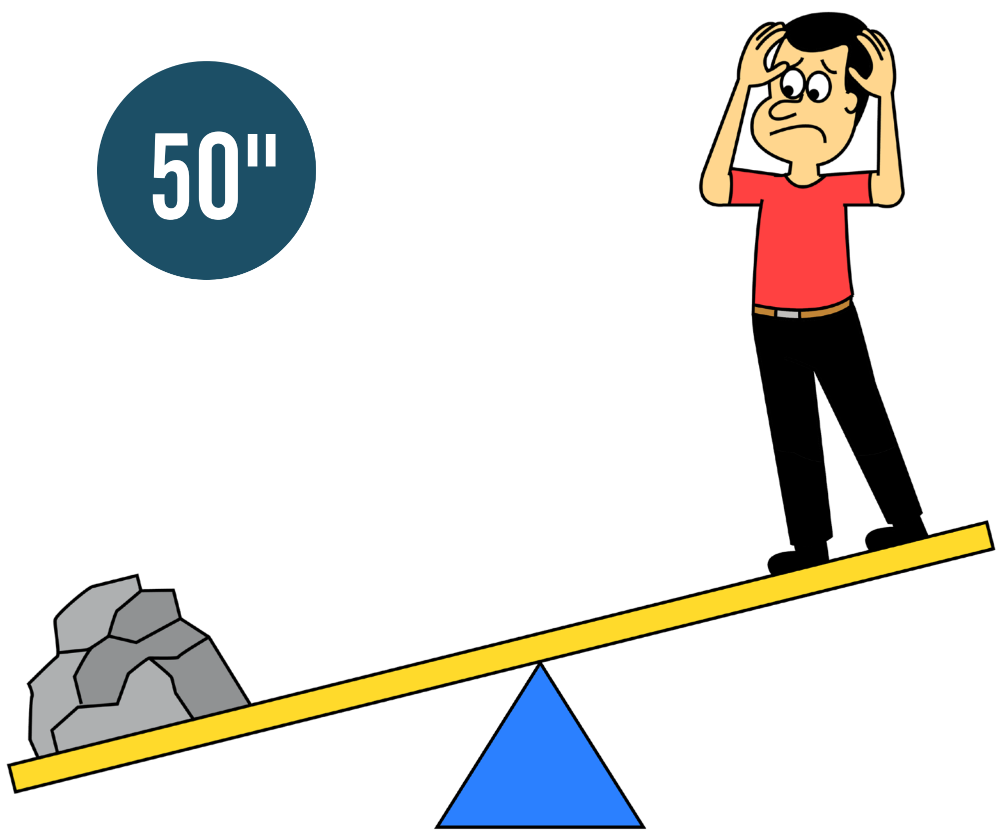
At the time of this picture, the home is 720 square feet with a blower door reading of just over 400, resulting in a 0.6:1 CFM to square foot ratio. That's not much leakage.

Getting to 74 Inches – The Tipping Point

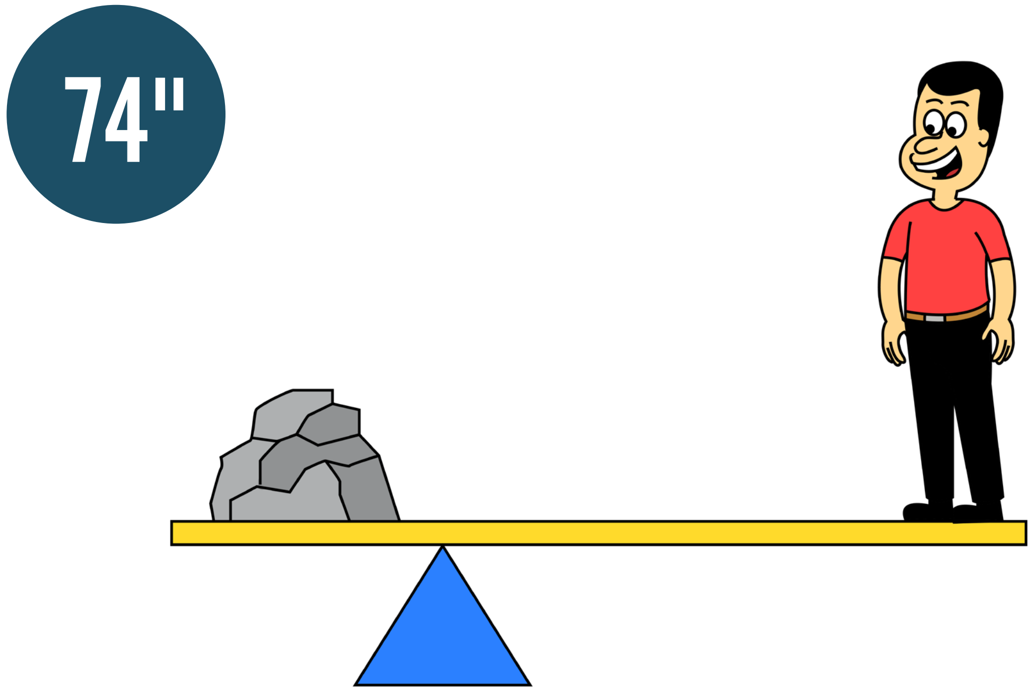
Every house has an almost magical tipping point. All of a sudden, awesome things start happening. Problems are solved. Energy use falls off a cliff. Marriages are saved. Disasters from evil masterminds are averted. (OK, the last one is hyperbole.) My business partner and I say this magical tipping point happens at 74 inches.

Why 74 inches? Because it's a little bit weird, and it tends to stick in the mind. I'll give some real world examples of 74 inches shortly.

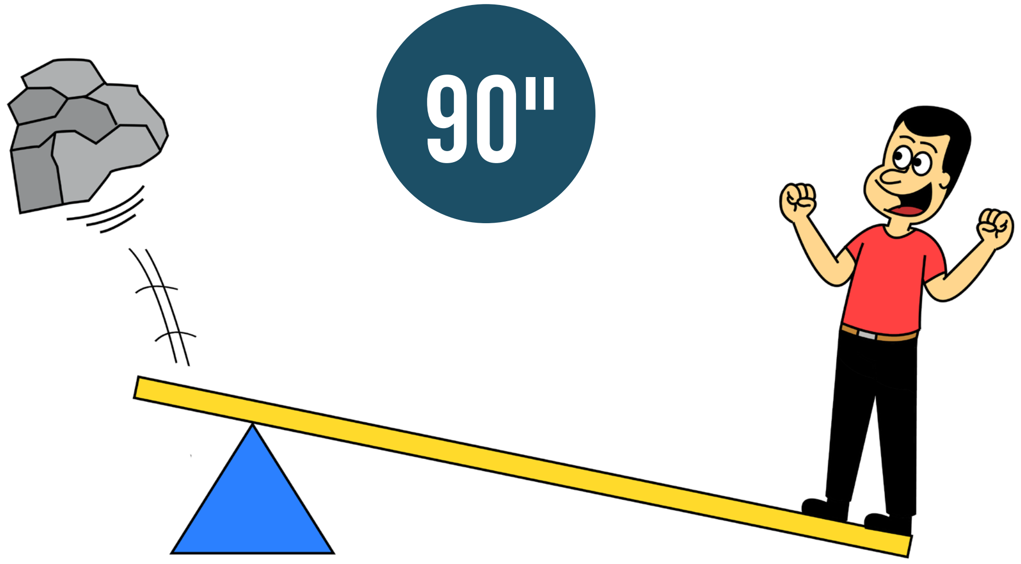
We like to think of this tipping point like trying to lift a large rock with a 100" board perched on a fulcrum, like a seesaw at a playground.



This is 50 inches. You simply haven't gone far enough. You may have spent a bunch of money and time, but nothing noticeable has changed. It's common to feel defeated at this stage. Worse, you may need to pay to undo what you already did so you can do it well enough to achieve results.



At 74 inches, you can lift the rock. Life is good, problems are solved. Be careful, though, one little mess up and you lose the battle. It's better to try and go a little further so when you slip up, you still get to 74 inches.



