SHAPING

Residential Sector Energy Performance

Michael MacDonald

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Energy Performance Measurement Institute

Shaping Residential Sector Energy Performance

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This book is dedicated to William R. Mixon, who
spent much of his career working to improve
residential sector energy performance

Foreword

A lot of words are wasted in today's world on climate change and sustainability. Climate change and sustainability are very nebulous terms, and their use could be considered deliberate obfuscation, if the real desire is emissions reductions in the atmosphere. This book is aimed at informing people about energy use in the residential sector worldwide and what can be done to make politicians and others more accountable for improving the energy performance of the sector, which is probably important if emissions reductions are desired. The tone is not scholarly and hopefully not too blunt.

The world can be divided into major energy-using sectors. All energy used in human activities on planet earth can be generalized to be used in the major sectors of industry, transportation, and buildings. The buildings sector is also sometimes considered as two sectors: residential and commercial. This book is about making the energy performance and efforts to shape the performance of the residential buildings sector more readily understandable. Most of the presentation is at a simple level that anyone able to read reports should be able to understand. Some complexity is introduced, but the complex parts are not necessary for understanding basic residential sector energy performance. Implications for national, supra-national, state, and local policies of actually making this performance readily understood are also covered.

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Synopsis

Energy is a complicated topic, and energy performance can also be challenging to determine. This book is about understanding and shaping energy performance of an entire economic sector, using the residential sector as the example, although not at a detailed level. The historical record of attempts to reduce energy use or carbon emissions of countries and the world is primarily one of failure. Should the response to continued failure be to continue to do more of the same? Insanity is sometimes defined in such a manner. The contention here is that change is needed.

Significant information on worldwide energy use and residential sector energy use is presented, including many factors that are unique to the residential sector. Energy performance measurement methods and data are also presented. Simplification of residential sector energy performance measurement is a key theme. If residential energy performance is easy to understand, more people can be engaged in discussing and promoting improvement.

Simple key performance indicators are used to present the state of the world residential sector, with additional detail on the United States and Europe, as well as developed countries as a bloc and developing countries as a bloc. Knowledge about the residential sector is used to identify policy considerations. The last part of the book is about energy and carbon reduction policies: how historical policies have not worked and the extent of what must be done if real results are desired. However, a complete solution cannot be presented in the short space here. Extensive program development is still needed.

The history of energy/carbon reduction policies is one of a continual quixotic quest for magic bullets to shoot at the problems and have them be killed off. That history continues today with presentation of magic technologies that will solve all the problems. Energy efficiency has been mostly ignored for decades, despite lip service on how important efficiency is. Information on scoping of large-scale energy efficiency programs is presented to allow better understanding of how much must be done to actually impact energy use on a scale that can be seen worldwide.

Using the information in this book, readers are invited to respond by asking central planners and policy makers to start making the energy and carbon situation more understandable and initiating commitments on the scale needed to achieve real worldwide efficiency impacts, instead of throwing too many trillions at magic bullets.

Introduction

Politicians, bureaucrats, and scientists are lying to you and to the world. Everybody knows that! (So they say in the commercials.) But did you know that they do not really understand how to achieve adequate improvements in residential sector energy performance within a reasonable time frame? What they do know how to do is make grandiose promises that they will achieve true sustainability, if only . . .

If only we give them . . . . .

. . . more money . . . more advanced technologies . . . more power . . . more time . . . more qualified people . . .

. . . the future will be a paradise of sustainability.

If you have an interest in being able to understand residential sector energy performance, this book will provide a lot of information that is not readily available. If some of you enter positions of decision-making that influence what is done to increase residential sector energy performance, this book will provide a basis for being able to ask the questions that cut to the core of what might or should be done. For those of you who are engaged in stimulating party conversations about residential sector energy performance, this book will make you the life of the party. The real hope is that better focus on energy performance improvement efforts and measurement of progress can be achieved.

There are many reasons why improvements in energy performance of entire economic sectors can be desirable, including a desire to reduce energy use in a sector. The residential sector is made up of many individual homes, so from a personal view, people can be interested in reducing their energy use in the home (or not). This book is not aimed at informing people about individual homes, as there are thousands of pages published already on this complex area. The interest here is how to understand entire countries or world regions and the residential sectors contained therein.

Now why would you want to understand an entire sector? One reason is that politicians and media outlets lie a lot (or at least confuse the truth with something else), so it can be helpful to try to understand things more yourself. Add to that, far too many bureaucrats and so-called scientists are really politicians in disguise. Possibly worse, scientists and those who write about scientific topics have become far too "religious" in their "scientific" pronouncements (this has been going on for 400 years or so). Politics and religion are closely related in many ways, so their entanglement is to be expected, although with problems for both. Entangling science in politics, and treating supposedly agnostic science as a religious "belief" system, both cripple useful outcomes.

Total energy use in the world is expected to increase by about 50% from 2010 to 2040, according to the U.S. Energy Information Administration (EIA) in the *International Energy Outlook 2013*. Residential sector energy use is also expected to grow about 50% by the EIA. Energy use worldwide in residences is about 14% of all energy use (although biomass energy changes that — see 2nd following chapter).

What's going on here?

So if you are wondering why energy use is projected to increase so much, part of what this book does is briefly explain why. Projections are risky, as they depend on some stability in the world. So with the understanding that the projections covered here could change if major upheavals occur, and that projections follow current trends but *do not* really predict the future, understanding the trends is helpful in grasping the reality affecting efforts to shape residential sector (or any sector) energy performance in the future.

The projected major increases in world energy use and residential sector energy use are inconvenient to sustainable development proponents, as the critical knowledge about what direction the trends are really headed raises prickly questions about what sustainability, renewable energy, and zero-energy buildings are accomplishing. While there may be importance to efforts in these areas, excessive focus on them obscures the realities. A lot of political promises are made about sustainability, but mostly they simply cover up the truth.

Most of the time political policy on energy performance improvement is set with little or no understanding of how the policy is to be achieved. Saving energy is complicated, so actions become mired in the details of the complex process. In addition, over time there is political agenda creep that seeks to sustain funding of activities that keep certain constituencies happy. The agenda creep is also caused by the need of politicians to be re-elected, and lying to voters is considered normal if it helps electability.

Part of what is going on is that world population is increasing, by about 30% from 2010 to 2040. Another part is that countries like China and India are going to use a lot more non-biomass energy per person in the residential sector than they do now. But the efforts to reduce energy use in the residential sectors in the United States and Europe have been failing in one critical aspect: they have mostly minimized consideration of the sector as an existing set of buildings at any point in time and instead have focused most effort on achieving major improvements to future buildings (this is despite any avowed focus on existing buildings).

Why Focus on an Existing Set of Buildings?

Buildings usually last a long time. The average home (including apartments and manufactured housing) in the United States was built in 1971, and is over 40 years old, so half the homes were built before or by the early 1970's. Only about 1% of homes have been built in the last five years. Guess how long it takes to have major impacts on residential sector energy performance if your efforts are future-focused? (Answer: 100–200 years.) Unfortunately, as things age, they break down in different ways, so sectoral improvements become more difficult.

So first consider why a future-focused mindset is problematic:

1. One is always chasing the rainbow, as the number of homes affected is very small, and it takes too long to reach a reasonable portion of the entire sector.
2. Degradation occurs over time. There is a "solar" house in my neighborhood that was built in the early 1980's to demonstrate a future-focused approach to building a high-energy-performance home. By the late 1990's this home was falling apart and ready to be condemned. Recently it is being rebuilt to maybe last more than 20 years. Degradation also impacts energy equipment and other parts of homes that can lead to degraded energy performance. Unless the focus is maintained on a buildings sector as an existing set of buildings, the goal of improved sectoral energy performance will always suffer from degradation and be a future dream with no present reality.
3. Saving energy in homes is complicated, especially since there are people in them, and people do the darnedest things. A future-based approach inherently ignores the complications of both the "present" energy-savings process and the behavior and system breakdown effects of people.
4. Political agenda creep is almost guaranteed, as promised performance is always in the future and never able to be measured but only projected.

Now consider why focusing on the residential sector as an existing set of buildings is so important. In many ways it is the opposite of a future-based approach:

1. The performance of the sector must be measured in the present, is known as a measured quantity, and can be followed over time.
2. Optimal improvements in performance can be determined, based on factors measured in the present, and measured improvements can be verified and tracked.

3. Degradation of performance is treated by ongoing efforts, as the degradation is already included in measured performance.
4. Increased standardization of the complicated process for achieving lasting energy savings in homes is more readily attainable, as efforts must reach a workable level to achieve measured performance improvements. Resulting stability of workforce and business activities increases the potential benefits of standardization of methods.
5. Political agendas can be held accountable to measured progress instead of “promises” about the future.

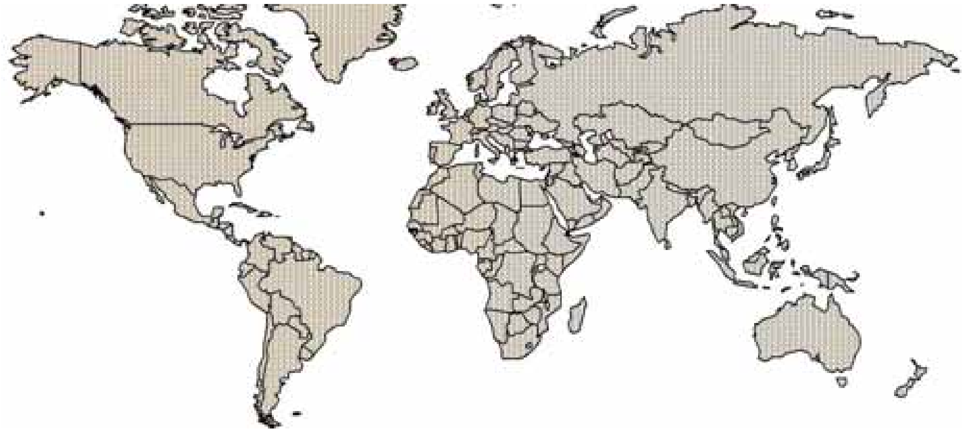
What is Energy Performance?

The “goodness” of energy performance will depend on current needs. The current need for most policy objectives is to reduce air emissions related to energy use, which is aided greatly by reductions in energy use.

Reducing energy use will be treated here as an increase in “goodness” of energy performance.

Related factors, such as indoor environmental quality (IEQ), are not part of the discussion here. Although basic IEQ is important to handle as part of energy performance improvements, excessive IEQ demands are often a debilitating diversion.

SECTION 1 — The Basics



Worldwide Sectoral Energy Use

If we want to measure sectoral energy performance, a method of measurement must be established. First a reasonable estimate of energy use must be obtained. The U.S. Department of Energy (DOE) measures energy use in many different ways, including extensive detail on energy use in the United States, and also some detail internationally. Measured energy use is the main quantity needed to develop methods of evaluating energy performance. Worldwide energy use is also determined by the International Energy Agency (IEA) (iea.org), but the IEA data can be harder to access.

The DOE energy data arm is the U.S. Energy Information Administration (EIA) (eia.gov), which publishes worldwide sectoral energy use data in the *International Energy Outlook* [1] biennially (and limited data every other year). Total world energy consumption by end-use sector, with 30-year projections usually, are now published for delivered energy in units of quadrillion Btu/yr. A quadrillion (10^{15}) is a million billions or a thousand trillions. A British thermal unit (Btu) is the amount of heat energy needed to raise a pound of water (about a half-

[1] EIA 2013. *International Energy Outlook 2013*, US Energy Information Administration, US Department of Energy, Washington, DC, DOE/EIA-0484(13). http://www.eia.gov/forecasts/archive/ieo13/

quart or half-liter) one degree Fahrenheit. In the international SI system of units, energy could be in calories or Joules. One Btu is the same amount of energy as 1,055 Joules, but this book will use SI units less, since the quantities can be too large to comprehend easily and often the units do not provide the important knowledge — the concepts do.

Although the quantities are large, a comparison can lend some sense of scale. For example, a quadrillion Btu (quad) can be obtained from about 180 million barrels of oil (about 10 billion gallons). If the United States imports about 9 million barrels per day, then 180 million would be the same as the amount of oil imported over a 20-day period. (Tons of oil equivalent will be mentioned later.)

EIA World Sectoral Energy Use, 2010–2040

Table 1. Total world "delivered" energy consumption by end-use sector, 2010-2040 (quad/yr)

	EIA Energy Use Estimates		Average annual percent change
Sector	**2010**	**2040**	**2010-2040**
Residential Sector	52.0	81.8	1.5
Commercial Sector	28.9	49.0	1.8
Industrial Sector	200	307	1.4
Transportation Sector	101	140	1.1
Total World (all sectors)	382	577	1.5

From Table F1 of the *International Energy Outlook 2013*

The total world "delivered" energy shown in Table 1 does not include losses resulting from generation and transmission of electricity, but the nature of the energy use growth can still be understood clearly based on delivered energy. Residential sector delivered energy use is estimated to be 14% of the world total in the year 2010 and in the year 2040. Residential sector energy use is projected to grow by 1.5% per year from 2010 to 2040, the same as average total world energy growth.

Current forecasts call for world delivered energy use to grow from 382 quad/yr in 2010 to 577 quad/yr in 2040, a 50% increase over 30 years. Residential sector energy use also grows by 50% over this time.

The growth rates in the buildings sectors, residential and commercial, are the highest. Impacts from energy emissions will generally grow in tandem with this growth in energy use. Most of the projected increase, about half, is to come from the industrial sector, since this sector starts out higher and stays higher, even with a lower growth rate.

EIA Regional Breakouts

The EIA provides further detail on energy use by major region of the world. Some detail on the regions is provided in Table 2 below. The Organisation for Economic Co-operation and Development (OECD) (oecd.org) has a mission to promote policies that will improve the economic and social well-being of people around the world. OECD Europe is not the same as the Eurozone and has 25 countries as of 2013 (see for example, http://stats.oecd.org/glossary/detail.asp?ID=1884). The EIA includes Israel in OECD Europe for statistical reasons.

Major world regions are shown in bold, with sub-regions of the major regions underneath but not bold. The two major analytical categories are OECD and non-OECD countries, and those categories are shown in bold at the top of each column.

Table 2. EIA Region/Country Breakouts

OECD	**Non-OECD**
OECD Americas	**Non-OECD Europe and Eurasia**
United States	Russia
Canada	Other
Mexico/Chile	**Non-OECD Asia**
OECD Europe	China
OECD Asia	India
Japan	Other
South Korea	**Middle East**
Australia / New Zealand	**Africa**
	Central and South America
	Brazil
	Other

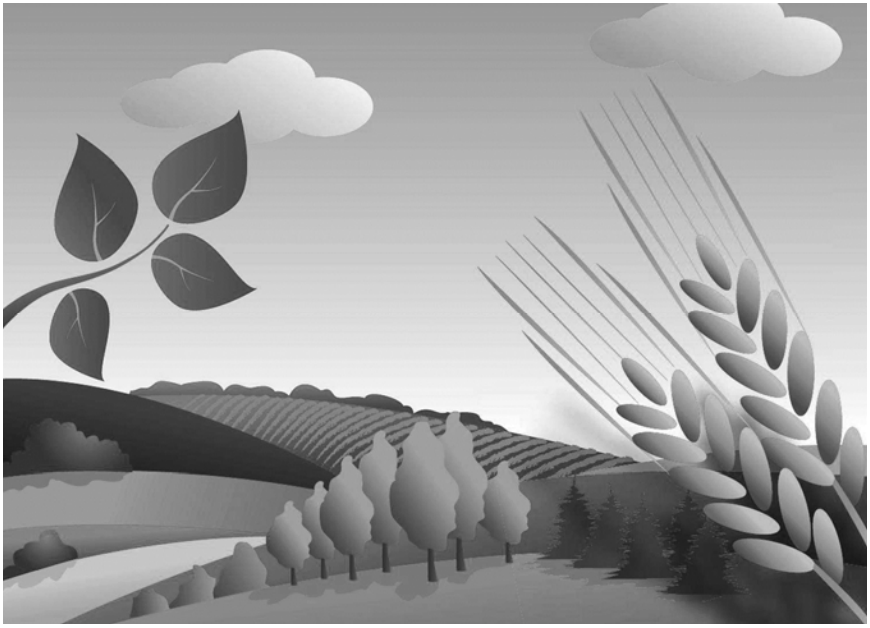
Residential Sector Regional Energy Use Estimates

The estimated residential sector energy use by EIA world region as listed in Table 2 is shown next in Table 3.

