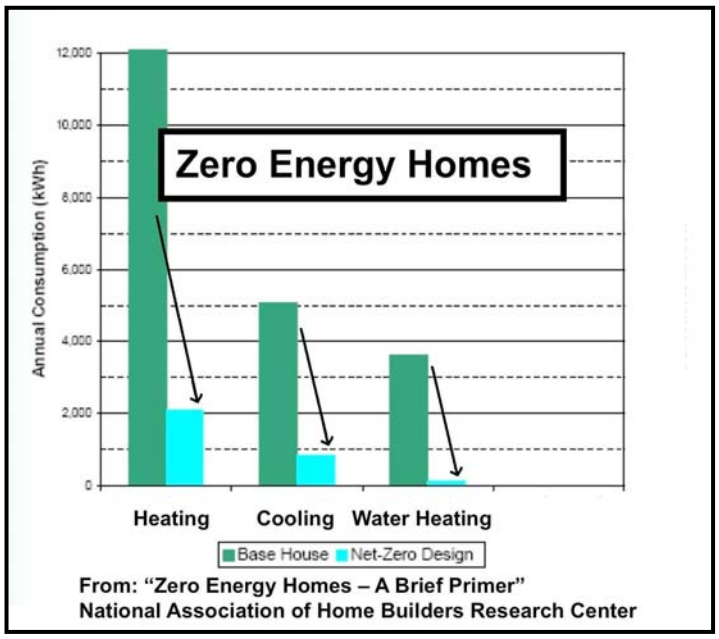
Checklists for Architects Designing

Net Zero Energy Buildings



Excerpted from

Addicted to Energy

Elton B. Sherwin, Jr.

Praise for *Addicted to Energy*

"I couldn't put it down. It's smart, practical, and proves the point that what is good for the environment is good for the economy."

David Miller
Mayor of Toronto

"Simple solutions for governments, corporations, and individuals"

William F. Miller
Former Provost of Stanford University

"Sherwin lays out an action plan tackling the most economically and environmentally attractive options we have. You don't need to agree with everything he says to find enough good ideas to fill the agenda for any state, county, city, or family."

James Sweeney
Director, Precourt Energy Efficiency Center, Stanford University

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"A practical cookbook for consumers, industrialists and policy makers.

…Bravo!"

Bill Keating
Executive Chairman, Skyline Solar

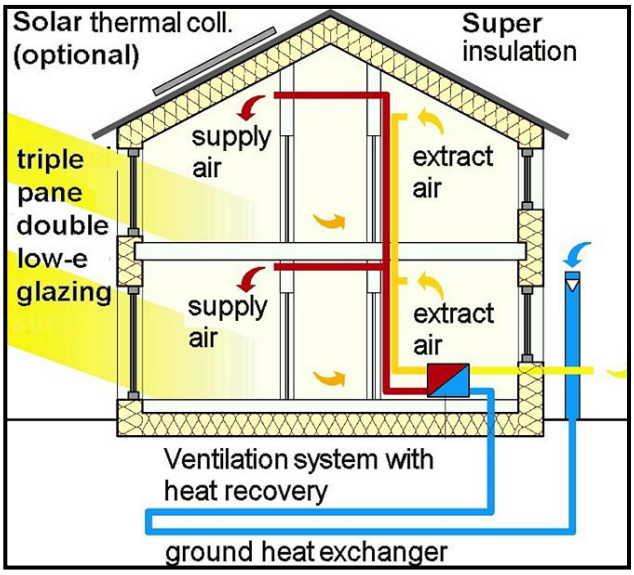
"A magnificent roadmap for creating jobs, wealth and real progress"

Nicholas Parker
Executive Chairman, Cleantech Group

How Innovative is Your Design?

How Will it Perform?

Is it an Award Winner?



My book, *Addicted to Energy,* is written as a letter to a fictional governor. Much of the book deals with problems in *existing* buildings.

This short document contains various checklists from *Addicted to Energy* that focus on green construction and remodels. The two *Design Logic* pages did not make the final edition of the book .