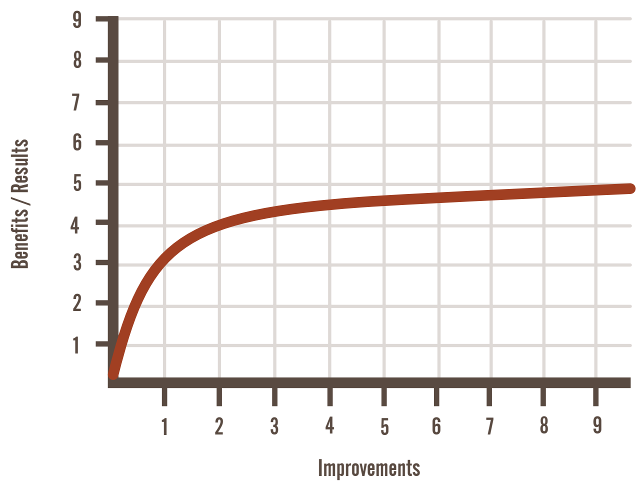
When you're figuring out how far to go on your home, it's important that you don't just aim at 74", though. Houses are tough. Surprises await you. We like to aim for about 80" and assume that we'll slip up somewhere but still hit that magical 74", lift the rock, and solve client problems.

Low Hanging Fruit Is Poisoned – And the 74 Inch Antidote

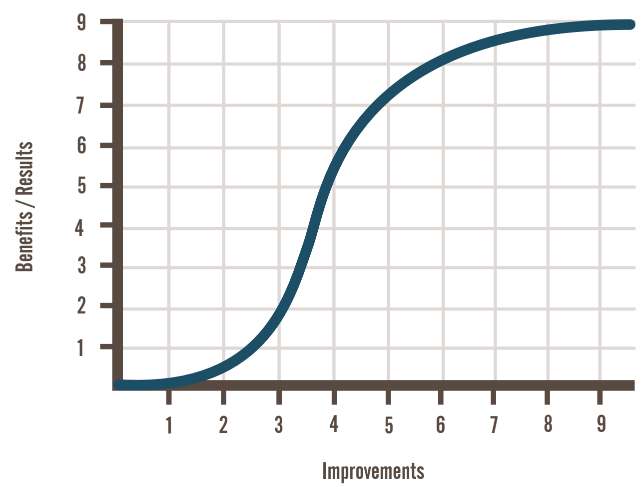
Let's apply "74 Inch Thinking" to how most people intuitively think "efficiency" improvements work. I put efficiency in quotes because these projects are almost always about comfort. (And that's ok!) The phrase "Low Hanging Fruit" usually pops up when talking about improving energy efficiency. Simply make a few easy changes to the house and big results arrive. Sadly, this is utterly false.

Here's what Low Hanging Fruit thinking looks like:

What We Think Happens: Big Results Fast

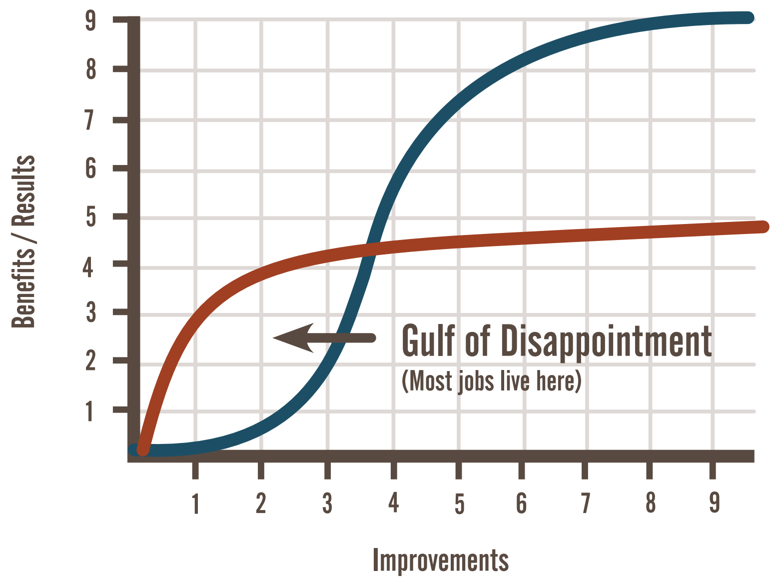


What Actually Happens



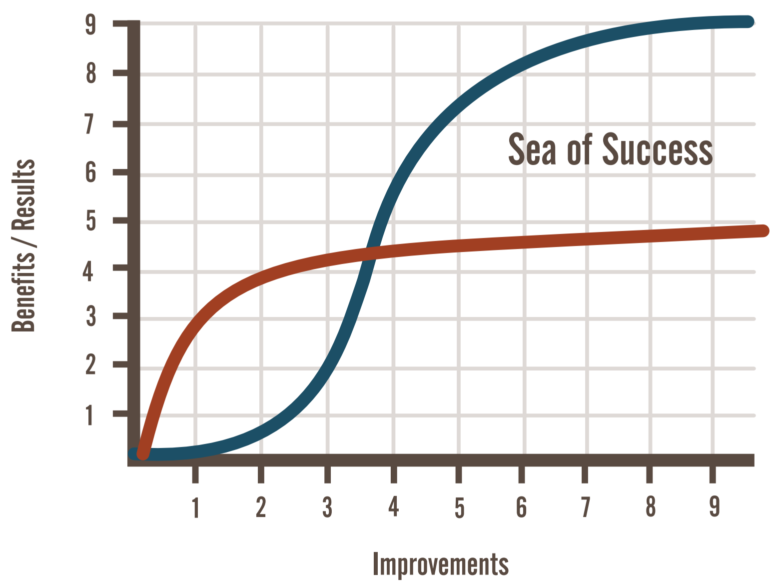
The truth is the curve on the right, in our experience. Nothing happens until you get fairly deep into a project, then the results start showing up fast!

If you are reading this book, the odds are high you've tried a few half measures and found they delivered quarter results. You discovered the Gulf of Disappointment:



Back when I did insulation contracting, a number of my projects failed to deliver good results. I didn't hear about many, since at the time we weren't tracking results, but the ones that I did hear about disturbed me greatly. Those failures led to a new business model, the development of these charts, and this book. You could say failure changed my life. It taught me that Low Hanging Fruit Thinking is broken. Don't be fooled by it.

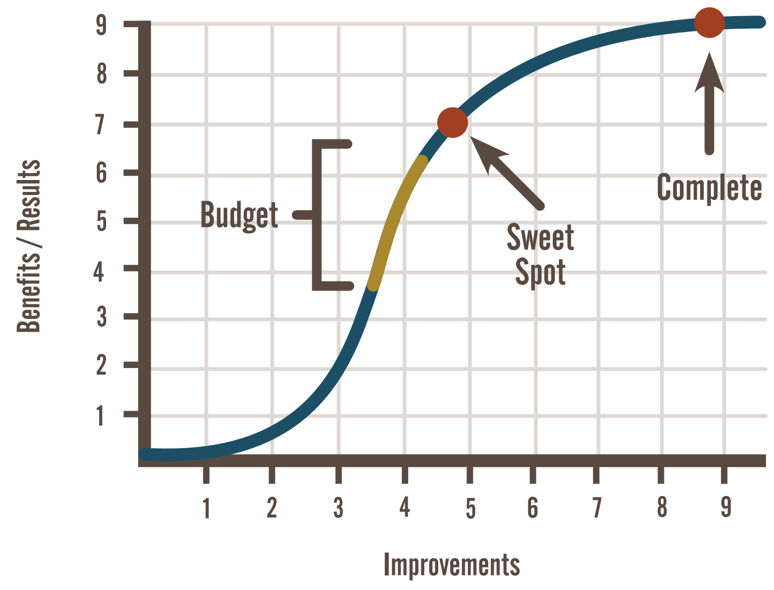
If you truly want to solve problems in your home, you need to aim for getting beyond 74, which looks like this:



When you go far enough, you get to well up the blue curve above the Sea of Success. The Sea of Success is the place to be. It happens when you get to the vertical part of the curve beyond where traditional thinking and reality intersect.

In Energy Smart's process, we build three different packages for clients. We start with a very deep package that we don't expect to happen (Complete), then start crossing off items to what we think is likely to solve the problem without going too crazy (Sweet Spot), and after that build a package to the client budget that we feel has a good likelihood of success (Budget.) Your Home Performance Specialist will likely do something similar.