Table 3. Residential sector delivered energy consumption by region (quad/yr)

World Region	EIA Energy Use Estimates		Average annual percent change
	2010	2040	2010-2040
OECD	**28.2**	**32.0**	**0.4**
OECD Americas	13.2	14.2	0.3
United States	11.4	11.6	0.1
Canada	1.1	1.5	0.8
Mexico/Chile	0.6	1.2	2.4
OECD Europe	11.7	13.9	0.6
OECD Asia	3.3	3.9	0.5
Japan	2.1	2.2	0.1
South Korea	0.8	1.1	1.2
Australia / New Zealand	0.4	0.6	1.1
Non-OECD	**23.9**	**49.8**	**2.5**
Non-OECD Europe and Eurasia	6.3	8.6	1.0
Russia	3.9	5.0	0.8
Other	2.4	3.6	1.3
Non-OECD Asia	10.6	29.6	3.5
China	6.9	20.0	3.6
India	1.7	5.0	3.7
Other	2.1	4.6	2.7
Middle East	3.4	4.8	1.2
Africa	1.6	3.2	2.4
Central and South America	2.0	3.7	2.1
Brazil	0.7	1.4	2.2
Other	1.2	2.3	2.0
Total World	**52.0**	**81.8**	**1.5**

From Appendix F of the *International Energy Outlook 2013*



Biomass

Biomass matters — a lot. The data shown in Tables 1 and 3 from the EIA presented in the previous chapter do not include most biomass energy. From the *IEO 2013* report:

> The *IEO 2013* projections for renewable energy sources include only marketed renewables. Nonmarketed (noncommercial) biomass from plant and animal resources — while an important source of energy, particularly in the developing non-OECD economies — is not included in the projection, because comprehensive data on its use are not available. For the same reason, off-grid distributed renewables — renewable energy consumed at the site of production, such as off-grid photovoltaic (PV) panels—are not included in the projection.

The International Energy Agency (IEA) has estimated biomass use worldwide, and some of the IEA data and information will be presented for reference.

One reason the data in Tables 1 and 3 are important is that policies for countries that use a lot of biomass might best be formulated by treating biomass differently than non-biomass energy. Also, multiple entities worldwide are working to reduce use of biomass in the residential sector, since it causes health problems from enclosed-space (indoor) pollution and it can cause deforestation or denuding of landscape.

The ongoing efforts to reduce use of biomass are mainly toward substituting fossil fuels or electricity (often fossil-fuel-derived), and these energy sources *are* included in Tables 1 and 3. A nontrivial part of what is expected to be happening in the residential sector over the next 30 years, as shown in Table 3, is a switch from biomass that is not included in the table to fuels that are included.

Biomass is "renewable" since it can be replenished in a time frame less than 100 years, although excessive harvesting can make the renewal challenging. In addition, biomass is usually considered "carbon neutral" in the sense that it is not adding carbon to the earth's biosphere when burned, but instead is part of an overall carbon cycle that is repeated over long time spans. Despite these "renewable" factors, biomass is often a topic of controversy, due to the factors mentioned above and some others.

Inclusion of biomass energy in the energy totals for the residential sector leads to a large increase in total energy use, from 52 quads/yr in the year 2010, to about 85 quads/yr, an increase of over 60%. The IEA has estimated the split in biomass energy use between OECD and non-OECD countries, with about 95% of this biomass use in non-OECD countries. Readers can consult Figure 3.1 in Section 3 of IEA's 2014 *Energy Efficiency Indicators: Essentials for Policy Making* (www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicators_EssentialsforPolicyMaking.pdf).

As these increases indicate, the potential for misunderstanding energy use in non-OECD countries by not including biomass is much greater than for OECD countries. However, the EIA growth rate in residential sector energy use in some OECD regions, including OECD Europe, is also partially due to substitution of other fuels for biomass.

The IEA has also estimated the number of people relying on biomass as their primary fuel for cooking. Table 15.1 from Chapter 15 of the IEA *World Energy Outlook 2006* is shown next to display those estimates.

Table 15.1: **People Relying on Biomass Resources as their Primary Fuel for Cooking, 2004**

	Total population		Rural		Urban	
	%	million	%	million	%	million
Sub-Saharan Africa	76	575	93	413	58	162
North Africa	3	4	6	4	0.2	0.2
India	69	740	87	663	25	77
China	37	480	55	428	10	52
Indonesia	72	156	95	110	45	46
Rest of Asia	65	489	93	455	35	92
Brazil	13	23	53	16	5	8
Rest of Latin America	23	60	62	59	9	25
Total	**52**	**2 528**	**83**	**2 147**	**23**	**461**

Sources: IEA analysis based on the latest available national census and survey data, including the 2001 Population and Household Census of Botswana; the 2003 Demographic and Health Survey of Nigeria; the National Bureau of Statistics of Tanzania, 2000/01; the 2001 Census of India; Energy Statistics for Indonesia, 2006; the Bangladesh Bureau of Statistics, 2005; the National Statistical Office Thailand, 2000; ORC Macro (2006); WHO (2006).

See https://www.iea.org/publications/freepublications/publication/cooking.pdf

For purposes of this book, while biomass is an important fuel in the worldwide residential sector, objectives for reduction in biomass use are in opposition to objectives for reduction of other fuels, so for the remainder of the book, reduction of biomass use will not be considered as part of “shaping” residential sector energy performance. However, measurement of energy performance for the United States, Europe, and OECD countries overall will typically include biomass (and other renewable) energy use in totals, since at this time the overall understanding of residential energy use is not affected too much by this approach.

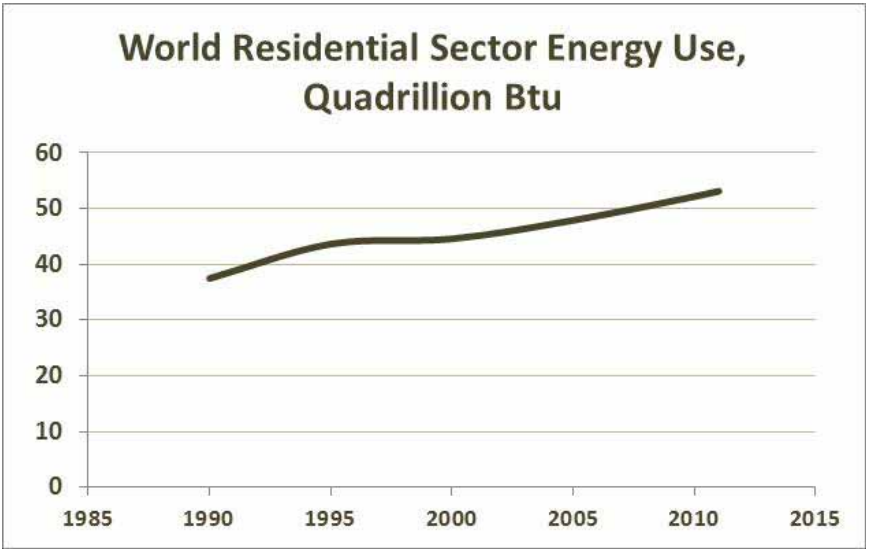


Figure 1. Worldwide residential sector *delivered* energy use

Evaluating Worldwide Performance

So if the objective is to reduce the (nonrenewable) energy use of the world, a quick look at recent history and the future projections in Table 3 is needed. What does the recent historical trend indicate (Figure 1), and what is important to understand in Table 3?

First, recent history (Figure 1) indicates that worldwide residential sector (low-biomass) energy use has increased about 40% over the two decades from 1990 to 2010, which is about 19% per decade. Table 3 indicates growth in this sectoral energy use of 57% from 2010 to 2040, which is 16% per decade, so some slowing in the growth rate is projected.

Now considering the projected growth through 2040, residential sector energy use in the year 2010, summed for the United States, OECD Europe, and China, is almost 58% of the total. In the year 2040, the sum total is almost as high percentage wise, at 56%. This information tells us that these three are highly important for reducing energy use in the residential sector, including for the next 30 years.

The rates of growth must also be considered in tandem with the magnitude of regional increases. While growth rates in energy use are important, if a decrease or lesser increase in worldwide sectoral energy growth is desired, the magnitude of the existing use and expected increases can be more important. If you had a choice between someone giving you a financial instrument worth $10,000, with a guaranteed interest rate of 10% for 30 years, or a financial instrument worth $1 Million and a guaranteed rate of interest of 2.5% for 30 years, what would you do? Even though the $10,000 instrument increases in value over 17 times, it is always worth much less than the $1 Million item. Magnitude often matters more than annual growth rates for time periods measured in decades.

There are no existing entities that are heavily evaluating worldwide residential sector energy performance, although there are a lot of people upset about global warming, which is impacted to a degree by worldwide residential sector energy performance. Most existing efforts are focused on sustainability and zero-energy residences, which are by nature heavily exclusively future-focused. Fortunately, there are extensive efforts to understand buildings sector energy use at country levels, and these efforts contribute to understanding country-level performance. Next a look at an indicator of residential sector energy performance will be presented.

International organizations like the OECD and the International Monetary Fund (IMF) examine worldwide and country-level *economic* performance first with simple indicators, and then with more complex models to dive more deeply into understanding economic performance. The simple indicators include rates of growth for specific national accounts — most often gross domestic product (GDP) or a variation, and simple normalized quantities like GDP per person (per capita). Normalization can be done many ways, including adjusting to some common base, like quantities per person.

Simple indicators are important because they are simple and easy to understand. Energy performance should also be understood using simple indicators before looking at more complex performance measurement.

Energy use per capita is an important normalized quantity that provides additional insight into residential sector energy performance, and at the worldwide level this normalization is probably the most important. Figure 2 shows this normalized indicator for the world for both recent history and projected to the year 2040 based on EIA data.

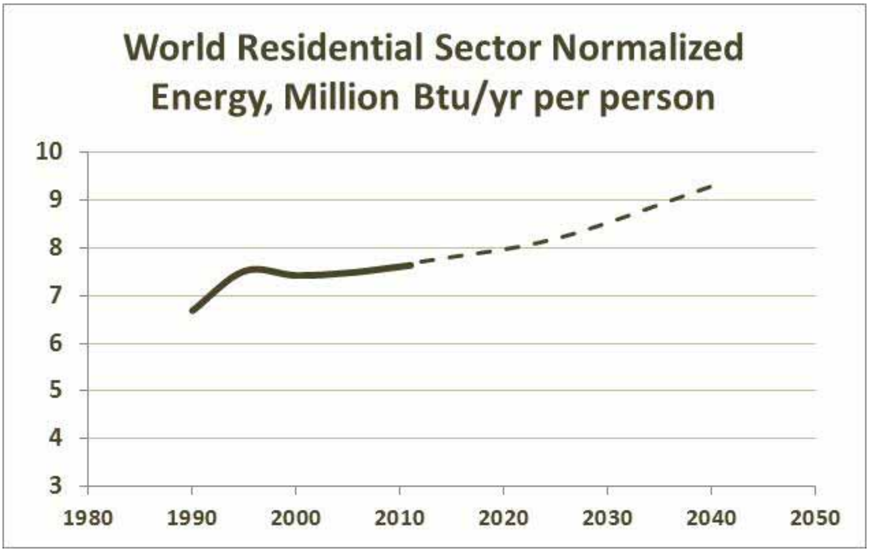


Figure 2. Per-capita worldwide normalized residential energy use

While the growth rate of total energy use in the residential sector is projected to slow a little from historical rates, the energy use per person is projected to start increasing. There are likely many causes for this, including an increasing switch from biomass to nonrenewable fuels in Asia and Africa. In addition, while the growth in total energy use is expected to slow, the rate of growth of population is expected to also reduce, at a faster rate than reduction in total energy use in this sector.

Table 4 below shows the per-capita residential sector energy use for major world regions (less detail than Table 3). Million Btu can be multiplied by 1.055 to convert to Billion Joule (GJ) or convert from Million Btu/person to GJ per person (total world energy use per person in the year 2040 heads toward 9.3 Million Btu per person or 9.8 GJ/person).

Table 4. Per-capita residential sector delivered energy consumption by region (Million Btu/person)

World Region	EIA Energy Use Estimates 2010	EIA Energy Use Estimates 2040	Average annual percent change 2010-2040
OECD	22.8	22.7	0
OECD Americas	27.7	23.3	-0.6
OECD Europe	21.0	23.1	0.3
OECD Asia	16.3	19.5	0.6
Non-OECD	4.2	6.8	1.6
Non-OECD Europe and Eurasia	18.7	25.7	1.1
Non-OECD Asia	2.9	6.7	2.8
Middle East	16.1	14.8	-0.3
Africa	1.6	1.8	0.5
Central and South America	4.3	6.5	1.3
Total World	7.6	9.3	0.7

From Table 16 of the *International Energy Outlook 2013*

The estimates are that only the OECD Americas and the Middle East regions will have reduced residential sector energy use per person over the next 30 years. OECD Europe and all other regions will go up, although Europe only reaches a par with the Americas by 2040.

With per-capita residential sector energy use as one of the primary indicators of improved energy performance, we might conclude that most of the world will not be improving performance. On the other hand, major disparities in the magnitude for different regions argue for differing measures of what "improvement" means by region. Also, since there are two major regions expected to have a performance improvement, there should be lessons to learn from why and how that is accomplished, if the trends hold.

Understanding this simple indicator is critical to being able to evaluate what politicians or bureaucrats say or what scientists promote about the residential sector. If the political or scientific promises are future-focused, there is almost certainty that there will be no change, or almost no change, from projected trends, absent major upheavals.

A common factor used to normalize buildings sectoral energy use is floor area, but the levels of uncertainty in measuring and defining the floor area values to be used[2] are large compared to uncertainties in population. Unfortunately, most normalizations of sectoral energy published to date are based on floor area, and these normalizations retain the large uncertainties associated with definition and measurement of floor area quantities. The greater concern, though, is the problem of allowing larger homes to have lower normalized energy (increasing the floor area of a home decreases the normalized energy use quantity of energy use per unit of floor area), when the opposite is actually the policy goal. Conversely, small homes are penalized.

Floor area will NOT be used here. In the next section of this book on performance indicators, the concept of performance measurement domains will be introduced (Fig. 4). Use of floor area as a normalization factor when attempting to compare sectoral energy performance across domains is almost certainly extremely difficult, if not impossible, due to difficulty in harmonizing floor area definitions. Why limit the usefulness of data by using highly uncertain quantities?

Before looking at more detailed data on the United States, as an example of what can be understood with more detailed information, a brief discussion of energy performance indicators for buildings sectors will be presented. With more detailed data, more complicated normalizations or models of performance can be constructed. These more complicated methods can provide better insight for more homogenous populations, such as the United States, while at the level of the entire world, the simple per-capita indicator is expected to be most reliable.

[2] In detached dwellings, the complications over whether to use heated floor area, gross floor area, cooled floor area, conditioned floor area, or other value are problem enough, but confusion over what to do with basements, attached garages, partially finished attics, partially conditioned sunrooms or porches, etc., becomes fairly convoluted. In multifamily buildings or apartment blocks the complexity and potential confusion over what value to use increases even more.