Those interested in innovative, net-zero buildings may also wish to visit the following websites:

www.zetacommunities.com

www.ruralzed.com

www.jetsongreen.com

Also see the Wikipedia entries for:

- Passive house
- Zero-energy building

The German Passive House standard has dramatically reduced building energy consumption, something that most American, point-based, green building systems have failed to do. Architects, builders and city planners interested in net-zero buildings should study this German success story.

What Ails America's Buildings?

Fifteen Practices that Steal America's Wealth and American Jobs

1. **Insulation** is insufficient and poorly installed.
2. **Heating and air conditioning** system is too large.
3. **Ductwork** for the HVAC system is too narrow, leaks, or was poorly installed.
4. **Thermostats** or HVAC controls are the wrong model, poorly programmed, or *one thermostat controls more than one room.*
5. **The wrong windows** are installed.
6. **Exterior window shades** are missing on sunny windows.
7. **Fans, pumps, and compressors** are fixed speed.
8. **Outside fresh air** is poorly managed; heat exchangers are missing.
9. **Ovens, refrigerators** and refrigerated display cases are inefficient or vent hot air inside buildings when air conditioning is running.
10. **Halogen and incandescent bulbs** are still used.
11. **No occupancy/daylight sensors** are installed *on lighting systems.*
12. **No occupancy sensors** are installed on *heating and air conditioning systems.*
13. **No real-time, energy-consumption feedback** given to building occupants.
14. **No knob for users** to turn *down* overactive heating and cooling systems.
15. **No switch for users** to turn *off* heating and cooling systems in individual rooms.

How Many of These Problems Do You Have?

These practices are almost universal in America. They export money and jobs out of your state. They are both environmentally destructive and wealth destroying.

A Simple Green Building Code for *Homes*

What can cities and counties do to lower the carbon footprint of new buildings and remodels? Below is a simple addition to a city, county, or state building code.

These 10 items add some cost to construction, but they pay for themselves quickly in reduced utility bills.

A Simple Green Building Code for Homes

New single-family homes should have all 10 of the following. Remodels should upgrade proportionally; for example, 20% remodels could pick two from the list, 40% remodels four, etc. Residential versions of items #1, #5, and #8 are difficult to find, so you may wish to phase them in.

These 10 items dramatically reduce the carbon footprint of homes, new and old.

1) ***Thermostat***. A separate thermostat with an occupancy sensor in each room, controlling the room's heating and cooling.

2) ***Furnace***. Variable-output, variable-speed, modulating furnaces with variable-speed fans and oversized ductwork, blow-tested at installation.

3) ***Air Conditioner***. Variable-speed, multistage, right-sized air conditioners.

4) ***Water Heater***. Solar heat or waste heat from a furnace used to preheat domestic hot water.

5) ***Windows***. R-10 spectrally selective windows.

6) ***Smart Lighting.*** No incandescent or halogen ceiling fixtures.

7) ***Insulation.*** Two R-values of insulation above California Title 24, with the building shell blow-tested and thermally imaged for leaks.

8) ***Power Monitoring.*** Real-time reporting to the homeowner of all power, gas, and water usage *by room.*

9) ***Utility Bill Disclosure***. All buildings claiming to be "green" must disclose their energy consumption.

10) ***High-efficiency, Zero Particulate, Closed Combustion Fireplaces.*** These fireplaces emit no soot, most often burning natural gas or propane instead of wood.

These are better homes. They have lower utility bills, and they are more comfortable.

A Simple Green Building Code for *Commercial Property*

You can slightly modify the residential building code on the prior page and get a commercial building code that dramatically reduces greenhouse gas emissions and utility bills.

The Top 10 Items Currently Absent From Commercial Building Codes

1) ***Thermostat***. A separate thermostat with an occupancy sensor in every room and office controlling the room's heating and cooling.

2) ***Furnace***. Variable-output, variable-speed, modulating furnaces and boilers with heat exchangers for outside air; variable-speed fans and pumps commissioned at installation.

3) ***Air Conditioner***. Variable-speed, multistage, right-sized air conditioners with a minimum of 40% thermal storage, commissioned at installation.