In theory, they look like this:

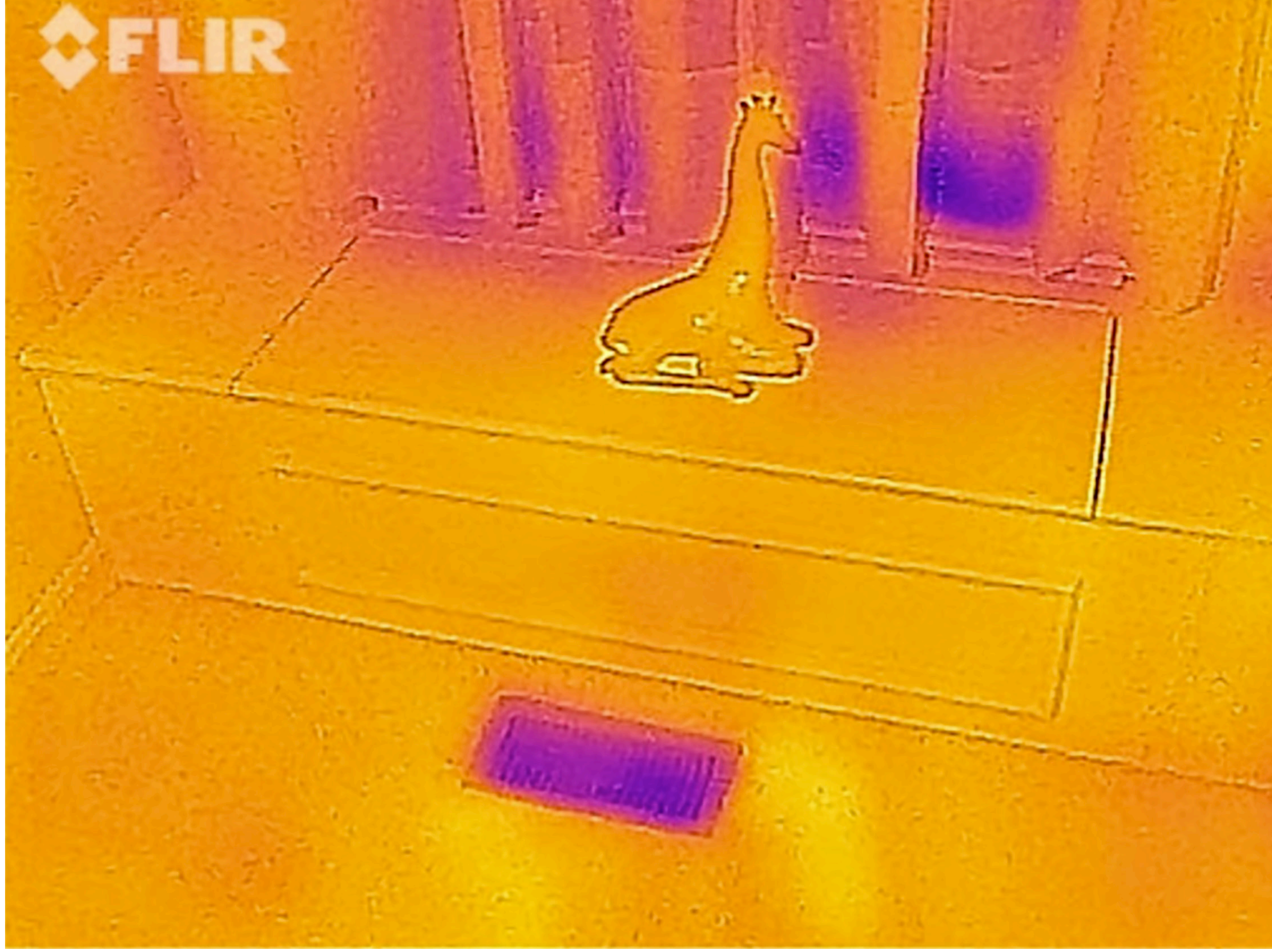


*Remember, this is all theoretical. We would encourage you to go one step further to ensure your desired results.

Note that the Budget package can vary where it falls on the curve. The goal is to at least get to where the curve goes vertical. I can't stress highly enough the importance of going far enough to get a real result. If you skimp, you may waste thousands of dollars and cause months or years of frustration.

One of the best ways to boost confidence that you'll go vertical is to reduce the air leakage number on your home to gain control of air, heat, and moisture movement in and out of the house.

At a minimum, do a really good job on either the top or the bottom. That means you need to know specifically where the big leaks in your house are. That is best found with a blower door and infrared scan.



This floor vent by a window seat is cold, which means outside air is leaking into the duct somewhere. Without a blower door, this is nearly impossible to find. And yes, that's a toy giraffe.

Air sealing and insulation can be inexpensive if you do it yourself. But you have to know what to seal first. Remember, air sealing *must* be carefully done and tested. Insulation must be installed properly as well to have the best result. See the Insulation Types or Air Sealing Guide for more. From that point, if there is money left over, spend it on the best HVAC system that fits your budget.

Through it all, I strongly recommend working with a Home Performance Specialist. Finding the 74" mark for your home is not an exact science. It lies in the tricky realm of probabilities and educated guesses. There are no guarantees, but a good HP Specialist can help deliver better odds by planning and watching the important but invisible details that make or break projects.

1915 Dutch Colonial

This home only saved 9% on winter natural gas usage. Very disappointing. This project was aiming primarily at chasing $1250 in rebate money from the gas company. That took our eye off the ball of reducing energy usage and improving comfort, which were the real client objectives. This house lives in the Gulf of Disappointment.

The job done on the attic was high quality. The house doesn't have central air conditioning, yet the client reported drastically improved summer comfort. The second floor is now nowhere near as warm as in years past.

Sealing the top alone in this house wasn't enough. The walls and basement remain uninsulated, and it retains an older inefficient furnace. I'm honestly not sure which improvement(s) is best to recommend, it would take another look at the house with my new eyes.

I've become a big believer in energy models, which are essentially a big spreadsheet that predict how much energy a home will use if you make various modifications to it. It lets you what-if a home. An energy model could help us understand how far we need to go with this house. There is frequently a tipping point with the models where savings go from modest to substantial with the right solution package. We could figure out where that tipping point lies, and hence where we are likely to succeed.

Real World Examples of the Gulf and the Sea

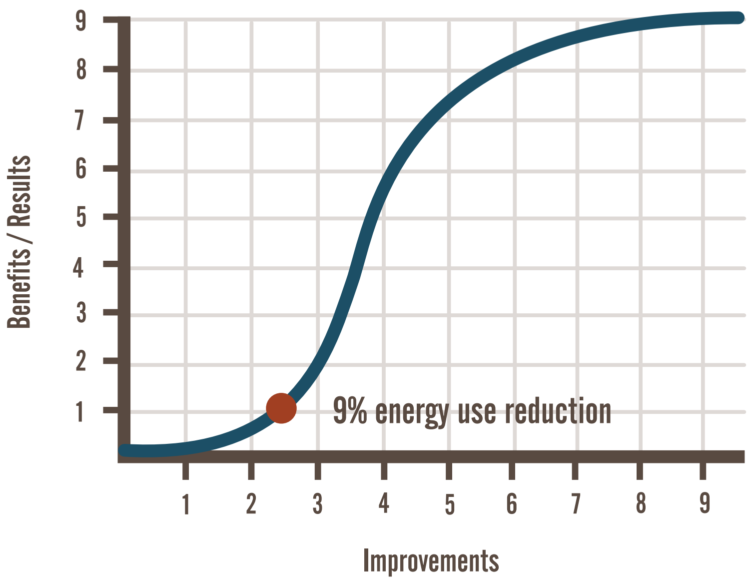
Here's an actual example of a job that failed to hit the tipping point. This project was late in my contracting career and was the first that I measured energy use on. Energy use reductions are a good proxy for success.

(A proxy is something that can stand in as a representation of something else. In this case, energy use is a proxy for both comfort and project success.)

The blower door started at 5800 and ended at 3500. It's about 2000 square feet, so 3:1 got reduced to 1.75:1. It wasn't close enough to the 1:1 likely tipping point.