Key Lessons

1. Residential sector energy performance must always be understood first on the basis of total sectoral energy use and energy use per capita (two key indicators)
2. Any plans to improve residential sector energy performance must present the planned changes to total sectoral energy use and energy use per person to be credible
3. Changes to these two key indicators become the basis for reporting improvements or shortfalls in expected performance
4. Planned improvements should initially have measured results within five years, and continuous thereafter, to assure a focus is maintained on measured performance

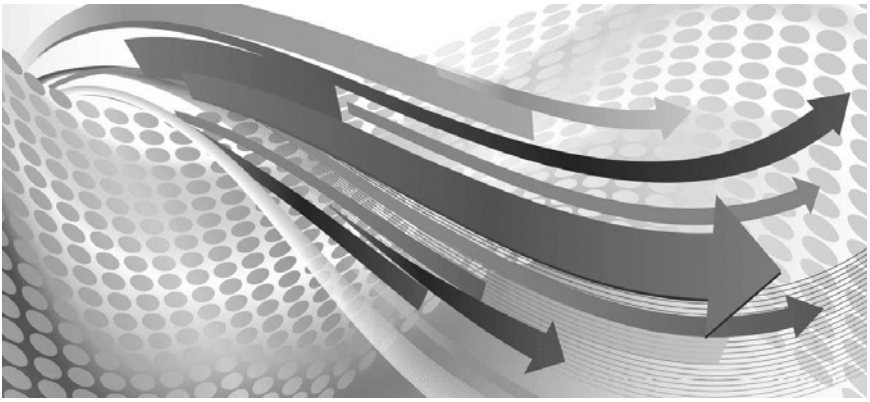
Complications

1. Biomass energy may or may not be added to energy use totals, and the impact can be large, so knowing whether biomass energy is included or not is critical to understanding the key indicators
2. Primary energy use includes energy losses from delivery of energy to residences, especially electricity, and the presentation here does not use primary energy, but instead uses delivered energy. The key indicators can be based on either delivered energy or primary energy, but it is necessary to know which is used for any indicator

Notes on Primary Energy

1. Worldwide residential sector primary energy use is calculated here to be 97 quad/yr in 2010 and 167 quad/yr in 2040 (based on EIA data)
2. Per-capita worldwide primary energy use is then 13.4 Million Btu/yr per person in 2010 and 18.0 Million Btu/yr per person in 2040

SECTION 2 — Performance Indicators



General Considerations

The ability to compare the residential sector energy performance of one state or one country with that of another is important for determination of national and international energy efficiency status and progress. This ability to compare allows more meaningful evaluation of different classes of building sectors and the situation of differing states or countries.

Rating the energy performance of a buildings sector differs from rating an individual building. Sectoral energy performance, as covered in this book, is focused on the entire aggregate group of specific types of buildings present in some type of geographic sector.

A geographic sector could be a neighborhood, a city, a state, a country, a region, or the world.

Methods for rating the energy performance of individual buildings cover a wide range. Extensive detail and examples can be found on this topic in *Building Energy Rating Schemes*, a 2014 report from the International Partnership for Energy Efficiency Cooperation (IPEEC):

http://ipeec.org/publications/download/id/1015.html

Our ability to understand energy use in the residential sector has been crippled by the carbon fixation of too many people worldwide working in the area of energy efficiency. Once energy use is converted to some type of carbon quantity, direct comparison with energy use is obscured, sometimes badly. Comparison of carbon values to energy values should be strongly avoided, since the nature of the carbon translation might distort the comparison. This is especially true for non-experts.

Presentation of ***energy*** *performance information in terms of carbon-based quantities only, without also presenting the energy data that the carbon quantities are derived from, should be considered deliberately obscuring the truth.*

Similarly, the inclusion of biomass energy or not in residential sector data or reporting is important to know, since biomass use can be a major issue in some countries or regions.

As renewable energy use grows, increasing its percentage of the total, sectoral energy performance will require increasing complexity to best understand. Probably the renewable and nonrenewable energy indicators should be treated separately, with the two key indicators defined in this book reported for both renewable and nonrenewable energy. Regrettably, there will be arguments over what is or is not renewable, but hopefully the definitions can be worked out so that measurement of performance can move forward.

Use of primary energy, where losses in generation and delivery of energy to residences is included, also introduces complexities. The data presented thus far are NOT for primary energy but are for delivered energy. Unfortunately, as more detailed performance indicators or models are introduced, use of primary energy becomes necessary due to statistical issues.

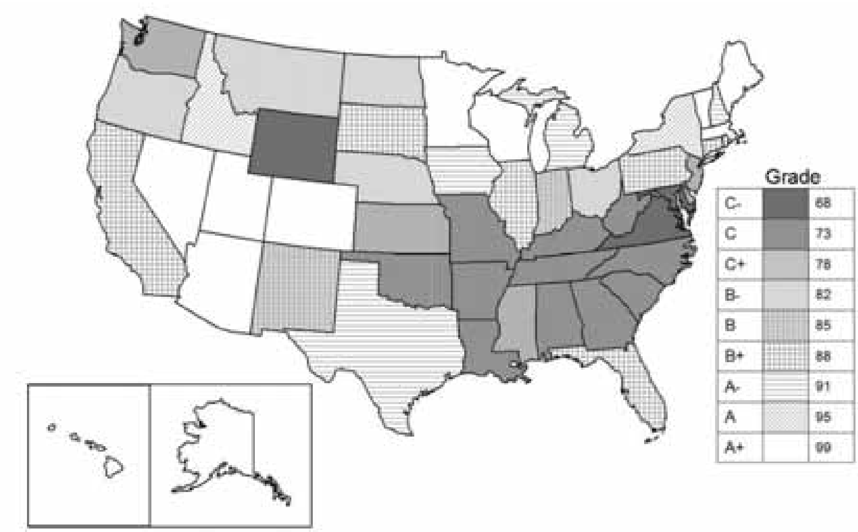


Figure 3 . Performance grades based on population and weather, 2009

Beyond the Basics

Although the basic indicators must be known to evaluate sectoral performance, there will be a need to develop additional normalization capabilities in some cases to allow additional factors to be determined for use in setting policy. Figure 3 is a map of building sector energy performance based on normalization of energy use for both population and weather factors. For this map, the buildings sector is the residential and commercial sectors combined. The normalization of energy performance is converted to a letter grade in addition to a number grade, with higher numbers indicating higher energy performance. Details on this performance grading are at:

http://epminst.us/states/st09ecgrade.htm

This example of a more complex normalization will be used to present and discuss the additional complications and factors that enter, as well as the reasons for using more complex performance measurement methods. The need for sectoral measurement will be presented first, followed by discussion of more complex methods and how policy issues affect decisions about what types of normalization to perform.

The Need to Measure Sectoral Performance

Energy performance rating systems for individual buildings have been in use since the 1990's. Ratings like miles per gallon for cars or typical energy costs for appliances had been developed earlier, but a need was seen for methods to rate the energy performance of buildings (readers can consult the IPEEC report mentioned earlier in this chapter on reasons for the methods). Buildings are more complex than cars or appliances, so the rating methods are also often more complex.

Standards for the design of new buildings and their energy systems have also been developed, starting in the 1970's, with the standards growing ever more complex, until today they are often hundreds of pages long and require extensive study to understand.

In recent years, there has been growing recognition that the entire buildings sector must see improvement in energy performance if any real progress is to be made. As a result, energy performance rating has begun to be legally required for many existing buildings, although only a small portion of the US residential sector is affected. In addition, bureaucrats and regulators are working in some locations to force increased use of the complex energy standards originally developed for design of new buildings onto existing buildings.

Sadly, as indicated at the beginning of this book, the standards approach is future-focused and unlikely to have lasting impact, while the use of energy performance ratings for a lot of individual buildings to achieve changes in performance of an entire sector is untested, uncertain, and does not measure performance of the sector directly.

The European Union promulgated energy performance directives for energy performance of buildings beginning in 2002, and learned much about how difficult such directives are to implement if the technical, financial, and workforce infrastructures are not quite in place to handle such directives. Making improvements to the directives about ten years later, there was still a sense that more was needed, given the perceived concerns about impending carbon-induced doom.

Learning from the buildings-focused and other energy directives efforts, the European Union has now required improvements in entire sectors of member states. The new approach provides flexibility as to how the differing energy end-use sectors will be addressed by member states in order to reach their energy performance goals.

The success of the EU approach is still to be determined, but the lessons to be learned here are that:

1. The only reasonable way to know if energy performance is improving for a country or a state is to actually measure the performance of entire energy end-use sectors
2. If performance improvement goals are set and tracked for entire sectors, policy implementation becomes easier to understand, since a sector must be tracked simply

At this time, most of the world is still focusing on complex standards and individual buildings, so the lessons here are still awaiting wider recognition.

For the United States, the EIA and other agencies provide a lot of data that can be used to develop more complex performance measurement methods and to track basic performance indicators for both the residential and commercial buildings sectors. Some of the issues related to more complex methods are covered next.

The issues are intertwined with policy considerations, so part of the complexity is related to policy decisions. The discussion of factors affecting complexity of performance measurement methods is followed by a discussion of some policy considerations.

Adding Complexity

Energy performance can be measured many ways. The simple indicators recommended in this book are the foundation for understanding sectoral energy performance, but the simple indicators provide only limited normalizing of the energy performance situation. Increasing the complexity of the normalization can offer improved ability to set policies.

Weather is one major factor that affects energy performance, and many people wish to take weather influences out as much as possible when evaluating energy performance of buildings. Cost of energy is another major factor affecting energy use and resulting energy performance.

The simple indicators consist of one sectoral sum of all energy used in the sector and a simple ratio of all energy used divided by the number of people using the energy. As long as the indicators are simple, the math methods are simple. Introducing additional factors, i.e., having multiple effects of different factors considered at the same time, makes the math methods more complex and multidimensional.

The purpose of normalization is to put the measured performance on a common basis. For the residential sector, one of the key simple indicators is total energy use divided by the number of people. In this way, the normalization brings the energy used to the basis of how much per person.

Weather affects heating and cooling energy use, but the energy used for heating is different than the energy used for cooling, and both of these are subsets of the energy used per person. To analyze multiple factors together requires a multidimensional approach that determines the average for a sector of the contributions of each factor.

For the multidimensional energy performance grading shown in Figure 3, the three key factors used in determining the grades were number of people, heating degree-days, and cooling degree-days.

The analysis method used is called multiple-parameter linear regression, a statistical method. There are other methods that could be used, but experience has shown that multiple linear regression best meets the need, especially for populations of buildings.[3] The Energy Star® performance rating system (PortfolioManager performance scoring under energystar.gov) is based on multiple linear regression results for several discrete specific populations of buildings.

Degree-days are a means of summing up outdoor temperature effects on heating and cooling over time. The degree-days used for the analysis of Figure 3 are obtained from the National Climatic Data Center, and are the population-weighted degree-days in 2009 for each state, both heating and cooling, with a base temperature of 65 F (readers can consult http://degreedays.net, "Degree days for beginners," for information on degree-days). Additional complexity occurs in that the degree-day effects must also be per person, so the actual analysis factors used were:

1. Population of each state (# of people)
2. Population-weighted heating degree-days of each state times the number of people in the state
3. Population-weighted cooling degree-days of each state times the number of people in the state

Simplistically, the regression analysis returns the average energy use of 50 states calculated for each factor. The effects of each "average" factor can be calculated for each state, based on the average for all the states, by multiplying the average effect for each factor times the value of the analysis factor for that state.

Summing these multiplied values leads to an estimate of what the "average" energy use of that state's building sector is expected to be based on the sectoral (50-state) average. The sectoral-average expected energy use for the state, divided by the actual state building sector energy use, becomes the state sectoral energy performance value (higher is better).

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[3] Readers can consult the report *Investigation of Metered Data Analysis Methods*, 1989, Section 2.1. http://epminst.us/ORNLproducts/CON-279.htm

The "grades" in Figure 3 were based on a grading curve that was again normalized with the range of state energy performance values adjusted to be on a scale of 1–100.

Finally, in order to use regression analysis on sectors that use multiple fuels, primary energy may be required instead of delivered energy. This is a major issue, since primary energy can be more challenging to calculate or determine in some cases. In the United States, there are statistically significant differences between populations of buildings that are all-electric and those that are not IF delivered energy is used for the calculations. If primary energy is used, the statistical difference is not significant. For performance measurement based on statistical methods, unacceptable biases can be introduced if there are statistically different groups pooled together in the analysis. Other means could be tried to overcome the difficulties of using delivered energy to develop more complex sectoral energy performance measurements, but the use of primary energy is simpler at this time.

Policy Considerations

Differing policy perspectives can strongly influence consideration of what parameters should be considered acceptable to include as part of determining "average" performance. The results of the regression model will adjust estimates of average effects of different parameters for a population based on the parameters included in the model. Each parameter included can have effects on other parameters, e.g., the price of energy can influence how much energy is used in a home for heating and cooling. The important point here is that decisions about what parameters to include are not only technical, but can be political, practical, or even judgmental.

Political, practical, and judgmental decisions are policy decisions. If the results of performance measurement are to be used to set or direct policy actions, then policy decisions are usually necessary in deciding what parameters to include in a more complex performance measurement.

The decision that energy use per person is one of two key performance indicators that must be known as a starting point is a policy decision of this author, based on decades of experience. Even if other indicators are used, energy use per capita is always needed for comparisons across larger performance domains.

The performance grades in Figure 3 are a strong reflection of the cost of energy for buildings in the states, but a policy decision was made in developing the grades that influence of energy cost was to be kept "outside" any normalization of performance values, so that the influence of energy costs would still be "seen" in the results. Normalization is directed at "removing" the effects of a specific parameter as much as possible, in order to understand performance without the effects of that parameter. Normalizing for weather is directed at taking out the effects of weather as best possible.

Care is needed to be aware of the policy decisions that are behind any energy performance calculations. Specific decisions are not necessarily "good" or "bad," although each person may have differing views on what should be considered good or bad policy. Performance results should be evaluated with strong consideration of what the "policy" decisions are regarding the methods used to measure performance. Simplicity is an important policy consideration.

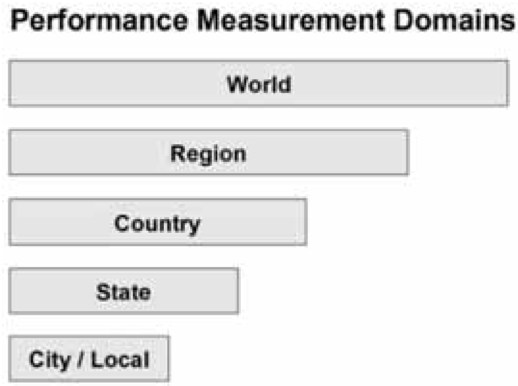

Figure 4. Sectoral Domains that can be important to compare

The Range of Indicators

Consider the wide range of sizes of performance measurement domains (geographic entities) shown in Figure 4, ranging from local geographic spaces up to the whole world. Going from the bottom to the top, each new level leads to larger space encompassed. Each additional level also raises the complexity of data gathering in order to measure a quantity like energy performance of an energy end-use sector at that domain level. At higher levels, there is less ability to handle detail since the data collection effort requires more resources to conduct.

The two key residential sector energy performance indicators specified in this book, total energy use of the sector/domain and energy use per capita, can be measured today with reasonable accuracy for each domain shown. Thus, performance in each domain can be compared to performance in any other domain using these two indicators. This ability to compare performance across domains is critical to being able to direct efforts to shape sectoral performance on a regional or world scale.

Regardless of what policies, directives, or programs exist in any country or state, as long as the two key basic indicators are reported, both residential sectoral energy performance and changes in performance over time can be understood reasonably well.

For an individual country or state, more complex indicators can be developed, as presented in the previous chapter. Adjusting for weather or other factor effects on energy use may make possible more careful crafting of directives or refined incentives to improve.

As indicated in the previous chapter, complex performance indicators could include a wide range of factors, and these normalization factors are those that are to have their effects minimized through normalization so that decisions on policies or directives are not based on influence of those factors.

Additional normalizations could be considered for a wide range of factors in addition to weather and population, including cost of energy, building types, construction features, location, carbon loading, and others.[4] Increasing the number of normalization factors does not necessarily make the measurement of performance better, but policy objectives may be served better in some cases with additional factors.

More complex performance indicator development should not be pursued before the basic indicators are measured and known. Once the basic indicators are known, residential sector energy performance can begin to be tracked over time, performance goals can be set, and progress toward goals can be measured.

If performance goals have been set and progress is being tracked, development of more complex indicators of energy performance can be pursued, but such development should only be pursued if there is a clear need to support improved policies or directives.

Goals for performance improvement should be set to start at five years or less, with continuing goals for the longer term. Having only longer-term goals should be recognized as unlikely to remain viable.