4) ***Water Heater***. Solar heat or waste heat from a furnace used to preheat hot water.

5) ***Windows***. R-10 spectrally selective windows.

6) ***Smart Lighting Systems.*** Dimmable fluorescents and LEDs with occupancy and daylight sensors.

7) ***Insulation.*** Two R-values of insulation above California Title 24, with the building shell blow-tested and thermally imaged for leaks.

8) ***Energy Monitoring.*** Real-time reporting of all electricity, HVAC and water usage *by room.*

9) ***Utility Bill Disclosure***. All buildings claiming to be "green" must disclose their energy consumption.

10) ***Roof.*** Reflective roofs, sometimes called cool roofs.[351]

These are better buildings. They have lower utility bills, lower CO_2 footprints, and will be more comfortable. These ultra-efficient buildings will also protect your state and its businesses from future energy price increases.

All green buildings must disclose their utility bills.

Designing Extraordinary Buildings—A Checklist

I originally developed this checklist as an alternative to the LEED point system. It has 50 points. Great buildings should have *at least* 25 of these features. Sadly, some "green" buildings today have less than five.

The ultimate test of a building's "greenness" is how much energy it uses, but this checklist can help you get there.

CO_2 footprint during construction

- All wood products are certified as sustainable.
- The CO_2 footprint of all building materials is calculated and reported.
- Uses low-carbon Sheetrock.
- Uses low-carbon cement.
- Less than 10% of building exterior is wood.[352]

Building comfort

- HVAC system monitors CO_2 levels at multiple locations on each floor and dynamically adjusts fresh air.
- HVAC system optimizes its performance based on humidity.
- There is a thermostat in every room.
- Building is designed to be habitable during a 24-hour power outage without AC compressors running. One point for each season of the year.
- Occupants can temporarily request more heat or AC in a room.
- Occupants can temporarily adjust blower speed in a room.
- Occupants can change direction of some airflow in offices (similar to an airplane seat).
- Occupants can control a window shade or equivalent in all rooms.
- Occupants can open a window or request more fresh air.
- Building has an open wireless network to receive feedback from tenants and visitors on building comfort, temperature, and problems. Feedback is collected and reported. Optimally, allows users to set some HVAC parameters (temperature, fan speed, and extended away times).

Tenant Feedback

- Building owner provides tenants with Web dashboard of the tenant's energy consumption updated every fifteen minutes or more frequently.
- Building manager bills individual tenants for their actual electricity consumption and enables large tenants to bill at a department level.
- Building owner provides tenants with breakdown of electricity consumption by room.
- Building owner bills individual tenants for actual hot water consumption.
- Building owner bills individual tenants for actual HVAC consumption.
- Real-time building energy consumption is displayed in building lobby.
- Real-time tenant energy consumption is displayed on each floor (for example, an LCD display in elevator lobbies of each floor).

Monitor and report energy consumption *by room*.

HVAC

- Major HVAC system components monitor energy consumption (electricity, gas, and oil), report problems, and alert facility managers to unexpected levels of energy consumption.
- HVAC system monitors and reports energy usage by floor.
- HVAC system monitors and reports energy usage by room.
- Occupancy sensors reduce HVAC usage in empty rooms.
- Weather forecasts help HVAC system anticipate load.
- Building system reports percent of air-conditioning load sent to rooms remaining empty for the following hour and the percent of heating sent to rooms remaining empty for the following two hours.

Lighting

- Lighting system tracks and reports its energy consumption by room.
- Addressable, smart lighting system automatically reduces consumption when natural light is present or when people are absent.
- Building monitors and records light levels and daylight availability in all rooms.
- Building system reports percent of power used by lighting, percent of lighting used in empty rooms, power saved by motion detectors on lighting systems, power saved by lighting level (brightness) sensors, and percent of lighting provided by daylight.

Plug Load and Occupancy Reporting

- Building monitors and reports electricity usage of subpanels.
- Building tracks and monitors electricity usage of individual circuit breakers.
- Building tracks and reports electricity usage of individual plugs.
- Building can sense, track, and report total power and HVAC load consumed by each room and calculate percent of total building energy allocated to unoccupied rooms.