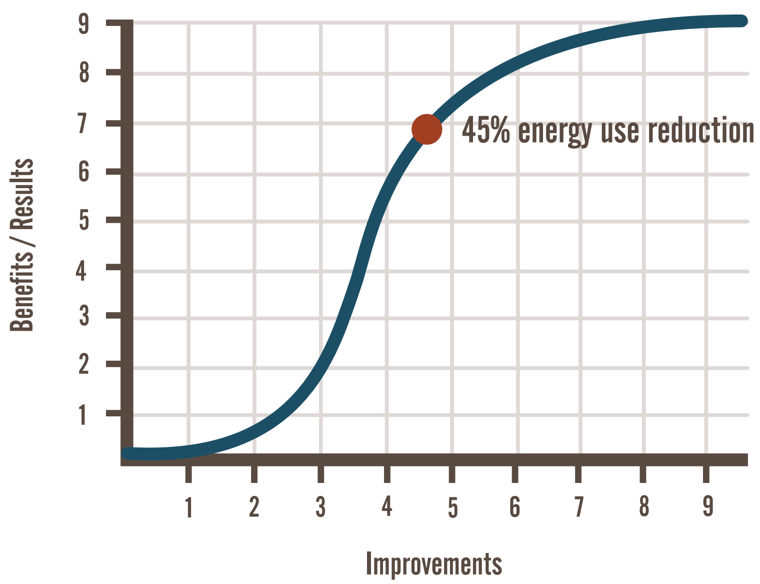
Gulf of Disappointment

Substantial attic job, very good air leakage reduction (38%)
*Didn't hit the tipping point



1959 Cape Cod

Conversely, this next home, which is similar in structure and size, is in the Sea of Success. You can read all about it, it's the 1959 Cape Cod Case Study. It started at a 5800 blower door and was reduced to 3100. It's 2400 square feet, so it went from 2.4:1 down to 1.3:1. We tackled a crawlspace, a few walls, and worked very hard on the five separate attics.



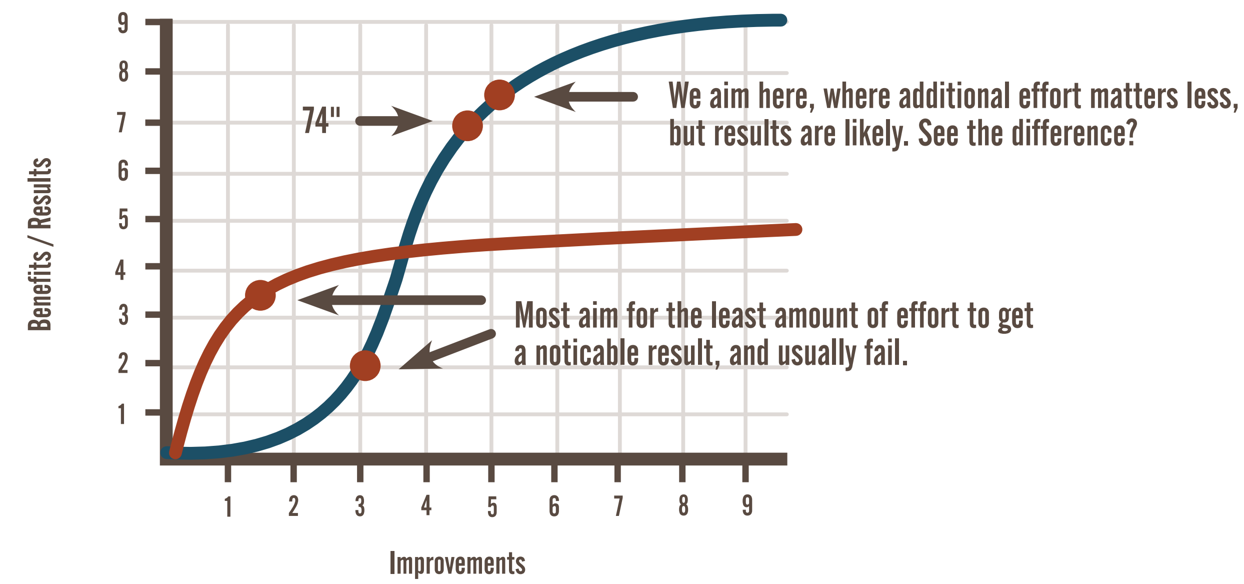
This home hit at least 74". It saved 45% in winter natural gas usage. A remarkable move. It was far more comfortable as well. Like I said, we find energy savings to be a good proxy for success. In the homeowner's review, he declared the project "a resounding success." This was the budget package, by the way. The second floor is never more than 2-3 degrees different from the first, a big move from a 10-15 degree swing before.

There are still a few things to deal with in this home that didn't fit in the budget. Humidity is still higher than we'd like indoors. A kitchen fan vented to outdoors and/or a whole home dehumidifier would likely remedy those problems. The fan was in the Sweet Spot package and the dehumidifier was in the Complete package. We likely wouldn't have known that humidity was even a problem in this house had we not installed an Ecobee thermostat that tracks indoor humidity, among other things. You can read more about this home in the 1959 Cape Cod Case Study.

I mention the minor issues still remaining with the home because it's important to understand that perfection is an impossible goal. Excellence is a better one. This house hit about 80 inches. It did not hit 95 inches. Our plans likely would get it to 95, but it is often more money than is practical to spend. If Adam and Rena live there for the rest of their lives, they may opt to make all of those upgrades.

Can you see why we focus on 74 inches? It's very frustrating to try several expensive things with no noticeable results. Better to spend some time and money planning before executing. You may avoid years of frustration!

Go Big or Go Home (to Disappointment)

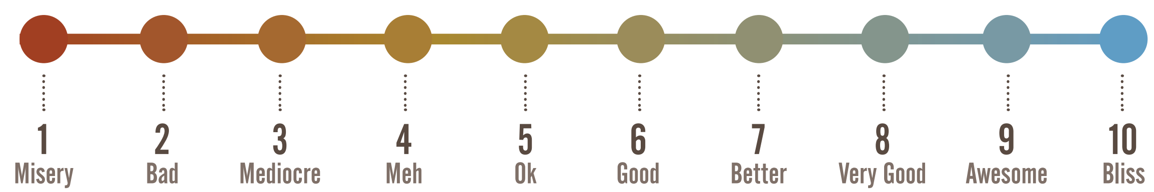


If you really want to solve a problem, the first round of upgrades needs to be substantial, or disappointment is likely. It's kind of like going on a diet. If you lose 10 pounds in the first week, you'll feel spurred on to do more. If you only lose a pound you'll likely react with a "meh" and go back to previous behavior. Aim for the upper inflection point, where more effort doesn't pay off as well. That should land you in the Sea of Success. Don't fall for Low Hanging Fruit Thinking and aim for the lower inflection point that tries to do the least amount to achieve a noticeable difference. The odds of landing in the Gulf of Disappointment are high there.

Aim for the upper inflection point where additional effort pays off less. You're much more likely to hit 74" and swim in the Sea of Success. You'll be glad you did. Did I recommend working with a Home Performance Specialist to help you discover where 74 is likely to be?

To reiterate, nothing is absolute. Success lies on a spectrum, so keep your expectations reasonable and tied to budget.