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[4] Examples of factors are found in *Benchmarking Residential Energy Use*, http://aceee.org/files/proceedings/2000/data/papers/SS00_Panel1_Paper15.pdf

Key Lessons

1. Reporting energy performance of countries or energy end-use sectors in terms of carbon quantities, without also providing the energy data basis for the carbon quantities, obscures truth
2. The ability to empirically measure and compare residential sector energy performance of countries and regions worldwide is critical to being able to direct or inform worldwide or regional energy policy
3. Once the two basic sectoral performance indicators are known, additional indicators that tend to be more complex can be developed to increase the ability to set policies based on additional factors
4. Care is needed to assure the energy data used for sectoral performance measurement is consistent from one geographic entity to another, in order to assure comparability
5. For more complex performance measurement methods, the use of primary energy may be necessary to make the calculations more workable
6. Complex method performance results should always be considered concurrently with the key performance indicators

Complications

1. The means of handling biomass energy in the energy data totals must be understood
2. With increasing use, the inclusion or treatment of renewable energy sources will raise more issues and complications in energy end-use sector performance measurements
3. It remains necessary to know whether primary or delivered energy is used for any indicator
4. Comparison of performance among indicators must be done with caution, especially if more complex methods are used
5. Policy issues and considerations can and often should drive decisions about how to measure sectoral energy performance

SECTION 3 — United States Detail

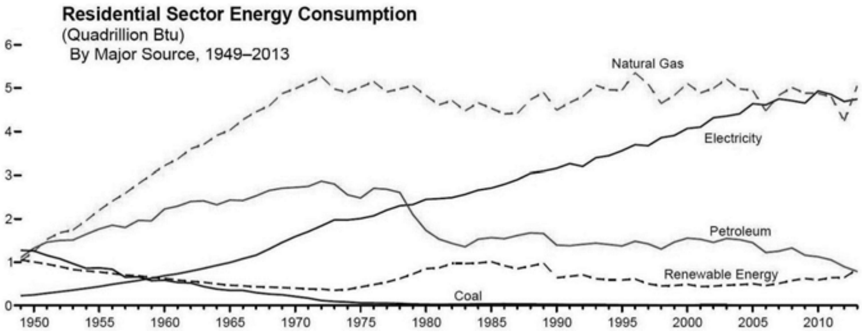


Figure 5. EIA U.S. residential sector fuel use by fuel, 1949 to 2013

EIA Data

As can be seen from Figure 5, the U.S. Energy Information Administration (EIA) is a storehouse for a lot of energy data. The EIA develops and stores a wide range of data on energy topics such as production, stocks, usage, imports, exports, and prices.

Of interest for analyzing residential sector energy performance are two main important data sources:

1. State Energy Data System (SEDS), with historical energy use breakouts for end-use sectors for each state
2. The Residential Energy Consumption Survey (RECS)

SEDS is the main data set of interest for this book because it is aimed at determining sectoral energy use by state. This is important if the concern is to account for all energy use and have all energy use assigned to an end-use sector: industrial, transportation, residential, and commercial typically.

RECS data are focused on obtaining more detailed data on the residential sector, meaning detailed data are collected on individual homes in a national survey, and then survey weights are developed to "boost up" the survey data to match known national totals using sophisticated statistical methods.

SEDS data are available down to the individual state level, and SEDS data for states sum up to the SEDS national totals. RECS data are available for individual homes with a fair amount of detail, but the survey weights must be used to obtain national or other totals. Limitations in the RECS survey approach include lower ability to account for fuels that are small parts of the national total, such as kerosene and propane products (LPG). Limitations on SEDS include lack of ability to distinguish different types of homes, which RECS treats as five types: single-family detached, single-family attached, 2-4 unit buildings (small multifamily), 5-or-more unit buildings (large multifamily), and manufactured housing (including mobile homes, double-wide pre-assembled, and other similar types).

While the differences must be understood at times, the main point is that the source of energy data must be specified and used consistently in order to have a sectoral energy performance measurement system.

Total SEDS residential sector energy use is larger than RECS energy use due to limitations in the RECS survey approach. SEDS has had in the past, and may still have, some minor issues with double counting of some fossil fuels, but the effect is tiny and not really an issue for understanding sectoral energy performance. Accounting for renewable energy sources is a minor issue also at present, but is expected to increase in importance as an issue in the future. RECS does not account for renewable fuels except for wood (which is biomass and part of the biomass issue).

For reference, a comparison of the 2009 RECS residential sector energy data totals to the 2009 SEDS totals is presented in Table 5. While RECS has some state-level data, Table 5 is only the national comparison. Note that SEDS *does include most biomass energy use* in the United States.

Table 5. 2009 RECS and SEDS U.S. Residential Energy Comparison

Fuel Type	RECS Total as % of SEDS Total
Natural Gas	96%
Fuel Oil	99%
Kerosene	86%
LPG	90%
Petroleum Total	95%
Wood	100%
Geothermal	0%
Solar/PV	0%
Electricity	94%
TOTAL Delivered Energy	94%

Based on the overall total for delivered energy, the national total for the residential sector from RECS is 94% of the SEDS total. RECS does not estimate geothermal, solar thermal, or photovoltaic (PV) energy for the residential sector. Other than these renewable categories, the kerosene use total is the farthest below the SEDS total, and estimation of kerosene use is difficult in a survey with the individual home as the unit of interest.

If the SEDS data are selected as the primary source for energy data to use in performance measurement of the residential sector, no differentiation is possible by type of residence, although the RECS data could be used to calculate a percentage breakout by building type that could be applied to the SEDS data nationally.

If the two key performance indicators are to be determined based on nonrenewable energy (renewable energy not included in the total), then the RECS total is 95% of the SEDS total.

There are tradeoffs in using any data set for performance measurement, but measuring the two key indicators is the most important starting point. With the SEDS data, the two key indicators can be measured down to the state level, and the indicators can treat renewable energy use distinctly if desired.

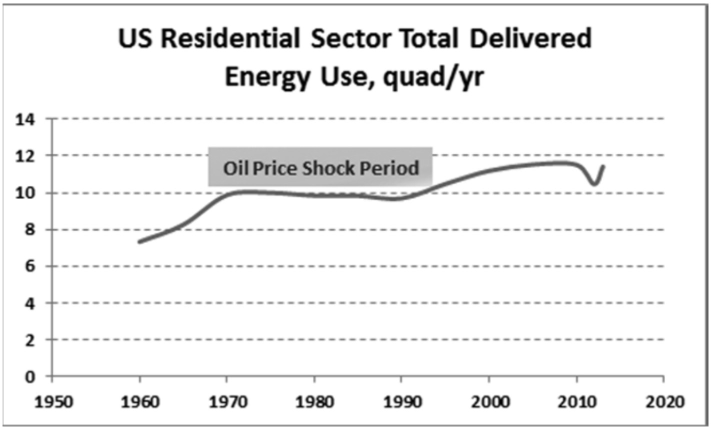


Figure 6. Total US Residential Sector Delivered Energy, 1960-2013

U.S. Country-Level Indicators

Residential sector total delivered energy use in the United States, as shown in Figure 6, has remained remarkably stable since 1970, despite population growth. Energy was inexpensive until the early 1970's and the Oil Embargo. The resulting oil price shock and aftereffects lasted until 1990. The dip in 2012 is the result of switching here from 5-yr to 1-yr intervals in the data, with weather effects showing, but by 2013 the total energy use was back up and about the same as in 2011.

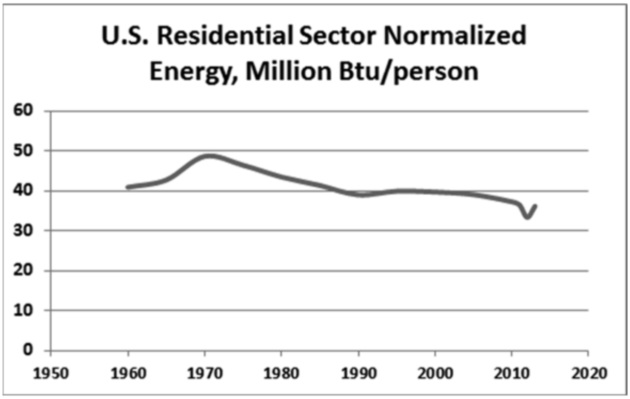


Figure 7. Per-capita US residential sector energy use, 1960-2013

In contrast, per-capita energy use for the residential sector has been on a downward trend, as shown in Figure 7, decreasing from almost 50 Million Btu/person in 1970 to about 35 Million Btu/person currently.

EIA projections in Table 3 show the total residential sector energy use in the year 2040 to be 11.6 quad/yr, only slightly more than the 11.4 quad/yr in 2013 (shown in Figure 6). Using U.S. Census population projections for 2040, the corresponding per-capita residential sector energy use is projected to be 30.6 Million Btu/person in 2040 — a decrease of 15% from 2013, based on a population of about 380 million.

The average rate of change in per-capita energy use from 1970 to 2010 is negative 0.66%/yr, while the projected EIA change from 2010 to 2040 is almost the same, at negative 0.67%/yr.

So 40 years of future-focused energy policy in the residential sector, from 1970 to 2010, has led to a 23% reduction in delivered energy use per person. With population growth, however, total delivered sectoral energy use has grown by 17%, from 9.9 quads in 1970 to 11.5 quads in 2010. Also recall, as shown in Figure 6, that sectoral energy use was almost constant from 1970 to 1990, and almost constant again from 2005 to 2010, so the 17% growth really happened between 1990 and 2005.

Current trends are for sectoral energy use to remain almost constant, while energy use per person continues to decline. Holding U.S. residential sector *delivered* energy use constant from 2005 to 2105 appears possible if the current 40-yr trend of reducing energy use per person in the residential sector at 0.66%/yr continues to occur. The EIA is currently projecting that average annual reduction to hold for the next 30 years. If this trend were to hold until 2105, the projections are for a total U.S. population of about 600 million people, and the energy use per person would then be reduced to 19.25 Million Btu/yr per person, with the resulting total sectoral *delivered* energy use at about 11.5 quad/yr, just as in the year 2005.

From a policy perspective, the trends in total sectoral energy use and normalized energy per person would be evaluated to see if desired outcomes are achieved. The future-focused approach to energy efficiency in the United States has led to being able to maintain residential sector *delivered* energy use reasonably constant for the past 10 years, although economic factors may have played a part. EIA projections indicate that the total sectoral *delivered* energy use is expected to stay constant for the next 30 years. This achievement may be an acceptable policy outcome.

However, if the desired policy outcome is to have total sectoral delivered energy use reduced back to 1990 (9.7 quad/yr) or 2000 (11.2 quad/yr) levels, greater improvements are needed. To reduce sectoral delivered energy use to 2000 levels by the year 2040 would require that normalized energy use per person would have to decrease an average of about 0.8%/yr, from 37.3 Million Btu/yr per person in 2010 to 29.4 in the year 2040. Similarly, to reduce sectoral delivered energy use to 1990 levels would require an average annual reduction of about 1.3%/yr, from 37.3 down to 25.5 Million Btu/yr per person in the year 2040.

Some lessons from the Commonwealth of Massachusetts on complexities related to state-level performance will be presented briefly after the next digression on primary energy.

Primary Energy

Although delivered energy use per person has been declining for decades, *primary* energy use per person has not been declining until recently (Fig. 8).

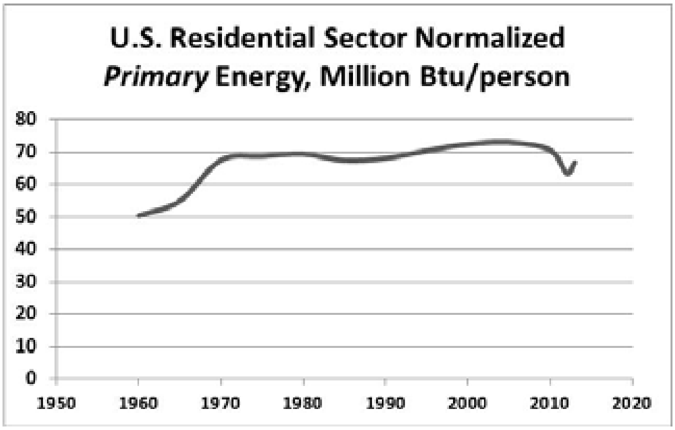


Figure 8. Per-capita primary energy use, 1960-2013

One effect of the oil price shock was that fossil fuel use — oil and natural gas, was reduced in response to the increase in prices, and use of electricity increased, since electric prices did not increase as much. Increased use of electricity increases the primary energy use, since the main difference between primary energy and delivered energy is the inclusion of losses for electricity generation, transmission, and distribution in primary energy values.

If air emissions are a primary concern, primary energy use is more closely related to air emissions than delivered energy. Since U.S. population has been increasing, total primary energy use and air emissions have been increasing until recently (Fig. 9).

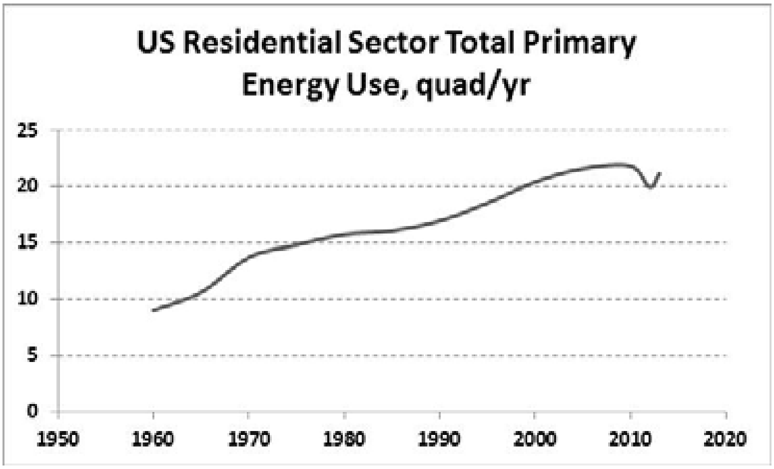


Figure 9. Total US residential sector primary energy use, 1960-2013

EIA projections for residential sector energy use were converted to primary energy. The calculated U.S. residential sector primary energy use increases slightly over the next 30 years, growing at 0.2%/yr on average, from 21.7 quads in the year 2010 to 23.1 quads in 2040.

The larger increase in primary energy results from significant growth in electricity use in the residential sector, at 0.7%/yr on average for the next 30 years. If major reductions in air emissions are needed, significant displacement of fossil-fuel-generated electricity is required.

Lessons from Massachusetts

Massachusetts is chosen as the example to present several issues related to trying to understand sectoral energy performance and the challenges of using comparisons among entities like states to try to set policies for improving sectoral performance. Massachusetts has been ranked #1 in energy efficiency in certain quarters, so it is instructive to see how #1 compares to others using different metrics.

#1

First, a warning:

Once comparisons of energy performance indicators are started, setting performance goals and establishing constructive policies becomes more complicated.

National policies aimed at trying to improve overall residential sector energy performance must be careful of attempting to introduce too many notions of *fairness* into the decisions required. Fairness is a killer of effectiveness in many cases. There is only one national collegiate men's football championship team each year, which could be considered "not fair" for many others. Performance requirements for being an Army Ranger might also be considered unfair, except the performance is a critical need.

On the other hand, policies can be very "fair" by establishing performance goals and requirements separately for each individual entity like a state. If goals are set separately for each state, then the performance metrics for each state can be considered individually.

Let's look at comparison of the key residential sector energy performance indicators for Massachusetts with the country as a whole, with some complications of comparisons presented first:

1. If delivered (site) energy is used for the comparisons, states that use more electricity will look better than states that use less. Why is this? Because electricity

allows higher efficiency equipment to be used, since electricity is a “high-quality” energy form that is achieved by complex generating plants (including thermal, photovoltaic, and hydro), but the overall energy efficiency of providing the electricity to the residential sector is ignored (losses that occur are ignored).

2. If primary energy is used for the comparison, the advantage for electricity goes away.
3. There are major effects due to weather and economic factors that can cause a lot variation in the key indicators from year to year, so care has to be exercised in how the indicators are followed.
4. Weather and economic factors also cause a lot of variation from state to state, which is why policies need to be developed with care.
5. Colder areas tend to use less electricity, so the weather, economic, and electricity influences become bound together.

So how does Massachusetts do in comparison with the country based on the key normalized factor in this book? Possibly only average.

In order to make comparisons, some normalization is needed if there is a wide range in size or other factors. In the year 2010, Texas used 25 times as much energy in the residential sector as North Dakota or Rhode Island, and almost four times as much as Massachusetts. Disparity in size makes normalization important if meaningful comparisons are needed.

Figure 7 shows the US average residential sector delivered energy (site energy) use per person over time. In 1960, the per-capita Massachusetts site energy was about 150% of the national average per person, but following the oil price shock (for this heavy user of oil), by 1990 the ratio was 130% of the US average. From 1990 onward, Massachusetts has had major efforts to reduce energy use in the residential sector. Governor Deval Patrick has been quoted as saying that efficiency is the “first fuel” of the Commonwealth.