Demand Response

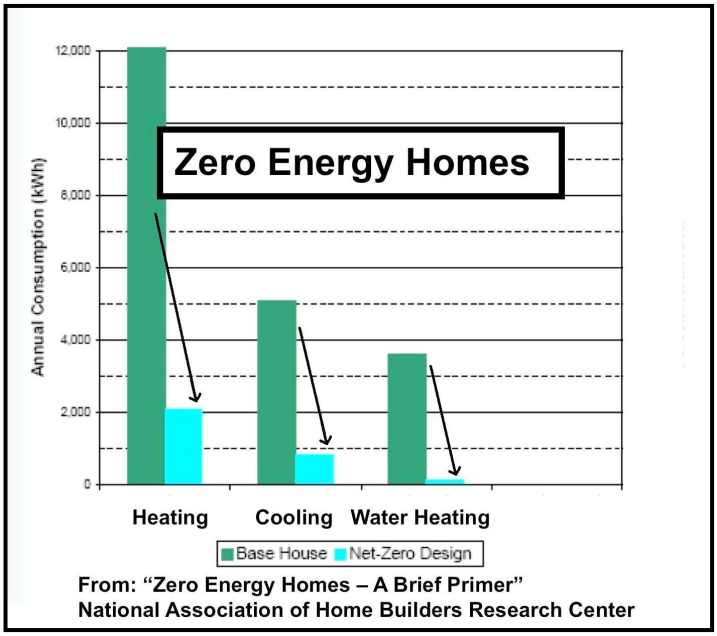
- Eighty percent of daytime HVAC system is controlled by a utility-demand response system.
- Seventy percent of lighting is controlled by a utility demand-response system.

Water

- Weather radio or sensor data adjusts 80% of landscaping irrigation and sprinklers.
- Water usage is monitored and tracked for landscaping and HVAC systems.
- Water usage is monitored and tracked for each room (restrooms, kitchen, etc.).
- Water usage is monitored and tracked at a fixture level (every shower, toilet, etc.).
- Hot water usage and energy consumption is monitored and tracked.
- Urinals average less than two cups of water per flush, toilets less than one gallon.
- Building owner bills individual tenants for their actual water usage.
- Building has a gray water system.
- Water usage data is available to tenants online.

Zero Energy Homes (ZEH)

Zero energy homes, or more accurately called "net zero homes," produce as much energy as they use. Typically, they reduce heating and air-conditioning loads by 80%, using better insulation and more effective HVAC systems. Hot water is pre-heated by the sun. The remaining energy is created by solar electric or occasionally by wind. A home is said to be *zero energy* or *net zero* when, over the course of a year, it produces as much power as it uses. Zero energy refers only to the utility bill, not the energy it takes to build a home.



From: "Zero Energy Homes – A Brief Primer"
National Association of Home Builders Research Center

Over the life of a home, reduced utility bills usually pay for the cost of building a net zero home.[163]

You should ban the development of traditional, inefficient subdivisions of detached homes. America already has enough of them. Once a home is built with the wrong walls, wrong windows, and wrong furnace, it is very challenging to morph it into a zero energy home.

Transitioning to Zero Energy Homes

Today, your state has few architects or builders who know how to build energy-efficient buildings, or zero energy homes. This is about to change.

As you start to grade, publish, and post the energy efficiency of your state's commercial buildings, hundreds of millions of dollars will be spent to improve their efficiency. Energy auditors, electricians, HVAC installers, and general contractors will be overwhelmed with work upgrading buildings, lowering their energy consumption, and improving their "grades."

Housing for the next 140 million Americans should be in high-density housing near rapid transit, or in zero energy stand-alone homes.

As the results of their work are reflected in utility bills and posted on the Internet, your state's architects and builders will learn which products and designs are cost effective in your state.

Zero Energy *Capable* Homes

You may wish to phase in zero energy homes in your state. The concept of a zero energy *capable* building is useful. This is a building that has reduced its heating and cooling by 70% to 80%, low enough that solar PV *could* run the building. In the early years, you might only require 20% of the new homes in large subdivisions to have solar PV on their roofs. It is sufficient that the remaining houses be capable of adding solar PV.