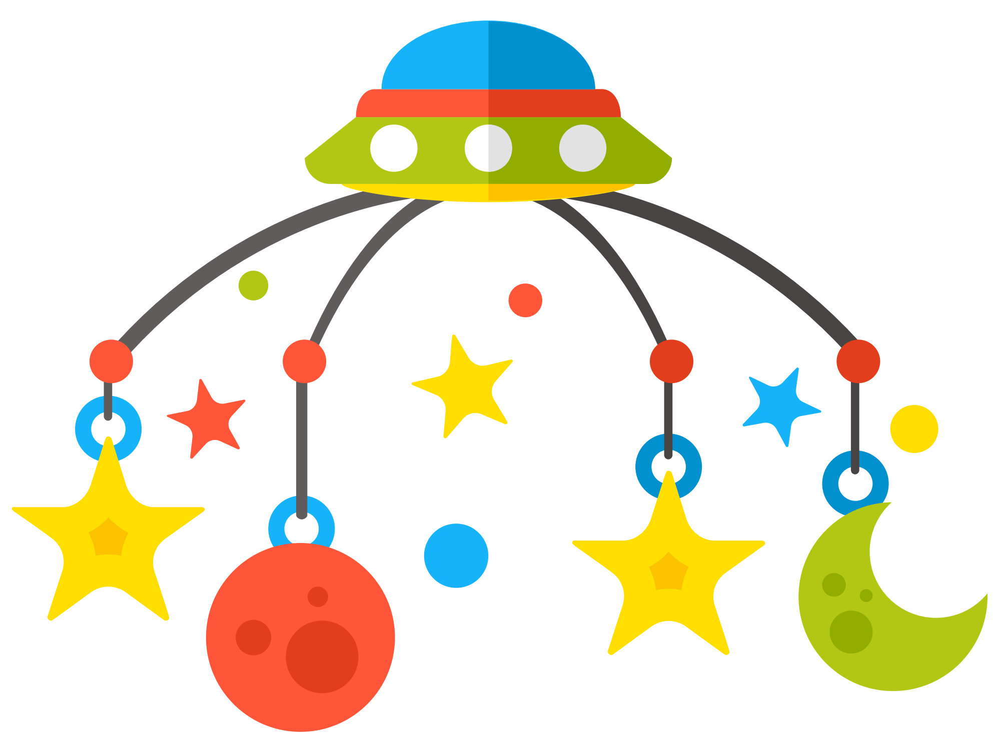
Results Spectrum



Budget determines what's possible.

Your Home is a Mobile – Get It in Balance

You may have noticed we really like thinking about homes in terms of balance. One of the best ways to wrap your head around how your house really works is by thinking of it like a hanging mobile - all the pieces have to be balanced for it to work well.



Thinking of a mobile is a great way to tie the myriad of concepts we've covered together:

The Five Priorities – Air seal, air seal, air seal, insulate, right HVAC
Blower Door – Aim for 1:1 or better
The Four Tenets – Comfort, Health, Durability, and Efficiency
Control – Controlling Air, Heat, and Moisture flow is the key to everything.
Heat Transfer – Convection, Conduction, and Radiation

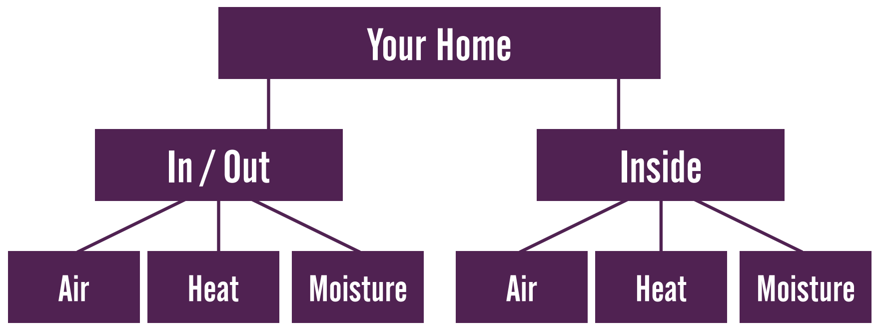
The Rules

- Hot to Cold
- Wet to Dry
- Gravity Acts Down
- Pressure Goes from High to Low Via Easiest Path
- Wet Goes to Cold

Your House is a Leaky Boat
Getting to the 74" Tipping Point
Swimming in the Sea of Success

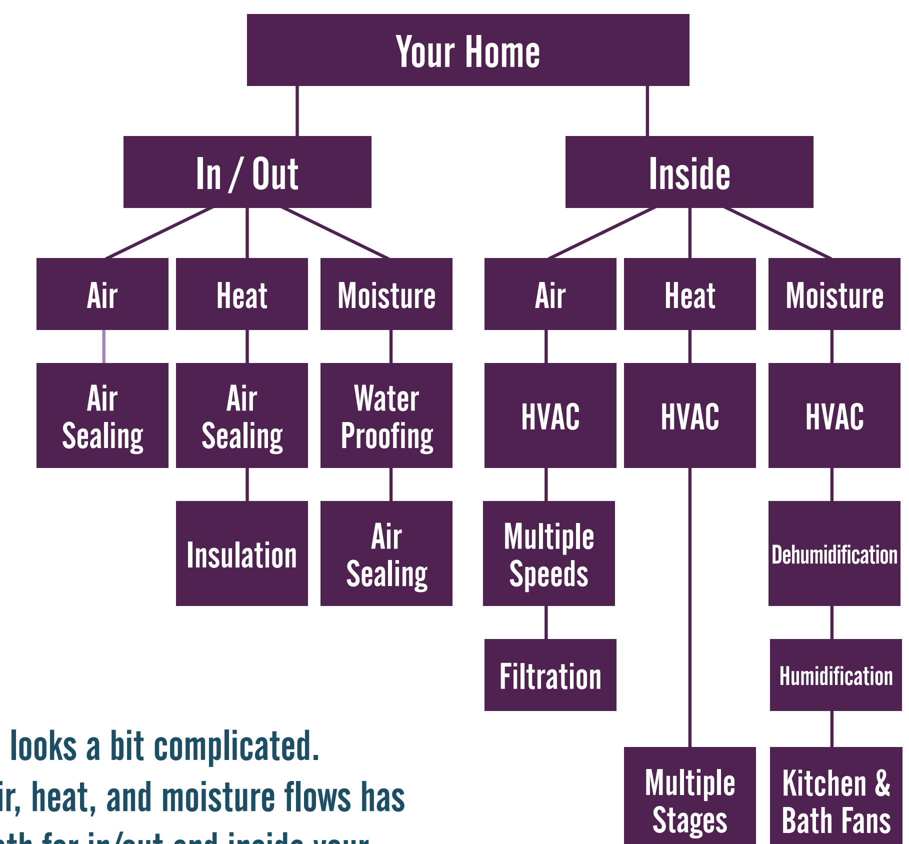
Let's translate everything we've learned into a hanging mobile, built step by step:

The first step is seeing that there are two main areas we need to control: what goes in and out of your home, and what stays inside your home. Easy enough.



The next step is getting control over air, heat, and moisture flows in both of the aspects we talked about – in & out, and inside.

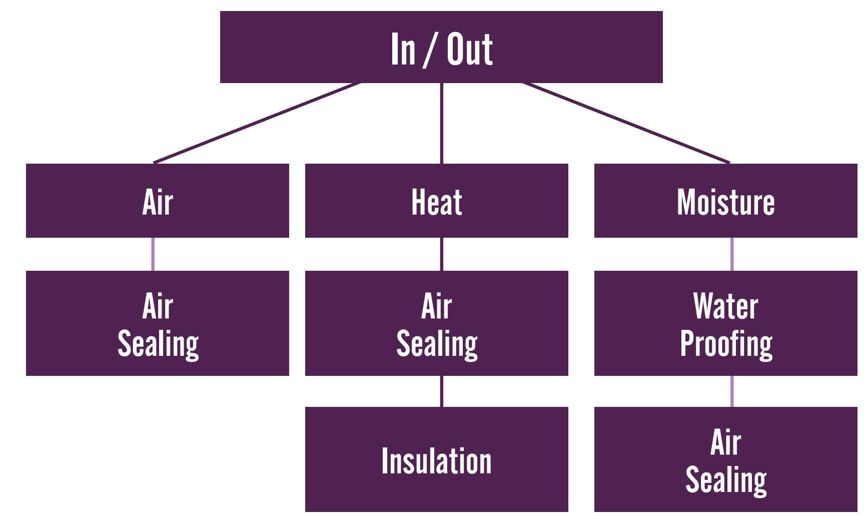
Until you have control over the left side, In and Out, you can't control much inside the house. It's like that leaky boat. If you want it to go fast, a bigger engine is not the first thing on the list, fixing the leaks is.



Whoa! Now it looks a bit complicated. Controlling air, heat, and moisture flows has a different path for in/out and inside your home. Let's break it down.

If it isn't clear by now, do not change your HVAC until you tighten your house if you expect to solve problems!