So despite “first fuel” status for energy efficiency, the real-world, data-based energy performance ratio has only improved to about 125% of US average on a site energy basis by the year 2010. On a primary energy basis, which is more “fair” relative to states that use a lot of electricity, the ratio has improved from 105% in 1990 to just under 100% by the year 2010 (Fig. 10). Colder weather also means more energy is needed for heating (weather normalization is covered in the chapter on *Performance Scoring*).

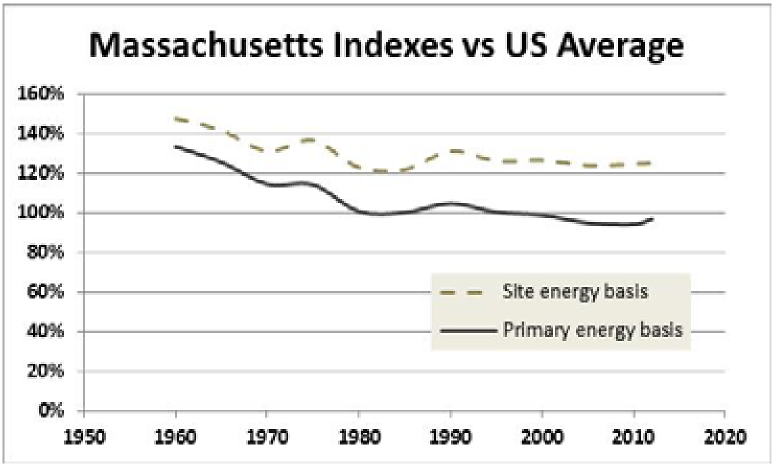


Figure 10. Massachusetts compared to the entire United States

So is it “fair” to say that Massachusetts has gone from “poor” performance to “average” performance? Possibly, but it also has shown a large improvement in performance over time. Unfortunately, the improvement over time appears to be primarily due to the oil price shock, since the primary energy per-capita index has been in the “average” performance range (about equal to the national average, at 100%) from 1980 onward. From an ad hoc subjective performance rating perspective, Massachusetts is #1, but using real energy performance data, residential sector energy performance appears to be average for the last 20 years.

This comparison is not meant to be definitive, only to indicate potential issues with subjective rating of performance. The state-level per-capita index is affected by weather, so more on indexes next.

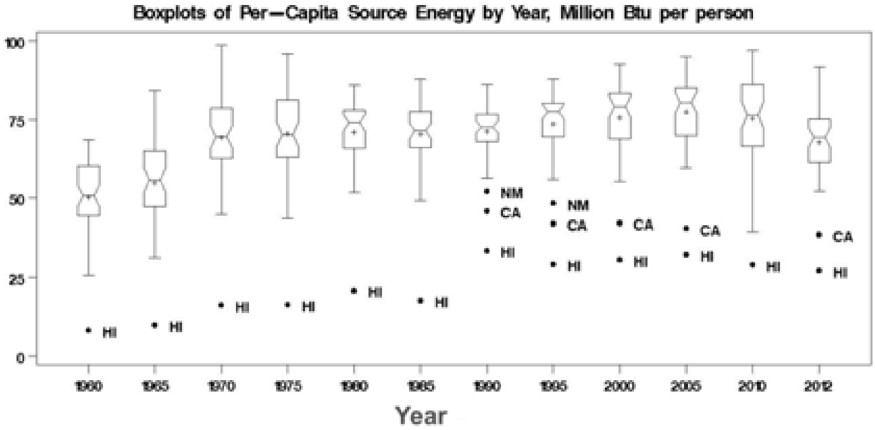


Figure 11. Distributions of per-capita state-level source energy indexes

U.S. State-Level Indicators

At the state level in the United States, Figure 11 shows there is a wide range in primary (source) energy use per person, with the range and magnitude of values increasing from 1960 to 1970, and variable after. There is a similar wide range in per-capita site energy use. The boxplots show the range in the values for 50 states plus the District of Columbia. (Information on boxplots can be found at: https://sites.google.com/site/davidsstatistics/home/notched-box-plots.)

In boxplot parlance, Hawaii is an “extreme outlier” on the low side for most of the years shown, but always an “outlier.” California is an outlier on the low side from 1990 onward, except for the year 2010, when the central distribution (the box part) widens, as the economic crisis of 2008–2011 caused a drop in residential energy use for many states. By 2012 residential energy use outside California increased enough that California became an outlier again. New Mexico became an outlier on the low side during the 1990’s, possibly due to defense realignments that necessitated major economic adjustments in that state. By the year 2000, New Mexico is no longer an outlier.

Source (or primary) energy is used to increase the “fairness” of following comparisons, but mainly to allow multiple parameter normalizations, as explained in *Beyond the Basics*.

Hawaii and California

Previous work on state-level energy performance normalizations has shown that Hawaii is much different than the rest of the states when it comes to energy use in buildings. Anyone who has been there will have some understanding of why heating and cooling of residences is mostly non-existent and why energy use is low. The bottom line though is that Hawaii can be congratulated in as many ways as desired, but Hawaii uses less delivered energy in the residential sector than the District of Columbia, less than all states or DC. Since electricity use is a little higher fraction than typical, the primary energy use is a little higher than Vermont or DC, where total energy use is a small part of the national total and electricity use is a lower fraction. Source energy use per person in Hawaii, as shown in Figure 11, is the lowest in the country. In the year 2012 Hawaii is only 70% of California, which has the second lowest energy use per person.

So from a policy perspective, Hawaii contributes 0.2% of total source energy use in the United States and has the best energy performance by far. If the goal is to reduce total U.S. source energy use, give Hawaii lots of awards and set individual goals for improvement, but focus more attention elsewhere.

California is a different case, as the most populous state contributes over 7% of total source energy use in the U.S. residential sector and must be challenged to keep reducing if total country-level source energy is to be reduced. California has the highest total delivered energy to the residential sector and is second only to Texas on total primary energy.

Hawaii will not be considered further here and will be treated as an outlier in some following sections. California will be included in further discussion, since it cannot be ignored if source energy use reduction is the goal.

Policy Development

A short discussion is presented in this section to understand how the key indicators could drive policies in order to shape residential sector energy performance.

If the main goal to be achieved is reduction in air emissions, then focusing on reduction of primary energy use is the most sensible way to achieve that goal. In 1990, total U.S. primary energy use in the residential sector was about 17 quads. In 2000 the total was about 20 quads. Either of these values could be selected as a target. In the year 2012, with the previously mentioned economic crisis effects, total energy use was about 20 quads, but by 2013 the total had increased to about 22.

EIA projections are that U.S. residential sector delivered (site) energy use will remain almost constant through the year 2040 (Fig. 12).

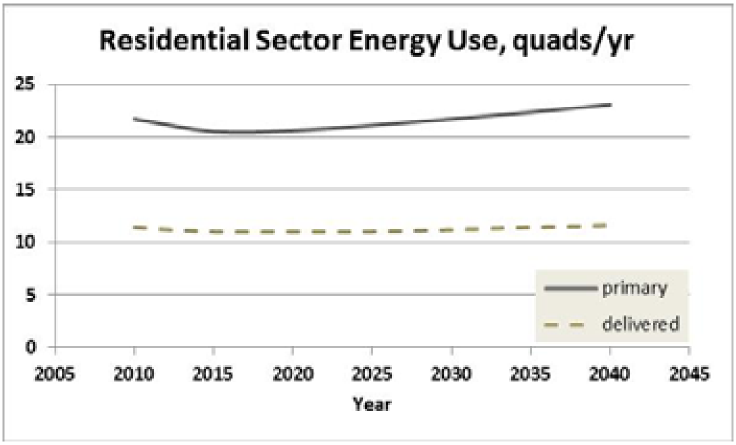


Figure 12 . EIA U.S. residential sector energy projections

The primary energy values are calculated based on available EIA data in the projections. As Figure 12 shows, residential sector primary energy is expected to reduce to 20.5 quads/yr by 2015, rising slowly thereafter.

If the main goal is to reduce this total, then some understanding of how much of the total each state causes is important. A breakout of primary energy by large states and groups of other states is shown in Figure 13. These shares of the primary energy total show that 24 states account for about 80% of the total.

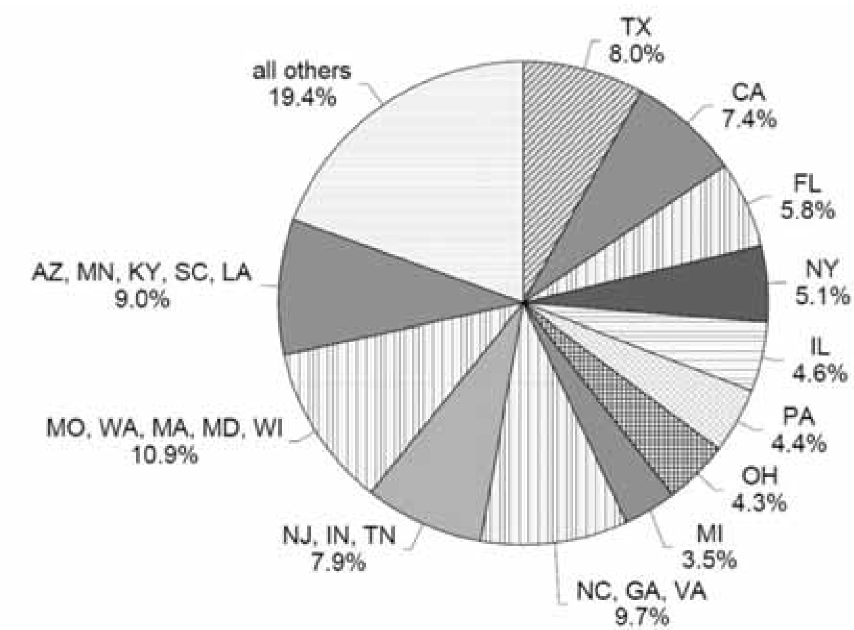


Figure 13. State shares of total residential primary energy use in 2012

Any policy that is intended to reduce total air emissions resulting from residential sector energy use in the United States should most sensibly be driven primarily by the key indicator of total primary energy use. Current policies have some minimal state interaction, but there are NO current means in place to establish incentives for states to specifically reduce total primary energy use in the residential sector. The primary federal government focus is the individual building or individual home.

Depending on the manner of government structure, the performance domain (see Fig. 4) of most import must be selected. In the United States, states have reasonably strong authority and history of activism, so states are a logical target domain in this area.

At present, states do not have specific publicly known goals of this type. Instead, the federal government directs several broad brush efforts aimed in multiple directions, including at states, to achieve reductions.

Should policies be primarily directed at the states? That is the argument here: states should be the primary target of federal policies in this area. In addition, state energy performance and improvement goals in the residential sector should be published and known to all who are interested. One reason this does not happen is that politicians prefer to promote “progress” that is less measurable, but it also does not happen because the methods of measuring energy performance have primarily focused on individual buildings for the last 20 years. One purpose of this book is to argue for a shift in focus to energy performance of states. Energy performance measurement methods for states are currently mostly ad hoc and subjective. The focus here is on empirical energy performance measurement.

The primary driver should be total primary (source) energy use, but using the second indicator of per-capita energy use allows adjustment for relative changes in population over time. The next section discusses a simple approach for setting state-level goals, and the next chapter examines more complex performance measurement and goal-setting.

Simple Per-Capita Index Goal

In setting goals, a baseline is important. The data in this chapter could represent a 2012 baseline. Goals are then set relative to the baseline. Adjustments are usually needed to address certain types of changes over time. Reduction of total source energy use is the primary goal, based on the first key performance indicator, and the per-capita indicator permits an adjustment over time due to changes in total population. Many arguments can be made for additional adjustment (normalization) mechanisms, but if methods are kept simple at first, ease of implementation can often improve.

Since a baseline is important, the data for 2012 will be used as an example. Data for 2013 are available as of July 2015, but data availability issues will be discussed later in the *Policies and Policy Development* section of this book.

One possible consideration, based on the shares in Figure 13, is to stratify policy efforts in phases, since some negotiation is probably needed to establish incentives, reporting, and other interactions with each state and the federal government. Although states could choose to try to implement changes on their own, the assumption here is that the federal government wishes to establish state-based goals and reporting. With a phased implementation, decisions would be needed about timetables for each state. Table 6 presents the key indicator data for the 24 states that account for 80% of U.S. residential sector source energy use. The other states are considered as starting later for this example.

Table 6. State level key performance indicators for 24 states, 2012

State	Source energy, Trillion Btu (TBtu)	Population, (000s)	Per-capita source energy, Million Btu/person
TX	1,599.0	26,059	61.4
CA	1,472.4	38,041	38.7
FL	1,146.3	19,318	59.3
NY	1,023.6	19,570	52.3
IL	915.0	12,875	71.1
PA	867.0	12,764	67.9
OH	863.6	11,544	74.8
MI	701.9	9,883	71.0
NC	676.3	9,752	69.3
GA	671.7	9,920	67.7
VA	579.7	8,186	70.8
NJ	552.4	8,865	62.3
IN	520.0	6,537	79.5
TN	497.9	6,456	77.1
MO	491.1	6,022	81.6
WA	479.6	6,897	69.5
MA	408.6	6,646	61.5
MD	401.0	5,885	68.1
WI	396.7	5,726	69.3
AZ	385.6	6,553	58.8
MN	373.3	5,379	69.4
KY	361.3	4,380	82.5
SC	339.9	4,724	72.0
LA	339.2	4,602	73.7

The EIA projections indicate a calculated total sectoral source energy consumption of 20.5 quads in 2015 and 20.6 quads in 2020. If the goal is set to maintain residential sector source energy use at 20 quads/yr, then a reduction of 0.6 quads/yr is expected to be needed by the year 2020. Since it is already 2015, there are five years remaining to work toward a reduction of 0.6 quads/yr by 2020. One possible option is to focus on the top 14 states with the highest total source energy use initially, to negotiate goals for those 14 that would achieve the needed reduction.

Using the per-capita source index for 2012 and projected population for all the states in 2020 from the U.S. Census Bureau, calculated energy for the country is 21.2 quads/yr, about 3% higher than the 20.6 quads/yr estimated by EIA for the year 2020. An adjusted per-capita index can be calculated for each state by fixed ratio (3% reduction) to bring the country-level total down to 20.6.

Starting with these 2020 adjusted per-capita values, a calculation check indicates that a reduction of 0.6 quads/yr can be achieved if only the highest 14 of the states are initially targeted, and each can reduce the per-capita index by 5% by the year 2020. Table 7 provides a listing of these values.

Table 7. Key indicator values and achieving 2020 goal

State	Projected 2020 Population, (000s)	2020 Adjusted per-capita source indicator	Calculated 2020 source energy, TBtu	2020 per-capita source goal	2020 source energy goal, TBtu
TX	28,635	59.6	1,705.8	56.6	1,620.5
CA	42,207	37.6	1,586.0	35.7	1,506.7
FL	23,407	57.6	1,348.4	54.7	1,281.0
NY	19,577	50.8	994.1	48.2	944.4
IL	13,237	69.0	913.2	65.5	867.6
PA	12,787	65.9	843.3	62.6	801.1
OH	11,644	72.6	845.7	69.0	803.4
MI	10,696	68.9	737.5	65.5	700.6
NC	10,709	67.3	721.0	64.0	685.0
GA	10,844	65.7	712.8	62.4	677.2
VA	8,917	68.8	613.1	65.3	582.4

State	Projected 2020 Population, (000s)	2020 Adjusted per-capita source indicator	Calculated 2020 source energy, TBtu	2020 per-capita source goal	2020 source energy goal, TBtu
NJ	9,462	60.5	572.4	57.5	543.8
IN	6,627	77.2	511.8	73.4	486.2
TN	6,781	74.9	507.7	71.1	482.3
Total			12,613		11,982
Savings					631

The savings value of 631 Trillion Btu/yr is a little more than 0.6 quads/yr, which is the target savings identified for 2020. These initial results are scoping information. Based on the scoping, decisions must be made about how to bring the states into the process of potentially reducing residential sector per-capita energy use, as well as defining targets and incentives for approaching or reaching the targets. More complex evaluation is also possible, and the next chapter will examine more complex methods.

Additional states can also be brought into the overall efforts, and the exact phasing is not covered here, as the development efforts for each state will require some negotiation and refinement over time. All states should be offered an opportunity to participate if they want, but methods and tools development should be phased by key indicator priority.