Zero Energy Home from rualZED*

Within the decade, your state will have the "greenest" construction workforce in America. More importantly, your state will have the most energy-efficient construction industry in America, able to attract businesses from around the world.*

Seven Important Steps to a Successful Zero Energy House
Adapted from www.toolbase.org [164]

1. Decrease the energy requirements for space **heating and cooling**:
    a. Orient the home and **shade the windows** correctly.
    b. Increase foundation, wall, and ceiling **insulation.**
    c. Use the **correct windows** with low solar heat gain (low SHGC).
    d. **Seal** all holes and cracks.
    e. Install ventilation correctly, using a **heat exchanger** for fresh air.
2. Increase the efficiency of the **furnace** (or heat pump) and the **air conditioner.**
3. Install a **solar hot water** pre-heat system, an efficient backup water heater, and an efficient distribution system.
4. Install efficient **lighting** fixtures.
5. Install efficient **appliances.**
6. Install properly sized **solar photovoltaic** (PV) panels.
7. **Turn off the lights**, computers, and appliances when not in use.

* Image from ruralzed.com. For other creative designs, search in Google *Images* for 'zero energy homes.' Also, see JestonsGreen.com.

Buildings and Homes

■ ■ ■

". . . In the United States we could save at least half the oil and gas and three-quarters of the electricity we use, and that efficiency investment would cost only about an eighth what we're now paying for those forms of energy."

Amory Lovins,

Co-founder and Chairman of Rocky Mountain Institute[155]

What are *Your Home's* Top Energy Wasters?

In my experience of visiting American homes, primarily in California, New York, South Carolina, and Connecticut, these are the biggest energy wasters.

Every home is different, but these are the first things to check:

- ☐ Pool and spa pumps
- ☐ Old refrigerators and freezers
- ☐ Incandescent and halogen bulbs
- ☐ Desktop and tower PCs left on
- ☐ Mini-refrigerators, wine refrigerators, and standalone ice makers
- ☐ Drafty or uninsulated walls
- ☐ Underinsulated ceilings and floors
- ☐ Windows with R-values below R-8 in cold or hot climates
- ☐ Unshaded, sunny windows that are *not* spectrally selective in homes using a lot of air conditioning
- ☐ Water heaters
- ☐ Heating and air-conditioning systems with only one thermostat per floor
- ☐ Fixed-speed furnaces
- ☐ Fixed-speed air conditioners
- ☐ Cable and satellite set-top boxes
- ☐ HDTVs
- ☐ Surround sound and PC speaker systems
- ☐ Stereo systems and entertainment consoles
- ☐ Game units left on
- ☐ Old or poorly programmed thermostats
- ☐ Whole house (attic) fans and gas fireplaces without twist timers[345]
- ☐ Fixed-speed or two-speed whole-house fans (attic) fans
- ☐ Fixed speed recirculation pumps
- ☐ Well pumps
- ☐ Rechargeable flashlights without LED bulbs

"We installed fluorescents. What else is there?"

Remark overheard on Stanford University bike path

What are *Your Company's* Top Energy Wasters?

What are the top energy wasters in your company? I talk to experts and visit businesses around the country. The amount of wasted energy is staggering.

Here are the most environmentally damaging things I see:

- ☐ Old, large-diameter fluorescent tubes and their fixtures
- ☐ Poorly calibrated HVAC equipment which needs re-commissioning
- ☐ Over-sized, over-aggressive air conditioners
- ☐ Lighting control systems either not installed at all, or installed without occupancy sensors, light-level sensors, and automatic dimmers
- ☐ PCs left on nights and weekends with power management systems disabled
- ☐ Inefficient manufacturing and transportation of products
- ☐ Incandescent and halogen bulbs–especially in restaurants and retail
- ☐ Water heated by burning oil or gas instead of using solar or waste heat
- ☐ Thermostats without occupancy sensors or twist timers[351]
- ☐ Fixed-speed pumps, fans, and motors with no back-pressure sensors
- ☐ Office equipment not ENERGY STAR rated
- ☐ Poorly maintained cooling towers
- ☐ Windows with R-values below 8
- ☐ Sunny windows that are not spectrally selective
- ☐ HVAC systems with fixed-speed fans
- ☐ Rooms without individual thermostats and occupancy sensors
- ☐ Under-insulated walls, ceilings, and floors
- ☐ Vending machines
- ☐ Air compressors in factories, auto-shops, and gas stations
- ☐ Refrigeration equipment and refrigerated display cases
- ☐ Agricultural pumps and wells
- ☐ Restaurant kitchen exhaust hoods and factory exhaust fans
- ☐ No thermal storage on air conditioners
- ☐ Windows or doors left open while the heating or cooling system is running
- ☐ Smoke and soot from fires and diesel trucks
- ☐ Refrigerants leaking or released into the air[352]

Climate-Safe Smart Buildings: Design Logic and Thought Process

In the certification of *existing buildings*, please note which features are present. If a particular product is being used, please note the manufacturer and model when available. Please annotate items that would be helpful to other professionals. For example, a comment under *Windows and Daylight, R-value,* might say, "Wisconsin winters need windows with much higher R value than were originally installed in this building."

In the certification of *new construction,* all of the following must be considered; none are mandatory. Under each topic *briefly* explain what strategy or product was used, or why this item was omitted.

Examples:

A highly reflective roof (white roof) or a living roof.

"In Alaska, white roofs and living roofs are not needed." Or,
"Neighborhood calls for tile roofs. Clear sealant that reflects IR and UV was used on all roof tiles." Include product name.

Design Logic and Thought Process Checklist

This section must be posted on the building Web site. These items are not required, but experience has found most are effective in minimizing a building's environmental footprint.[421]

Overview

- Objective for this building

Building Siting and Design Considerations

- Features of the previous building that were retained
- Building located to maximize passive or active solar
- Historic features or neighborhood character

Building Exterior

- A highly reflective roof (white roof) or a living roof
- Minimize the use of exterior wood[422]

Renewable Energy Plan

- Solar electric
- Wind-generated electricity
- Passive solar heating
- Active solar heating
- Solar hot water
- Active solar cooling

- Passive cooling
- Energy storage

Windows and Daylight

- Window solar heat gain. How much of the AC load will it be responsible for? How much of the building's heating needs will it offset?
- Management of winter sun versus summer sun
- Window differences between southern exposure and northern exposure
- Use of daylight
- Window R values
- Operable windows

HVAC and Thermal Management of Building

- General description of system and HVAC strategy
- Dehumidification
- Thermal storage
- Oscillation between heating and cooling
- Fresh air management
- Insulation and R values
- HVAC chillers and compressors delay returning to service after power outages until signaled by utility
- Furnaces and water heaters have modulating burners
- Fans have variable air flow with feedback loops
- Pumps are variable speed and have feedback loops
- Features designed to minimize air and water backpressure
- Management or reuse of waste heat from refrigeration systems, furnaces, boilers, water heaters, and air conditioners.
- Will the waste heat from refrigerators, freezers, and vending machines be vented inside the building increasing AC load?

Landscaping

- Sprinkler system dynamically changes water flow based on weather conditions
- Sprinkler system dynamically changes water flow based on soil moisture
- Drought tolerant species chosen
- Native species chosen
- Recycled or gray water used

Miscellaneous:

- Indoor air pollution management

Superstar Thermostats

My company, Ridgewood Capital, was a pre-IPO investor in Comverge (NASD: COMV), and one piece of their business is advanced thermostats. Since Comverge went public, I have met with several other companies building advanced thermostats. Every couple of years, I buy the most advanced thermostat I can find and try it out on my family.

A smart thermostat should not require any programming.

I will make 12 controversial predictions. They are controversial for professionals in the HVAC business. You, like me, may think they are obvious, but in professional circles, I get pushback on these.