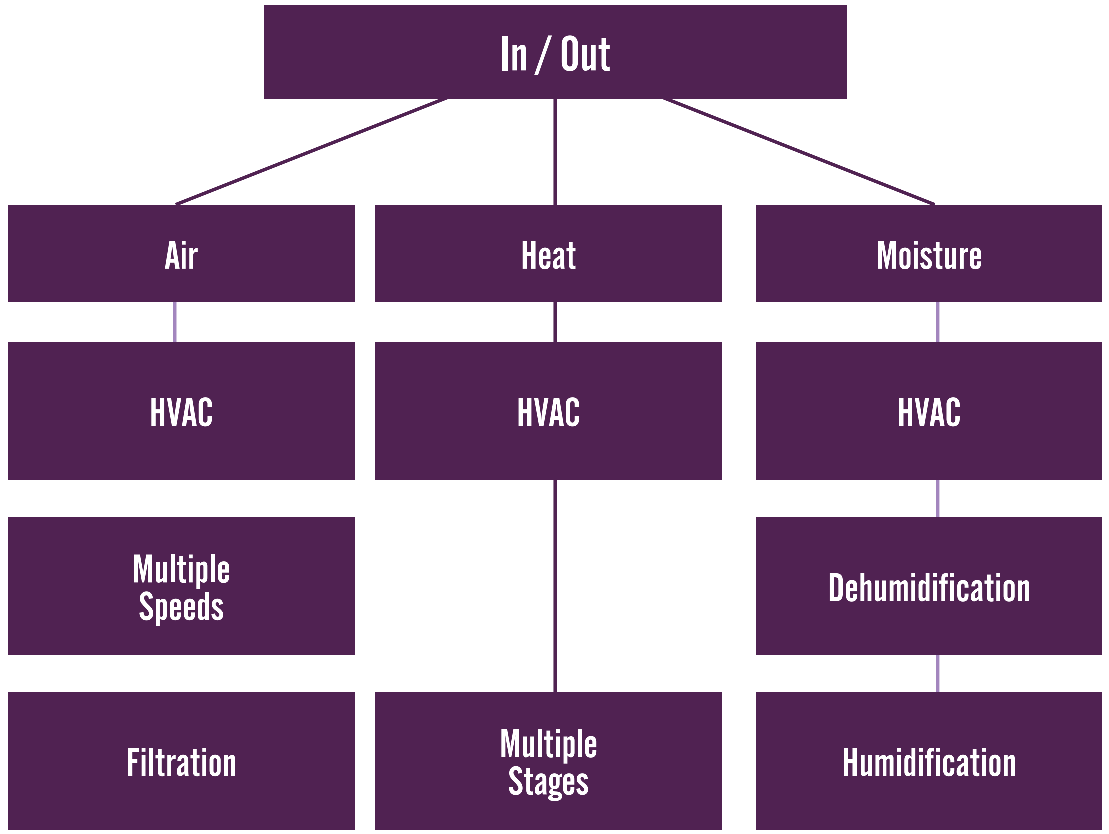
Control In & Out of Your Home

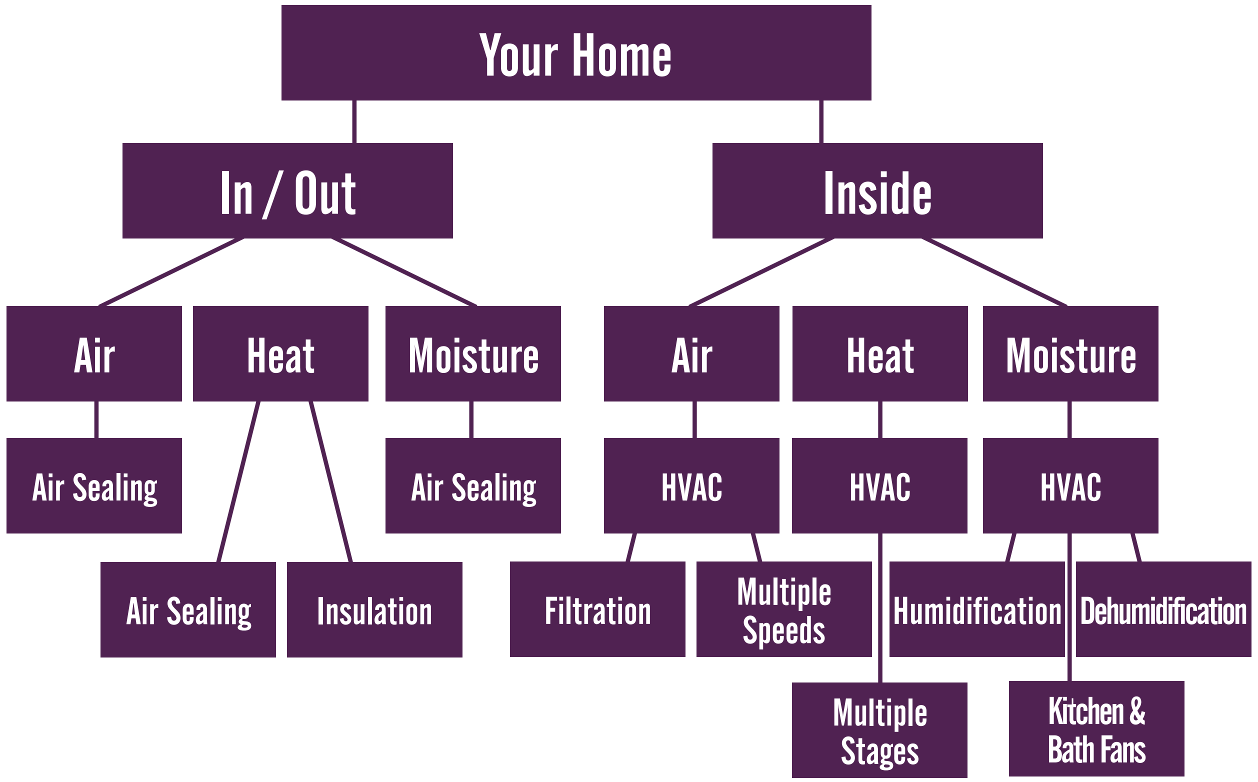


See why air sealing is so critical? It looms large in all three of the air/heat/moisture aspects. With moisture, waterproofing may need to happen first, but then air sealing is next. For heat, insulation is important, but until the air seal is complete, it's like wearing that holey sweater on the end of a cold, windy pier: pointless. I don't think it is possible to overstress the importance of air sealing your home.

By the way, you can't actually make a house too tight, you just need to provide fresh air for the occupants with a fresh air system. This system can be very simple to very complex. They are a good idea regardless of how tight a home is. See the Fresh Air chapter for more.

Control Inside Your Home





Inside, your HVAC system rules. This could be a furnace, air conditioner, heat pump, boiler, wood stove, humidifier, dehumidifier, fresh air system, or any combination of those. It's what heats and cools your home. As we'll learn later in the book, it's what provides healthy air as well.

For air flow, you want just enough, but not too much so you don't notice air blowing and get uncomfortable. That takes multiple fan speeds. A little air blowing mixes the air in the house and improves Mean Radiant Temperature. Mean Radiant Temperatures is the average temperature of the walls, ceilings, and floors around us.

For heat or cool flow, we want just enough to match what the house needs. That requires multiple heating and cooling stages so it can deliver small doses of heat or cool. Because they can dole out small doses of heat and cool, right sized HVAC will warm or cool surfaces to improve Mean Radiant Temperature at the same time they help keep the air temperature and humidity just right. More on that in the HVAC 101 and HVAC 102 chapters.