The savings process requires many political, technical, and partnership decisions, as well as tool and manpower development, which cannot be covered here but will be touched on in the section on *Policies and Policy Development*.

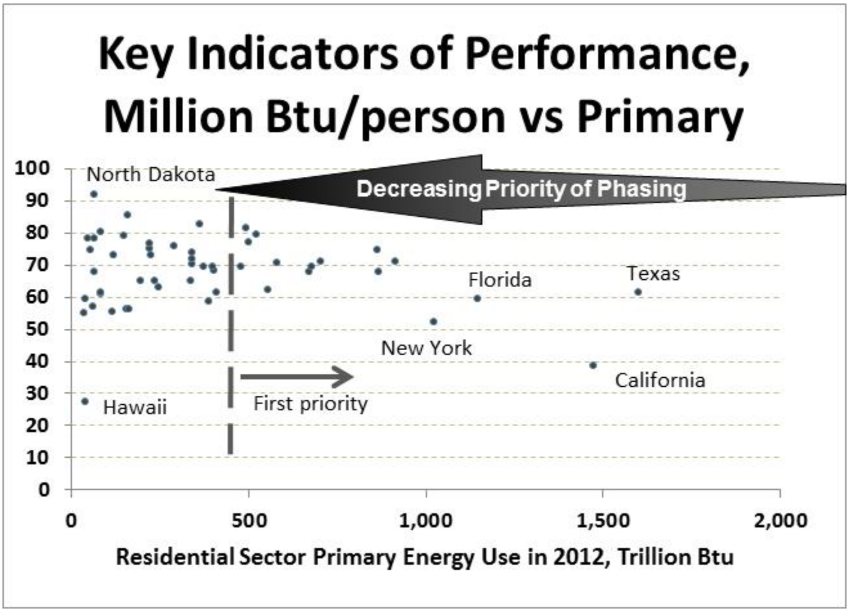


Figure 14. Mapping of two key indicators by state in 2012

Performance Scoring

If the goal is to reduce primary (source) energy use, and if the states are a focus for implementation, then some attention should be paid to total primary energy use of states, and as this book recommends, secondary attention should be paid to primary (source) energy use per person.

Total residential sector primary energy use in the year 2012 is mapped by million Btu per person for each state and the District of Columbia in Figure 14. A dashed vertical line is arbitrarily drawn in this figure to indicate that states to the right of some point should be first priority for any energy performance improvement implementation. The 16 states to the right of this line accounted for 65% of total residential sector primary energy use in 2012. A first priority slogan could be 16 gets you 65.

Current planned policy in the United States is a legal fog blown over the states that will require air emissions reductions as part of a "clean power plan." There is intense debate about whether the planned regulations will be good or bad. There is controversy over whether the proposed efforts actually do much, or whether they "smash" the status quo. An important point here is that there is no prioritization or phasing of policy that would allow more reasoned policy and activity development, and federal hegemony prevails.

If this power plan is finalized in 2015, and if it isn't held up by litigation, states' implementation plans would be required by June 2016, but not really. Extensions up to two years will be allowed and then plan reviews are likely to take at least another year. Implementation may not have to start until 2020, if there are no litigation or other delays or reversals. Readers may recall the warnings in this book about future-based policies.

However, the proposed clean power plan is a good example that the U.S. federal government often does direct policy implementation efforts at the states.

The effectiveness of top-down commands that affect all states at once is a concern for implementation. Often the complexity of dealing with such command-centric approaches mires implementation activities in mediocrity. A phased approach can be more flexible and adaptable.

Backdrop

There is a lot of information in Figure 14, but the data only provide one normalization based on population, and if there is a mistaken focus on per-capita energy use as an adequate overall stand-alone indicator of performance, a lot of argumentation may ensue.

One of the important features of the simplified approach presented in the last chapter is that excessive focus on per-capita energy use is avoided by starting with the premise that it only provides a measured value for each state individually against which progress is measured.

If performance comparisons among states are desired, modeling of performance in order to obtain a measured performance score can become more complex. The benefits of performance modeling with normalizations beyond just total population include:

1. Energy performance scores of states can be compared with increased confidence, although there are likely to always be complaints about scores and methods
2. Improvements in performance scores can be used as goals
3. Relative performance of states might be used to determine levels of incentives or types of incentives that are offered
4. If the credibility of the performance scores is reasonably good, the scores can provide some political motivation for action

The main drawback is that modeling complexity increases.

An important concern is to normalize for weather, since weather is known to have large effects on energy use. Population-weighted heating and cooling degree-days by state are available from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA):

ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/

Reliable data from this location are available from 1999 onward.

For those familiar with the Energy Star Portfolio Manager (PM) tool, weather normalization is accomplished using NCDC data also, with energy performance scores for specific types of facilities based on "Weather Normalized Energy." The normalization done by PM is directed at comparing individual building performance under "typical" weather conditions. For more information, readers can consult:

https://portfoliomanager.energystar.gov/pdf/reference/Climate%20and%20Weather.pdf

The interest here is different, in that the normalization must cover all residential buildings in a state, and population is used as an additional normalization factor to extend the weather effects to all buildings.

Additional factors, e.g., the price of energy, could also be considered for normalization, but weather is usually considered the most important, and weather normalization is complicated enough that weather is probably as far as should be attempted here.

As suggested using Table 7, an initial phase of energy performance improvement efforts would involve negotiations with those states that account for the largest percentages of the primary indicator, total source energy use. The national-level goal could be as simple as "assure total residential sector source energy use in the year 2020 is 20 quads or less." The negotiations would be aimed at informing states of the data available and the goals, and then soliciting state input on how to achieve a state-specific goal that would contribute to the national goal. Input on methods and tools could also be sought. Many states are currently in the mode of trying to accomplish energy performance improvements (typically under the rubric of sustainability), and many would likely be willing to contribute, if they understand a clear energy performance measurement system and have a say in establishing reasonable goals for improvement.

Scoring Model

Similar to the example in the chapter on *Beyond the Basics*, generating a scoring model for the states that also adjusts for weather will be presented here for the year 2012. This model can be used for any year, since it adjusts for weather, if the weather and other input data for the year to be scored are used in calculating a score.

The details of model development are messy, and the model presented here is not meant to be considered definitive, only a good example of the structure of a scoring model to use in comparing residential sector energy performance of the states.

The final model selected can be recommended for use, but further scoring model development may be desired by some.

The scoring model is based on total residential sector primary energy use of all 50 states plus DC, using the SEDS data for 2012. Population-weighted heating and cooling degree-days for 2012 are from the NCDC. This analysis employs multiple linear regression of total residential sector primary energy (derived from the SEDS data) on:

1. Population (per-capita energy use effect), thousands
2. Population-weighted heating-degree-days TIMES population PLUS population-weighted cooling-degree-days TIMES population (combined degree-day effect), divided by one million
3. Ratio of site energy to source energy TIMES population (proxy used to adjust for the difference in heating degree-day and cooling degree-day effects)
4. Population-weighted heating-degree-days TIMES population-weighted cooling-degree-days TIMES population (cross-product to adjust for correlation of heating and cooling degree-days) , divided by one billion

The combined degree-days are used since the disparity between cooling-dominated climates and heating-dominated climates is so large, leading to poor correlations if used separately. However, 20 years of experience in developing such models leads to the observation that the coefficient for cooling degree-days is typically larger (even twice or more) than the coefficient for heating degree-days when modeling primary energy, so by combining the degree-days in one parameter, a bias in favor of heating-dominated climates is introduced in any performance scoring to be done.

Parameter 3 in the list above is introduced to try to offset this heating climate bias as reasonably as possible. Further scoring model development may find more elegant means of achieving this objective.

Since the population-weighted heating and cooling degree-days are somewhat correlated (R-square about 0.75, see Fig. 15), parameter 4 is introduced to adjust for this correlation.

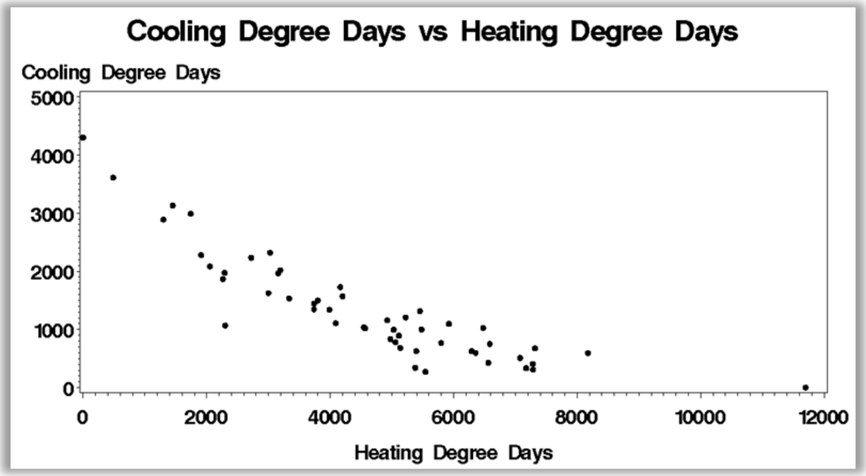


Figure 15. Cooling vs Heating Degree Days for 50 States and DC, 2012

The regression model predicts an "average" performance relative to all 50 states plus DC for the year 2012 statewide residential sector primary energy use. The prediction of expected primary energy use for each state (the expected value for average performance) is divided by the SEDS-derived 2012 total residential primary energy use for each state to calculate a performance scoring figure of merit. The scoring value for each state can be divided by the highest score (after Hawaii is dropped) and multiplied by 100 to adjust the scoring to a "grade" with the highest score of 100 (Hawaii's score is around 200 usually). In the approach here, Hawaii also receives a score of 100.

The one state in Figure 15 that is closest to the origin (0, 0) point is California. The population weighted degree days for California reflect the large number of people living along the coast, especially the southern coast.

The residential sector energy performance "grade" for each state is generally reflective of the price / cost of energy in each state, with lower-cost states generally not doing as well, and higher-cost states doing better ("cost" might be relative to income). From a policy perspective, this result is not necessarily "bad."

Scoring Model Results

The scoring model is based on a linear, ordinary least squares regression of the population and weather normalization parameters against the dependent parameter of total annual primary energy use in 2012 for each state and DC, N = 51.

In the initial regression, parameters 1, 2, and 3 are significant at better than 0.0001, and parameter 4 is significant at the 0.009 level, while the intercept is not significant (p=0.15). The intercept is 11.8 Trillion Btu, and it is preferable to eliminate the intercept (force it to zero) in order to prevent unacceptable bias upward for small states.

In the revised regression with no intercept, there are slight changes in the parameter coefficients, but overall the model is much the same, with a little higher effect going to degree days. The significance of the cross product reduces slightly. R-square and the F-statistic are technically not defined, but they can be estimated. Statistical results are summarized in Table 8.

Table 8. Regression Model Statistics

1	Dependent Parameter		Total primary energy use in 2012	
2	# of observations		51	
	Model adjusted R-square		~ 0.99	
	Model F Statistic		~ 1177	
	Model Significance		< 0.0001	
3	**Parameter**	**Model Coefficients**	**T value**	**Significance**
	Intercept	(forced to 0)		
	Population (000s)	0.05227 TBtu/yr	13.56	< 0.0001
	Parameter 2	0.00782 TBtu/yr	10.70	< 0.0001
	Parameter 3	–0.07117 TBtu/yr	12.08	< 0.0001
	Parameter 4	0.00170 TBtu/yr	2.67	0.0103

Model R-square of 99% indicates the linear model is appropriate and estimation of the combined effects of population and weather should be good. Without parameters 3 and 4, R-square drops to about 95%.

Although some may have a keen interest in understanding relative income impacts of this type of model, income effects might be better modeled separately from the population and weather effects, where income effects are handled in a second stage that is state-specific, and geared toward state programs and resources.

State numerical "grades" are presented in Table 9, along with corresponding letter grades similar to school subjects. After Hawaii, Alaska had the highest score. Letter grades are also presented on a map in Figure 16.

Table 9. 2012 Residential State Energy Performance

State	Performance Grade	
	Numerical	Letter
Alabama	71	C
Alaska	100	A+
Arizona	92	A-
Arkansas	74	C
California	81	B-
Colorado	87	B+
Connecticut	71	C
Delaware	81	B-
District of Columbia	91	A-
Florida	79	C+
Georgia	71	C-
Hawaii	100	A+
Idaho	85	B
Illinois	79	C+
Indiana	75	C
Iowa	89	B+
Kansas	79	C+
Kentucky	70	C-
Louisiana	68	C-
Maine	84	B-
Maryland	81	B-
Massachusetts	75	C
Michigan	74	C
Minnesota	94	A
Mississippi	73	C
Missouri	73	C
Montana	78	C+

State	Performance Grade	
	Numerical	Letter
Nebraska	83	B-
Nevada	92	A-
New Hampshire	87	B
New Jersey	76	C
New Mexico	85	B
New York	85	B
North Carolina	78	C+
North Dakota	83	B-
Ohio	73	C
Oklahoma	76	C
Oregon	80	B-
Pennsylvania	78	C+
Rhode Island	72	C
South Carolina	74	C
South Dakota	89	B+
Tennessee	73	C
Texas	87	B
Utah	99	A+
Vermont	74	C
Virginia	78	C+
Washington	77	C
West Virginia	64	D+
Wisconsin	89	B+
Wyoming	81	B-

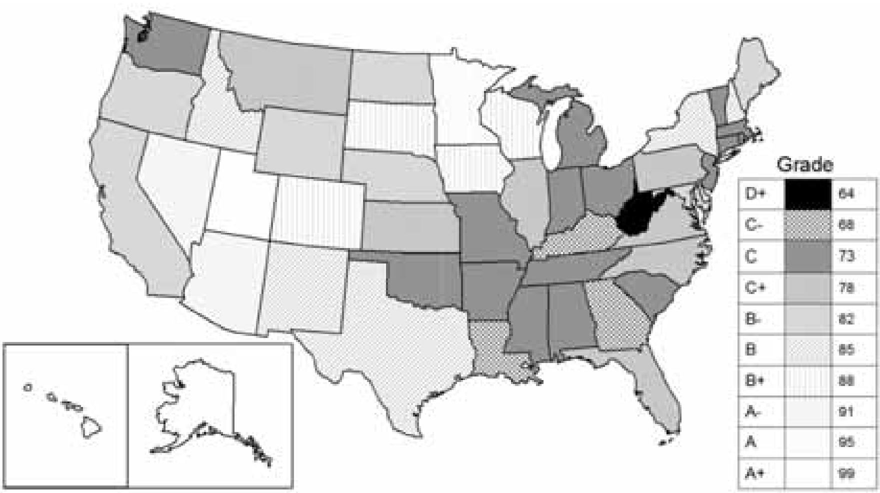


Figure 16. Map of energy performance grades

So what can be done with these grades? The grades can be used to go to the next level of prioritization on phasing of activities, where both the total sectoral primary energy use and the grades affect priority of phasing. In the easiest approach, the grade replaces the per-capita energy use as the secondary indicator — possibly a more reliable one but definitely more complicated to generate. Some benefit for negotiations with states may also apply. Per-capita energy use becomes mainly a planning parameter, but remains critical for comparisons across larger domains.

Massachusetts received a 'C' for this energy performance grading, which is one more indication the Commonwealth is only average in its accomplishments. California energy use per capita is the lowest after Hawaii, but California receives a 'B-' here.

The beginning of this chapter displayed Figure 14, showing a mapping of the two key indicators. If the energy performance grade is substituted for the per-capita indicator, then higher is better performance (Fig. 17). Texas and New York have fairly high grades, but they still could be asked to do more. California, Florida, and several other states could improve noticeably to help achieve savings goals.