The most *efficient* thermostats will have:

1. **No programming** requirements. They will just have an ↑ up arrow and a ↓ down arrow to change temperature. Smart thermostats will *learn* what you like.
2. **Half degree** increment adjustability.
3. **An *occupancy* sensor** to detect when a room is empty.
4. **An *infrared* sensor** to detect the temperature of the whole room.
5. **A *light* sensor** to detect when a room is dark.
6. **A *humidity* sensor** and perhaps even a CO_2 sensor.
7. **A radio receiver** for a remote thermometer to detect temperature and motion in another room.[126]
8. **Internet connection** to get the weather forecast and various other pieces of useful data from the electric utility.
9. **PC connectivity** to send detailed usage data to building owners.
10. **A remote emergency off switch** to enable electric utilities to turn off air conditioners in a crisis.
11. **Twenty-four months of memory**. Long-term memory in thermostats is helpful for finding problems in home heating and air-conditioning systems.
12. **Superior comfort**. They will learn the rhythms of a house and have fewer temperature swings.

Smart thermostats should cut heating and cooling cost by more than 20%, with a similar reduction in CO_2 emissions. Homeowners will prefer these superstar thermostats because they will save money and deliver superior comfort.

Over time, these superstar thermostats should become quite clever, with the ability to discriminate between pets and people and, ultimately, between an empty room and an individual asleep on the sofa.

45% of residential energy is used to heat and cool homes.

US Department of Energy and Buildings Energy Data Book[127]

Another Thought Experiment: A World without Volume Controls

What if home stereo systems were installed like home heating systems?

Every room in the governor's mansion would have a speaker. Each floor would have only one on/off switch. There would be no volume controls. When the stereo was on, it would be on in every room, *full blast*.

There would be no way to listen to music in only one room.

There would be no way to listen to music softly.

Variable-speed systems can save 40% to 70% of heating and cooling costs.[157]

Off or full blast would be the only choices. This is actually how the heating and cooling systems are installed in most homes, and many businesses. If you want to heat the master bathroom on a cool morning, you heat your whole house. If you want to cool one office on a sunny afternoon, you must air-condition every room, even the ones that are already cold.

An advanced industrial society in the 21st century can do better than this.

Every room in your state needs its own thermostat.

If the governor's mansion has four or five empty guest bedrooms, they do not need to be air-conditioned. If you don't use your formal dining room for breakfast, don't heat it in the morning.

A thermostat in every room saves a lot of energy, often reducing some air-conditioning bills by over 50%.[158]

Room-level controls require more expensive furnaces and air conditioners, ones that are variable speed. Analogous to volume controls on a stereo, variable-speed blowers and fans can put just the right volume of hot or cold air into a room. This also requires smart ductwork to route the heat or air conditioning to the correct rooms.

One company that specializes in such systems is Home Comfort Zones, www.homecomfortzones.com. I met them at the 2008 Cleantech conference in San Francisco. They have a product called MyTemp™ for "room-by-room temperature control of your home."

This combination of many thermostats and speed controls on heaters and air conditioners saves money and also creates a more pleasant environment. No longer are some rooms too hot, while others are too cold. Gone also are the wild temperature swings.

Room-by-room temperature controls with variable-speed HVAC systems save enormous amounts of energy. They should be the rule for all new residential and commercial construction.

All new furnaces should be variable output and variable speed.

"It's refreshing to see someone writing about actual solutions to the problems."

Rick Woodbury
President, Commuter Cars Corporation

"Powerful, pragmatic and engaging"

Carol F. Smith
Founder, Eco-green Group

"Lucid pragmatism"

Colin Rusch
Director – Cleantech Research, ThinkEquity, LLC.

"Sherwin's story about burning his fingertips on a hot window at a hotel in San Diego is a memorable story. Most writers on energy efficiency issues do not understand how much energy America loses through single and dual pane windows. Sherwin is astute when he calls for universal use of ultra-efficient, high R-value windows."

Kevin Surace
CEO, Serious Materials

"Sherwin is correct when he says that ice is the key to widespread deployment of wind turbines. Unfortunately, this is not obvious and very few policy-makers understand it. Sherwin gets it exactly right and describes it in understandable terms."

Frank Ramirez
CEO, Ice Energy