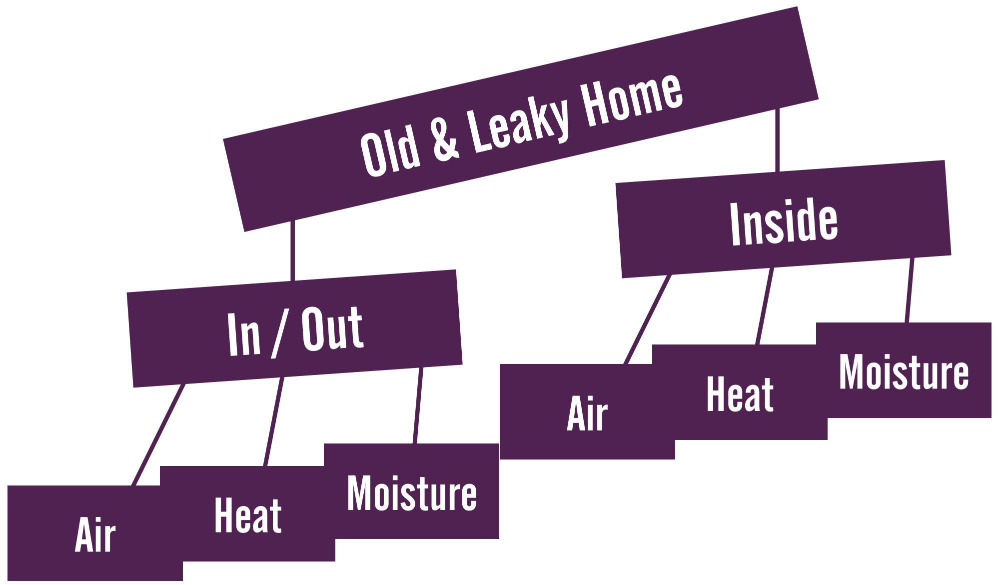
For moisture flow inside your home, you want to be able to add or subtract it as needed. In the winter you may want to add some moisture with a humidifier, although tighter homes need that much less. If you live in a climate with humid summers, you'll want to be able to remove moisture as needed to make the house more comfortable. Then your sweat can evaporate and keep you cool, even in higher temperatures. We find most clients like 74-78 degrees when humidity is under control in the 40-50% range. That may sound crazy, but it's not. See the Home Comfort 102 Chapter for more.

If you get the In/Out and Inside pieces of the mobile balanced, you can have an amazingly comfortable home that is also healthy, largely free of moisture problems, and is inexpensive to operate.

Most homes aren't balanced, though, so next we'll look at a few examples.

Old, Leaky House

My favorite homes are those built before 1945, they have craftmanship, charm, and character. But they also tend to leak like sieves. They usually have huge temperature differences between rooms and floors. Their basements are damp. And their furnaces are usually 2-3 times larger than necessary. Here's what one might look like on the mobile:



Air leakage overrides other problems

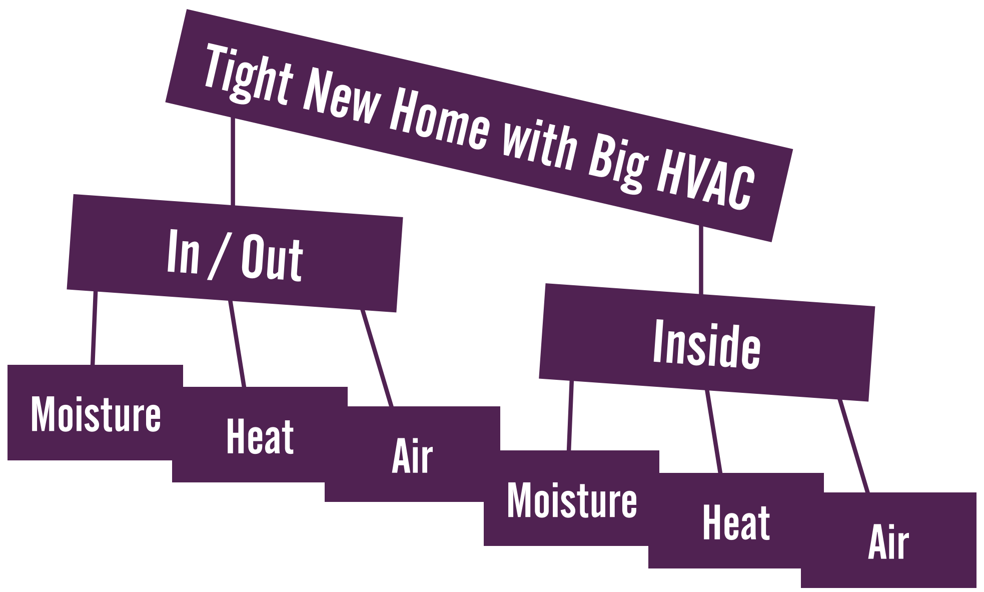
HVAC may be messed up, but it's not the weakest link

Because it's so leaky, the In/Out side is wildly out of balance. Air leakage is allowing tons of air, heat, and moisture to leak in and out of the house, there's very little control.

The Inside side of the mobile could be really messed up, but we won't really know until the In/Out side is in balance. Energy modeling can help us understand what size HVAC might be needed. Until we find out exactly what blower door number we achieve with air sealing, we can't have confidence in what size furnace, heat pump, or boiler to install. Hence air sealing and insulation always comes first, if feasible. If not, size your HVAC for where you are going (on the small side), not what you need today. That will prevent having to replace it again later. Yes, that's a bit scary, but the difference you need on a cold day is likely one or two space heaters. See the HVAC Sizing chapter to help take the fear out.

A leaky old house is a pretty typical problem, but let's take a look at a much more surprising one: a tight new home with comfort problems:

Tight New House with Oversized HVAC



House is tight

Oversized furnace doesn't warm far rooms

MRT is poor

I've tested a number of homes built in the last 10-15 years that are quite air tight, but are still very uncomfortable. The culprit? A huge furnace and air conditioner. It kicks on for a few minutes, then kicks back off. Often the rooms furthest from the furnace freeze in the winter because the heat didn't make it there before the furnace turned off. The walls remain cold because heat comes in blasts, like a bucket of water being dumped over your head vs. a nice shower.

While the In/Out side is in balance, the Inside side of the mobile is out of whack. Sometimes you can simply turn up the temperature and it helps, but often the solution is to rip out the HVAC system and replace it with a well-designed, right-sized one. That isn't greeted with happy faces in a newer home, but it's quite common.

The Insulated Leaky Old House with Fancy New HVAC

These ones are the most painful to me. The homeowner just forked over many thousands to insulate the house, but no air sealing work was done. This isn't uncommon. Speaking with one of the test out auditors from my gas company's energy efficiency rebate program, he said that most homes he tested out had no change to their blower door number, or just a token amount. That's scary, because air sealing is extremely difficult to do well after insulation is installed.

The HVAC is also a new, fancy-schmancy top of the line modulating furnace which does everything but your laundry. At the right size, I love modulating furnaces (which have 3 or more stages) because they solve a lot of problems. If they're too big, though, they often have to be replaced. Otherwise comfort is still unattainable and there's still a very hot or very cold room. Often the second floor is 5-10 degrees different from the first, making sleeping difficult in summer.

People don't call me for giggles, they call because they have a problem. Now I have the awful job of telling them to throw a very expensive HVAC system away. I hate having to tell people that. Furthermore, the house still grows massive icicles because heat leaks into the attic through all the gaps that weren't sealed. Gutters are ripped off, ceilings collapse, and walls are ruined.

But wait, there's more! Because they insulated the attic, which used to be warm, the roof deck is now cold. Wet goes to cold. Since the moisture inside the house can escape into the attic, it condenses on the cold roof deck and presto! Mold! I wrote an article for the Journal of Light Construction called "The Petri Dish House" about a situation like this.

Very moldy roof deck in an older home. This is spectacularly difficult to make happen in pre-1945 homes, the central humidifier was set to high plus they were running six (?!) room humidifiers. One of the homeowners is from a very warm and humid climate and wanted to recreate it. Creating a tropical environment during a Cleveland winter is not a good idea. Because physics.

To fix this whole messy situation correctly, the HVAC likely needs to be ripped out along with the insulation. Mold remediation needs to happen. Then we have to start over with new air sealing, insulation, and HVAC.

The mistake of poorly insulating and installing the wrong HVAC in an older home could easily cost tens of thousands of dollars to fix. Sound like fun? Of course not. And why? Because air sealing was not a priority. I've seen all of these problems hundreds of times. It bums me out, but it's part of why I wrote this book: I hope to help many more avoid these expensive mistakes.

Every House, Every Homeowner, and Every Budget Is Different

When you put the whole mobile together with all of its parts you can begin to see how complex a home is: In/Out vs. Inside; Air, Heat, and Moisture; Air Sealing, Insulation, and HVAC. All of those elements affect the Four Tenets: Comfort, Health, Durability, and Efficiency.