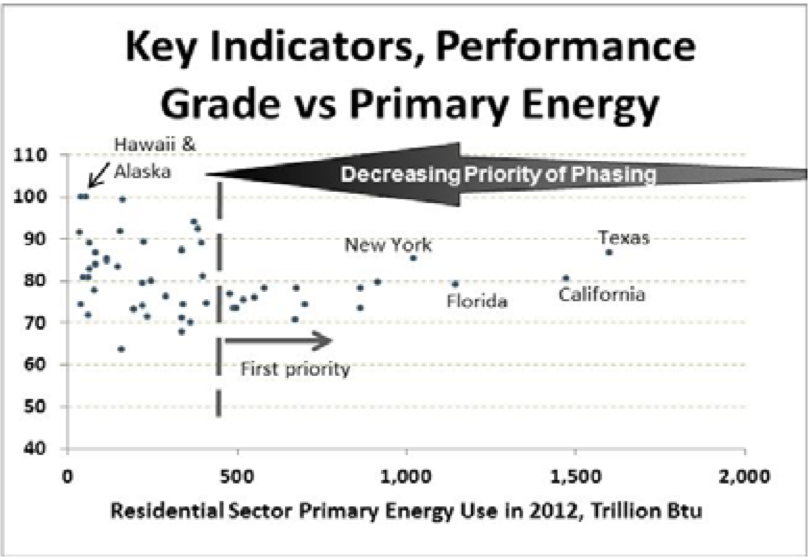


Figure 17. Mapping of sectoral performance grade as second indicator

Scoring Data

In addition to providing a "grade" on sectoral energy performance, the raw scoring results also allow calculations of reductions in total primary energy use needed to achieve improved scores. So while the per-capita data also allow calculations of improvements needed to achieve goals, the scoring data may be preferable to use in some cases.

Table 10 lists the calculated "average" primary energy use expected to be used in the residential sector for each state (Modeled Primary) based on the scoring model. The Scoring Ratio is the Modeled Primary energy divided by the SEDS-derived sectoral energy for 2012. Alaska was set to 100, so if a state wanted to score 100, the modeled primary energy would need to be 1.242 times the actual energy used. Similarly, since Arizona scored 92, the ratio would need to be 1.147 to achieve a score of 92.

Table 10. State Scoring Data

State	Grade	Modeled Primary Energy, Trillion Btu	2012 Primary Energy, Trillion Btu	Scoring Ratio
Alabama	71	298	338	0.883
Alaska	100	68	55	1.242
Arizona	92	442	386	1.147
Arkansas	74	204	222	0.920
California	81	1,473	1,472	1.001
Colorado	87	365	337	1.082
Connecticut	71	208	234	0.886
Delaware	81	62	62	1.001
District of Columbia	91	40	35	1.136
Florida	79	1,127	1,146	0.983
Georgia	71	590	672	0.878
Hawaii	100	75	38	1.967
Idaho	85	122	117	1.051
Illinois	79	903	915	0.987
Indiana	75	487	520	0.936
Iowa	89	248	224	1.107
Kansas	79	217	221	0.985
Kentucky	70	314	361	0.870
Louisiana	68	286	339	0.842
Maine	84	84	81	1.040

State	Grade	Modeled Primary Energy, Trillion Btu	2012 Primary Energy, Trillion Btu	Scoring Ratio
Maryland	81	404	401	1.007
Massachusetts	75	379	409	0.926
Michigan	74	648	702	0.924
Minnesota	94	436	373	1.168
Mississippi	73	176	194	0.910
Missouri	73	448	491	0.912
Montana	78	78	81	0.964
Nebraska	83	152	147	1.033
Nevada	92	177	155	1.141
New Hampshire	87	88	81	1.077
New Jersey	76	522	552	0.944
New Mexico	85	123	116	1.059
New York	85	1,085	1,024	1.060
North Carolina	78	656	676	0.970
North Dakota	83	66	64	1.029
Ohio	73	787	864	0.911
Oklahoma	76	275	290	0.947
Oregon	80	245	246	0.994
Pennsylvania	78	841	867	0.971
Rhode Island	72	53	60	0.891
South Carolina	74	314	340	0.923
South Dakota	89	72	65	1.106
Tennessee	73	453	498	0.911
Texas	87	1,718	1,599	1.075
Utah	99	198	161	1.232
Vermont	74	34	37	0.924
Virginia	78	563	580	0.971
Washington	77	457	480	0.953
West Virginia	64	125	159	0.790
Wisconsin	89	438	397	1.104
Wyoming	81	45	45	1.001

Issues

Many issues could be raised about how to set priorities and goals, and the validity of the scoring model could be argued. Hopefully though, one can begin to see that having the best scoring model or best method for setting goals and priorities become time drains, if the priority is to reduce sectoral energy use. So either one keeps planning the party or one starts the party.

Wood or biomass energy use in western states may be under-estimated — in Alaska especially. But even if that is the case, the validity of *relative* energy performance is not altered much, likely shifted up or down a little.

Poverty levels also probably have some influence on the scoring results, but dealing with poverty issues should probably be handled downstream of initial scoring at the state level, through state-level goal segmentation by relative income or other economic or market factors.

Large homes may not be distributed evenly throughout a state, and the population-weighted degree days are not forgiving of having uneven distributions of large homes that may use a lot of energy per capita.

Regardless of arguments about what a performance scoring model should or should not do, the basic methods that allow any governing entity to measure sectoral energy performance and set goals for shaping that performance are available now as presented in this book.

Key Lessons

1. EIA SEDS data can be used today to measure U.S. residential sector energy performance on the basis of total sectoral energy use and energy use per capita (two key indicators)
2. Relatively stable U.S. residential sector *delivered* energy use projected over the next 30 years appears possible if current trends of per-capita energy reducing by about 0.67%/yr hold, and that same total is likely to hold until 2100, if the same rate of per-capita reduction continues
3. With these same trends, total sectoral *primary* energy is expected to grow by about 6% from 2010 to 2030, due to increasing use of electricity
4. In order to compare state-level energy performance, *primary* energy should be used if air emissions reductions are the goal
5. If reducing sectoral energy use is a goal, then larger states *must* be given priority in developing and establishing programs and policies, since 24 states account for 80% of sectoral *primary* energy use (this also means use them to work out the kinks)
6. All states should be allowed to participate in meeting national goals, but initial focus should be to make sure things work in the larger states
7. Simple sectoral performance improvement goals could be set for each state today, with measurable key indicators everyone can understand
8. Without measured energy performance, improvements in performance may be treated too subjectively, leading to uncertainty over what has really been accomplished
9. More complex performance scoring methods can be developed to substitute for per-capita energy use, but more advanced methods should not delay policy development and sectoral improvement implementation efforts if improvements are needed
10. The primary federal role should be to work with the states to establish the performance measurement methods and state-level goals
11. States should have the primary responsibility for deciding how goals can be met, although federal model programs may help
12. Income and poverty issues are probably better handled at the state level, after state performance goals are set, in order to better mesh with state-specific means-tested programs

SECTION 4 — Europe Detail

Eurostat Data

The statistical office of the European Union (EU) is called Eurostat, and is headquartered in Luxembourg. Eurostat offers free statistics on member states and different portions of the EU.

European boundaries and exactly what might constitute Europe or the EU are more changeable than for the United States. Norway and Switzerland are part of Europe but not officially part of the EU at this time. What about Turkey, Cyprus, Armenia, and Georgia? Exactness of boundaries and total coverage is not attempted here. Eurostat data will be used to present residential sector key energy performance indicators for several European countries.

European residential sector energy use normalizations are typically available based on floor area, and some climate parameters. As explained earlier, in the chapter on *Evaluating Worldwide Performance*, use of floor area as a normalization factor is highly problematic if one wants to compare sectoral performance across several domains (Fig. 4) or among countries or regions that may use differing floor area definitions. And the major concern remains, that using floor area discriminates *against* smaller homes and provides unwarranted advantage to larger homes. The Eurostat data will be used to calculate the key indicators used here, and floor area will not be used.

Continuing with the complexity over boundaries, OECD Europe (as covered in Tables 2 and 3) consists of 25 countries that are different but mostly the same as the 28 EU countries included in the Eurostat data. Thus, there will be some (not large) differences between the EIA data in Table 3 and EU-28 data. The differences also likely include some differences in biomass energy accounting, as the EIA data do not include biomass that is not part of a financial transaction, while the EU data are intended to account for all biomass use.

The Eurostat data are available in thousands of tons of oil equivalent (metric tons, ktoe), which are converted here to Trillion Btu by multiplying by 0.03968 (10/252). Quads are Trillion Btu divided by 1,000.

Energy data are from the 2014 final Excel format files at:
http://ec.europa.eu/eurostat/web/energy/data/energy-balances

Population data can be accessed via links at:
http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_and_population_change_statistics

EU-28 Indicators

Primary energy is more difficult to calculate for Europe, due to large differences in electricity use and generation for countries. For the EU-28 in total, primary energy can be estimated based on EIA estimates of electricity losses[5] for OECD Europe as a whole. At the country level, only *delivered* energy will be used for the key indicators of residential sector energy performance.

EU-28 Overall

Total EU-28 residential sector *delivered* energy use has increased from 10.9 quads in 1990 to 12.3 quads in 2010. *Primary* energy use has to be calculated from the Eurostat data, and is calculated here as displayed in Figure 18. *Primary* energy use in the residential sector has increased at about the same rate, from 14.7 quads in 1990 to 17.7 quads in 2010.

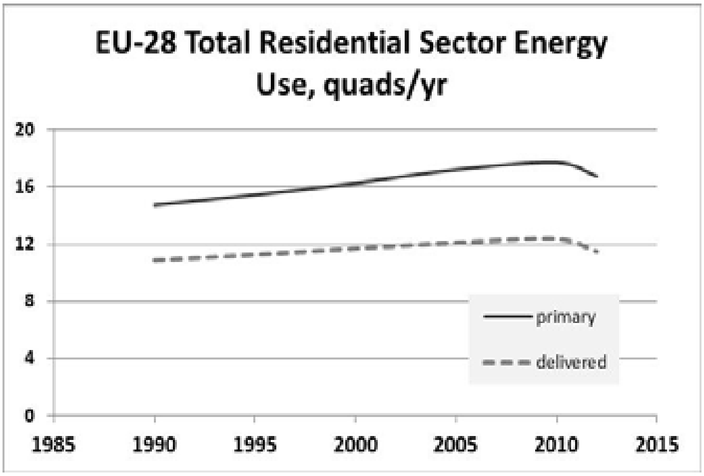


Figure 18. EU-28 residential sector energy use based on Eurostat data

[5] Consult the Data Annex values for "electricity losses factor" in the EPMI working paper, *Worldwide Buildings Sector Energy Use Trends, 2010–2040*, http://epminst.us/states/worldtrend1.htm. OECD Europe is at 1.86 in 2010.

Some EU member states have had economic "crisis periods" around the year 2010, so the downturn from 2010 to 2012 may be influenced by economic conditions. Use of biomass has increased from about 8% of total sectoral *delivered* energy use in 1990 to 13.5% in 2012. "Renewables" energy use for energy supplied to the residential sector is estimated here to be 19.5% of total final consumption (delivered) for the residential sector as a whole.

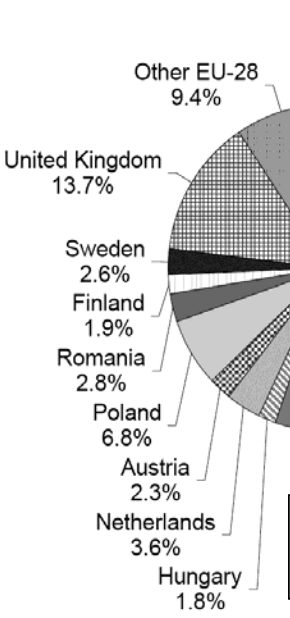


Figure 19. EU-28 residential delivered energy breakout in 2012

Of the 28 member states, 14 are shown by the data (Fig. 19) to account for 91% of *delivered* energy use to residences in 2012 (and also in 1990).

While overall EU-28 delivered residential sector energy use is more than in the United States in both 1990 and 2012, primary energy use in the residential sector is only 84% of residential primary energy use in the United States in 2012.

Table 11. EU-28 per-capita energy use, Million Btu/person

Year	Population (000s)	Primary	Delivered
2005	494,679 (est.)	34.8	24.4
2010	503,235	35.2	24.5
2012	504,057	33.2	22.8

The per-capita indicator for the EU-28 is shown for three different years in Table 11. The per-capita primary energy use is about half of the per-capita indicator for the United States as a whole (on a par with Hawaii). Delivered energy per capita for the EU-28 is about two-thirds of per-capita delivered energy in the United States. Note that the delivered per-capita use is higher than in Table 4 for OECD Europe, due to the EIA not including all residential biomass use in those totals.

Country-Level Indicators

The slogan for the United States might be "16 will get you 65," when it comes to prioritizing states that are the most important target for shaping residential sector energy performance, but for Europe — where 14 will get you 91 — only six member states are needed to reach about 70% of total residential energy use, although the per-capita indicators might change the 6th candidate.

The top six member states as far as total *delivered* energy use are Germany, France, the United Kingdom, Italy, Poland, and Spain. While these six account for a little over 70% of total delivered energy use in 2012, the per-capita use in Spain (Fig. 20) is so low as to bring into question having Spain as an initial target. For overall EU residential sector performance improvement program development, the Netherlands are probably a preferable target candidate for the 6th position.

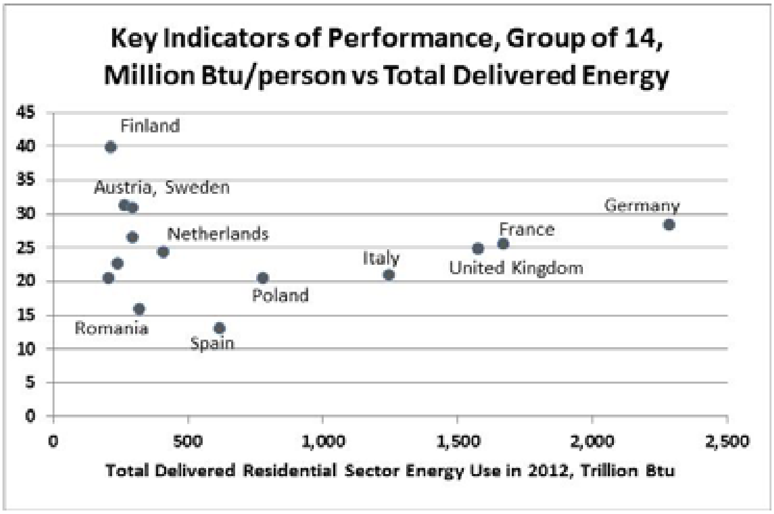


Figure 20. Group of 14 map of key residential sector indicators in 2012

Having the Netherlands at the 6th position means the group of six has over 69% of total EU-28 residential energy use in 2012.

The per-capita energy use for the "Other EU-28" is fairly low, at 18.2 Million Btu/person per year (14 member states in aggregate).

The per-capita energy use in Spain could be a performance target for other member states, in that improvements could be measured as progress toward the Spain and Romania benchmark of about 15 Million Btu per person per year.

The mix of Renewables energy also begins to play a role in these decisions. In 2014 and 2015, Spain has had a large portion of electricity generation from wind energy, and as Table 12 shows, even though Spain has the lowest per-capita energy use in the residential sector of any member state in the Group of 14, Spain also has a high percentage of Renewables energy in that total. The renewables fraction is one more reason to use Spain as a potential performance improvement benchmark and not a target for additional program implementation.

Overall for the EU-28 in 2012, Renewables generated 22% of electricity (the US value for 2012 is 12%).

The three points not labeled in Figure 20 are Hungary, Czech Republic, and Belgium. Austria, Sweden, and Finland could be secondary targets for performance improvement program development, but the high percentage of Renewables energy for these three also indicates possible need for different approaches there.

The percent of total energy delivered by Renewables is calculated here by using the total of renewables directly attributed to the residential sector by Eurostat, plus the percentage of Renewables in the overall electric generation country-wide times the residential electric use for the country (without being highly accurate on exports and imports). Biomass is a large part of total Renewables energy for many countries, and likewise hydro power is a large part for some countries.

As an example on performance goals, if every country in the Group of 14 had a per-capita residential sector energy use of 15 Million Btu per person, total delivered energy use for the group — and for the EU-28 — would be reduced about 35%/yr.

Alternatively, if every country in the Group of 14 that uses more than 20 Million Btu per-capita could reduce per-capita energy use to 20, total energy use for the Group of 14 and for the EU-28 would be reduced about 15%/yr.

Table 12 presents the total residential sector energy use and the percentages of total delivered energy from biomass, total renewables, and from electricity for the Group of 14 and the EU-28.