Can you balance all of these things at the same time? Of course! But it may not fit your budget.

If you've heard the phrase "good, fast, or cheap: pick two, we find it doesn't work with effective Home Performance work. Go too fast, and you'll miss something. Cheap out, and something won't work or will cause major issues down the road. There really is only "good." If you do work yourself (DIY) you can often reduce the budget a great deal, but good and cheap work from contractors is likely to live with unicorns and sea monsters.

Figuring out what "good" is for your home is why design and planning is necessary to see how much you can do within your budget. You have specific problems you'd like to have solved. Your home has various things that it needs to solve your problems. And you have a different budget from everyone else, which means that the solution is custom to you and your home.

There are no shortcuts or cookie cutter solutions. Design and planning are required. I'm happy to be proven wrong, but I've already failed enough trying shortcuts that I won't take them anymore.

How to Really Solve Problems in Your Home

The key to solving problems, staying on budget, hitting the 74 Inch Tipping Point, and swimming in the Sea of Success is planning. We've beaten our heads against a lot of walls working to figure out a process for doing this, here it is:

1. **Learn**
   Get educated on what the root causes are and how to fix them. You are now a partner in the solution process, not an onlooker.
2. **Define**
   What problems do you want to solve? How important is each one to solve? How much does your home leak? What problems does it have? What is the budget for the project?
3. **Plan**
   Develop plans to solve as much as you can within the budget you are comfortable with.
4. **Implement**
   Get bids, do the work, test the work during and after completion, track to see if the predicted results match actual ones, and optimize the house to be the best it can be.

If I thought you could truly DIY (do-it-yourself) this process, I'd tell you so. There are many parts of the upgrades you can DIY, but you're going to need a helping hand with planning.

I need help myself. I've been ruminating about what to do with my own home for years now, and I've needed the help of my business partner. Think about that: I know enough to write this book and I still need help making a plan! I simply can't divorce my emotions from what needs to be solved. Worse, because I haven't settled on budget, I haven't settled on a solution package! I'm out of process, I am trying to skip from step 2 to 4. Until I firm up my budget, and get back in process, I'm likely to fail. A Building Scientist can help keep you in process.

The time, money, and frustration saved should more than make it worth working with a Home Performance Specialist. Many of our clients become friends through the process, this is a satisfying way for everyone to work.

Conversely, please don't be the people in the old insulated house with new HVAC that all needs to be redone. The odds are that house will never be fixed, it's just too painful to admit to wasting tens of thousands of dollars, then spend tens of thousands more to undo the work and redo it correctly.

Half measures lead to quarter results. Remember the promise you made me at the beginning to be open and to not take shortcuts? Now it's time to keep that promise. You're in Step 1: Learn. Keep learning.

When you are ready to make a plan, find a Home Performance Specialist. Here's our guide on what to look for.

Congrats! You now understand the basics of how your house really works!

If you want a comfortable, healthy, long lasting, and efficient home, get a plan using the Five Priorities: air sealing, air sealing, air sealing, insulation, and well designed and installed HVAC.

We highly recommend that you keep reading and educating yourself. Be sure to define the problems you want to solve, the "why" of your project. When you're ready to tackle your project, here are a few things to do.

5 Things to Do to Prepare for a Home Performance Project

1. **Don't Procrastinate**
   Before your furnace or air conditioner dies, begin the planning process so you understand the opportunites your home has for improvement. Winging it often leads to lousy outcomes and HUGE mistakes. These projects take time, often 4-8 months from initial consultation to project completion. The faster you go, the more likely you are to miss things and waste money. If you want to be ready for next winter, start at the end of winter, not in October. Start now or risk wasting a ton of money on the wrong solutions to deliver comfort, and having to replace them again or live with mediocrity.
2. **Make a Ranked Pain List**
   What bothers you about your house? Make a list. Uncomfortable rooms? Mold? Icicles? Asthma or allergies? Rate the problems from 0 (you don't notice) to 10 (I don't care how much it costs, fix it now!) Now put them in order from high pain to low pain. The Ranked Pain List is your priority list that you will judge success or failure of the project with.
3. **Consider Budget**
   Don't share this with your Home Performance Specialist yet. What is it worth per month, to make each of the Ranked Pain List items go away? How much to make them all go away? As a rule of thumb, if it's not at least $50/month (half a cell phone bill), it probably doesn't make sense to chase. Solve with space heaters and window air conditioners. The higher that number, the more likely a solution is.
4. **Consider DIY Ability and Availability**
   This is a great way to save money on a project, if you have both time and ability. On an ability scale from 0 (which end of the screwdriver do I use?) to 10 (Bob Vila), where do you rank? On an availability scale of 0 (I ain't got time for that) to 10 (I have all the time in the world to work on my house), where are you?
5. **Do Your Homework**
   You may not be able to find a practitioner in your area who meets your needs. The more educated you are, the more likely you'll be able to spot problems and get a good result. You may consider buying the rest of this book if you only downloaded this chapter. (Yes, it's a blatant plug, but it's also why I wrote the book: to help consumers do their homework and get better results.)

6 Things to Look for in a Home Performance Specialist

Once you tackle those preparation steps, it's time to find a Home Performance Specialist. You are looking for one thing: proof they can predictably deliver results. You want a partner, not a salesperson. Here are 6 things that will help you understand if they can deliver. Don't waste thousands or tens of thousands of dollars, look for these things:

1. **Case Studies**
These are still very rare. A detailed look at what the objectives were, how the project went, and if the objectives were met. Expect before, predicted, and after blower door readings at a minimum. Before, predicted, and after energy use is also good to look for, it is a proxy for success. We built Energy Smart's case studies to raise the bar on case studies, check them out and look for a home like yours.

2. **Concern for Outcomes**
Do they talk very specifically about solving client problems? (Not platitudes or PR bull puckey, but real human concern.) Do they have blog entries that talk about specific projects? Do they talk about making adjustments after a project to get it just right? (It's called project commissioning or continuous optimization.) Can you get contact information from satisfied clients? Call them and ask how much they heard from the company after the project was complete. Did they call a week later, a month later, after the seasons changed? Did they ask for energy use a year later? If someone does all this, you probably have a good HPS.

3. **Positive Reviews**
Reviews should be pushing a 5 star average. If there are negative reviews, are the concerns valid or just whiny? Did the people who left negative reviews actually have work done by the company? Check multiple venues such as Google, Angie's List (which is now free), and Yelp. Do they match up? Do you suspect employees, friends, or family may have written some reviews?

4. **Meaty Reviews**
"They were really nice and cleaned up well" is not meaty. Here's a meaty review: "They listened to our concerns, developed an excellent plan, and showed lots of care about the details. Our bedroom is substantially cooler on hot days just as we asked. We are sleeping much better." Meaty reviews are long and detailed.

5. **Subjective Proof**
At the end of the day, comfort is a state of mind and can't be measured. Do the reviews and/or case studies have quotes from the homeowners stating that problems were solved to their satisfaction and expectation?

6. **Objective Proof**
Home Performance is all about measurement. There should be numbers all over the case studies and reviews. Do clients mention blower door numbers in reviews? Do case studies include before, predicted, and after blower door numbers? Is energy use predicted? Is it measured after the fact? Do predictions line up?

Go forth and conquer the things in your home that drive you nuts!

We will be emailing you more information as time goes on. If you want to read more, right now, go here and download more guides to learn more about how your home works and how to truly solve problems.

Resources

Thermodynamics: It's Not Rocket Science Joe Lstiburek. I borrowed my rules from Dr. Joe, he's part of my R&D program: ripoff and duplicate. Or said in a nicer way, he's one of the giants that I stand on the shoulders of. His website, buildingscience.com, is one of the very few that I almost entirely agree with. Watch the dates of the articles. Building Science changes, make sure there isn't a newer article.

Portage County Habitat for Humanity Deep Energy Retrofit Project Energy Smart Blog. This tells the story of the challenges and triumphs during the planning and retrofitting process of a 1900 era ranch type home that probably should have met the bulldozer. Instead it was turned into a comfortable, healthy, durable, and efficient home. The series was also published in the Journal of Light Construction.

The Stack Effect Dr. Energy Saver - Larry Janesky demonstrates and measures the stack effect in a real home. Nice explanations, too.