Table 12. Group of 14 residential sector energy data for 2012

Country	Trillion Btu	% Biomass	% Renewables	% Electric
Belgium	295	7.5%	9.3%	22.8%
Czech Republic	239	19.0%	20.8%	20.8%
Germany	2,282	11.1%	15.9%	20.5%
Spain	615	15.9%	30.9%	41.7%
France	1,670	17.6%	21.0%	32.3%
Italy	1,243	11.4%	16.7%	19.1%
Hungary	204	14.1%	14.7%	17.8%
Netherlands	408	2.9%	4.3%	20.9%
Austria	263	25.3%	44.3%	22.8%
Poland	778	14.2%	15.0%	12.4%
Romania	320	40.7%	45.4%	12.8%
Finland	215	24.5%	32.2%	35.3%
Sweden	294	16.1%	47.2%	45.2%
United Kingdom	1,575	1.0%	3.0%	24.8%
Rest of EU-28	1,073	21.6%	33.3%	27.0%
EU-28	11,473	13.5%	19.5%	24.6%
Total of 14	10,400			
Group of 14, % of EU-28	90.6%			

In comparison, the United States 2012 residential sector delivered energy is 10,468 Trillion Btu, and electricity is 45% of delivered energy. Renewables energy, calculated as for the EU-28, is 11.6%, and biomass is 4% of U.S. residential sector delivered energy.

Norway is also interesting, in that electricity provided 79% of residential sector energy in 2012, and with the high level of hydro power, the Renewables energy is 95% of total residential sector energy.

Policy Considerations

Europe is a heavy importer of energy, and supply security (or lack thereof) causes political issues for many. Further, extreme utopianism in the electorates about a "green" future has fostered disconnects in establishing coherence in energy efficiency policies. Fixation on climate change fears has caused some paralysis in thinking, but the pressing nature of supply security may help prod some increased coherence.

The high level of "Renewables" energy in the supply mix to the residential sector in Europe should be seen as an important accomplishment — far above the United States. Hopefully the Renewables supply fraction can be maintained, possibly increased steadily, and possibly the laggards might be nudged to do more in this area.

Hydroelectric power and biomass are the major contributors to the residential sector Renewables totals for Europe, and while other Renewables sources typically receive exclusive coverage as the definitive contributors in the lobotomized media, utopian goals on Renewables based on information from lobotomized sources are likely to be counterproductive (just as the "deindustrialisation" of Europe may be counterproductive).

The use of an overall sectoral approach to measuring energy performance, setting goals for improvements, and tracking progress is possible if readily measured quantities, such as presented here, are used to do so. Currently, some disconnection lies between policy goals and energy efficiency directives. The Energy Efficiency Directive (2012/27/EU) [EED], which is related to energy goals for 2020 for the EU, is an example of movement toward a more sectoral approach to energy efficiency policy and more definitive measurement of progress.

Lofty pronouncements about fighting impending climate change doom and “decarbonisation” of the EU may please some, but as far as energy efficiency improvements go, they are “in the ether.” The EED moved policy in the direction of more concrete goals for sectors, but the requirements are still not as reasonably simple as needed to see progress clearly and easily. The blurry connection between lofty policy goals and measurable progress is not totally obscure but is hard to see through at this time.

The use of the key indicators presented here for setting goals would mean that progress could be measured easily using readily available Eurostat data quantities that even non-experts could understand.

If more coherence in energy efficiency policy is desirable, and if a more focused sectoral approach appears sensible, then making goals easily understood and measurement of progress relatively easy to do should allow much better likelihood of development of energy efficiency efforts that can accomplish stated goals.

Key Lessons

1. Eurostat energy balances and population data can be used today to measure overall EU and member state residential sector energy performance using the key indicators of interest here
2. Energy losses from generating and transmitting electricity are fairly low for the EU-28, and the fraction of electricity from Renewables is fairly high, at 22%
3. Biomass supplied over 13% of total residential sector final consumption (delivered energy) in 2012 for the EU-28, which is up a lot from 8% in 1990. Maintaining this percentage may require some resource management.
4. Due to the lower fraction of electricity in the total energy supplied to the residential sector, and also the fairly high level of Renewables energy supplied, use of delivered energy is probably acceptable for determining member state residential sector energy performance and for comparing performance among member states
5. Renewables energy is primarily hydro power and biomass — not wind and solar — though wind is important for Spain
6. Energy efficiency improvements for the residential sectors in only five or six member states are critical to overall energy efficiency improvements for the EU-28 as a whole
7. As the EU works to integrate energy infrastructure and improve energy security, energy efficiency improvements can help, but a better focus on sectoral improvements could make policies and goals more easily understood and visible
8. For the residential sector overall, per-capita energy use reductions should offer a simple, clear means of defining improvement goals, measuring progress, and making projections

SECTION 5 — Worldwide Redux

Worldwide Indicators

Now that the key indicators for measuring and understanding residential sector energy performance have been examined in some detail for several major OECD countries (OECD is dark on the map above), it is time to look once again at the key indicators for the world and consider the influence of biomass again. Biomass is a fairly minor consideration for the United States, but for Europe it is not as minor. For non-OECD countries, biomass has a large impact.

The differences between the indicators for OECD and non-OECD countries in total, using EIA data with low values of biomass and IEA data that covers all biomass use, are compared. Figure 21 shows the worldwide totals of delivered residential sector energy for OECD countries and non-OECD countries based on the two data sources. For the OECD countries, the EIA data include over half of the biomass use, and there is not much difference between the total residential sector energy from the two sources. For the non-OECD countries the difference is large.

The per-capita indicators (Fig. 22) tell us that the residential sector energy intensity in the OECD countries in 2010 is much larger for both data sources.

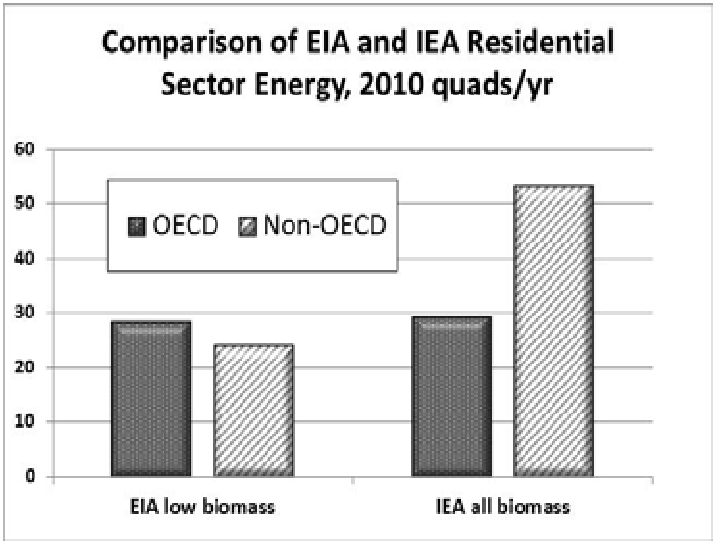


Figure 21. Comparison of total OECD and non-OECD residential sector energy use totals based on EIA and IEA data

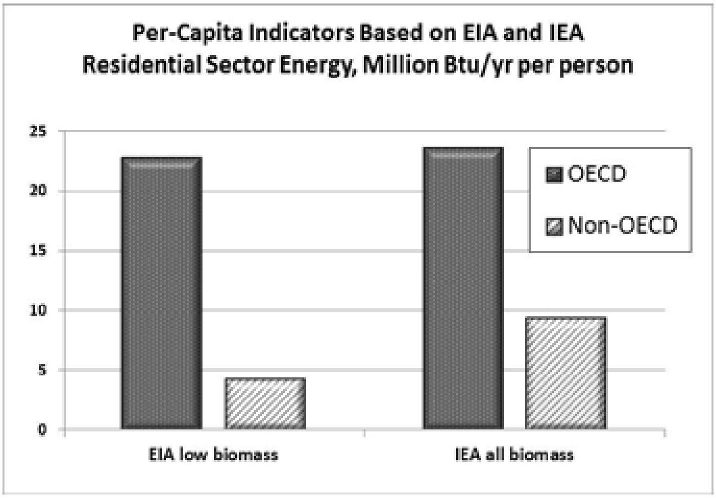


Figure 22. Comparison of per-capita residential sector indicators for 2010 based on EIA and IEA data

The IEA data come from a publicly available document, *Energy Balances of Non-OECD Countries, 2012 Edition*, found at:

http://www.iea.org/media/training/presentations/statisticsmarch/balancesofnonoecdcountries.pdf

Biomass accounts for 57% of total residential energy use in non-OECD countries in 2010 and only 8% in OECD countries as a whole. Electricity use accounts for 35% of total OECD residential sector delivered energy in 2010 and only 12% for the non-OECD countries, if biomass is included. Biomass is considered Renewables energy in this book, and total Renewables energy for the non-OECD residential sector as a whole is about 60%, while only 13% for the OECD zone.

What influence should this information have on efforts to shape the energy performance of the residential sector? Several questions can be posed, and three initial questions are:

1. Should the non-OECD countries be recognized as having 60% Renewables energy in their total residential sector energy use?
2. Should the non-OECD countries be encouraged to retain the high percentage of Renewables energy?
3. From a worldwide policy perspective, is it reasonable to expect that non-OECD countries that use less than 5–7 Million Btu/yr per capita of non-Renewables energy will reduce their residential sector energy use?

As a sidebar, a Million Btu/yr = 0.0252 metric tons of oil equivalent, or 1.055 Billion Joules (GJ).

For the residential sector, keeping per-capita non-OECD non-Renewables energy use below 7 GJ/yr on average could be a major factor in trying to keep fossil-fuel-based air emissions worldwide manageable. China and India use a lot of coal, and China is trying to decrease use while India may be increasing use. Increasing fossil-fuel use in the non-OECD residential sector will increase worldwide air emissions. From a sectoral perspective, the industrial sector is a major driver of coal use, so maintaining residential sector biomass use in the non-OECD countries close to present levels may be an important factor in worldwide energy performance and air emissions over several decades yet.

The OECD and non-OECD zones will be presented next in a fashion similar to the United States and Europe previously.

OECD Overall

Total OECD residential sector delivered energy has grown from about 24 quads/yr in 1990 to about 29 quads/yr in 2010, a little less than 1% average growth per year over 20 years.

Figure 23 shows the percentage shares of total OECD residential sector delivered energy for 13 large users and the balance of the OECD (34 countries total) in 2010. Efforts to impact OECD residential sector energy use could focus on 8–10 large users initially.

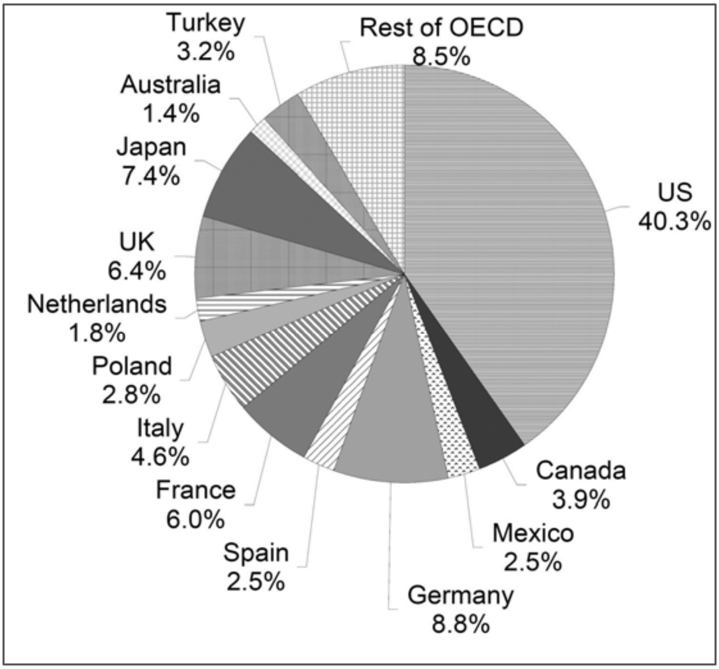


Figure 23. Residential sector delivered energy shares for OECD countries

The large share held by the United States indicates overall OECD energy performance will be strongly driven by U.S. performance. As shown in Figure 24, the United States and the EU-28 as a whole should be the primary targets for residential sector energy performance improvements in any overall OECD policy design for OECD residential sector energy performance.

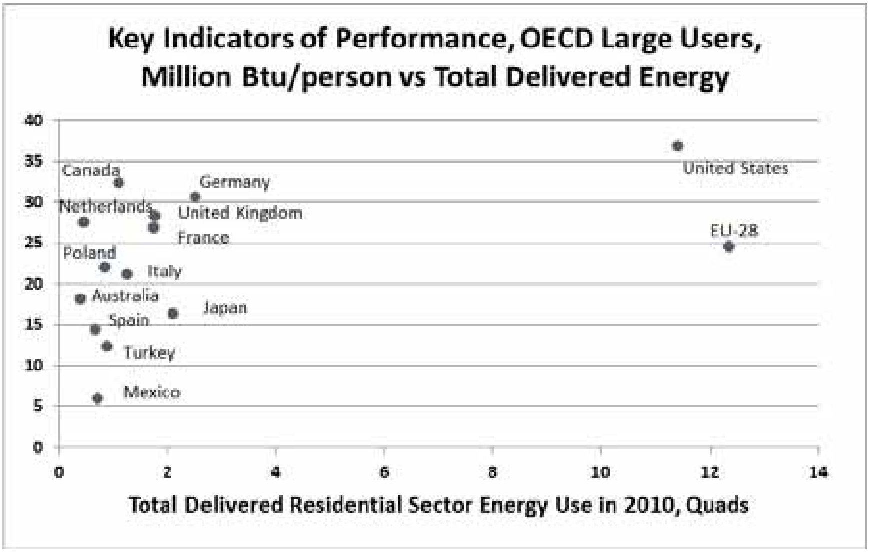


Figure 24. Mapping of key indicators for high-priority OECD targets

For the OECD countries, most biomass energy was included. Mexico, with its low per-capita energy use, had a biomass fraction of 34% of residential sector energy in 2010. The data suggest a near-term target of 25 Million Btu per capita for OECD countries that are higher, although a target of 30 for the United States might be challenging enough in the near term. Although the EU-28 includes non-OECD countries, the data point for the EU-28 is shown for comparison (the EU-28 could be considered OECD-centric). If policy can be coordinated well for the short term, possibly the EU-28 as a whole would aim for 20 while the United States and Canada aim for 30. (For the EU-28, 20 Million Btu per capita would be 21 GJ per capita, or the goal could be 20 GJ per capita.)

Over the longer term (possibly by 2040), a not-to-exceed target of 20 GJ per capita might be set for overall OECD-centric entities. As indicated previously, the United States is currently trending toward a value of 20 by the year 2100. Renewables targets may best be handled as percents of totals, and possibly differing targets by country.

If the six countries in Figure 24 that are greater than 25 now were reduced to 25 Million Btu per capita, total OECD residential sector energy use would be reduced 16%.

Non-OECD Overall

Total non-OECD residential sector delivered energy use values are highly dependent on whether biomass is included or not. In addition, non-biomass residential sector delivered energy is so low in some areas that whole continents have less impact than several OECD countries.

Treating the non-OECD countries as a bloc may be the easiest way to deal with the difficulties of tracking data at the country level, especially since whole continents may be more important to consider. Targets based on non-biomass energy (or low levels of biomass energy) may also be the most workable.

The low- or non-biomass non-OECD total delivered residential sector energy use has grown from about 13 quads/yr in 1990 to 23.0 quads/yr (no biomass) or 23.9 quads/yr (low biomass) in 2010, a growth rate of about 3%/yr. From Table 3, the overall non-OECD residential sector low-biomass delivered energy use is expected to more than double from 2010 to 2040, to almost 50 quads/yr. The growth rate is projected to be 2.5%/yr for that 30-yr period. From Table 4, the low-biomass per-capita residential sector energy intensity grows from 4.2 Million Btu per capita in 2010 to 6.8 in 2040, a growth rate of 1.6%/yr over the 30 years.

Consideration of how to treat biomass energy in non-OECD countries is important, since it can have large effects on policy direction and content. The energy mix in the non-OECD zone in total is heavily influenced by whether biomass fuel use is included. Comparisons with OECD countries are also more challenging.

Figure 25 shows OECD and non-OECD zone energy mix factors. The hydro power percentage is relative to total electricity use (not just residential sector). The major points to consider, if biomass is included, are:

1. Most non-OECD residential sector biomass use should probably be considered “renewables” energy use, which makes the percent of total residential sector renewables energy large
2. The level of electrification may be harder to understand if biomass is included in the total

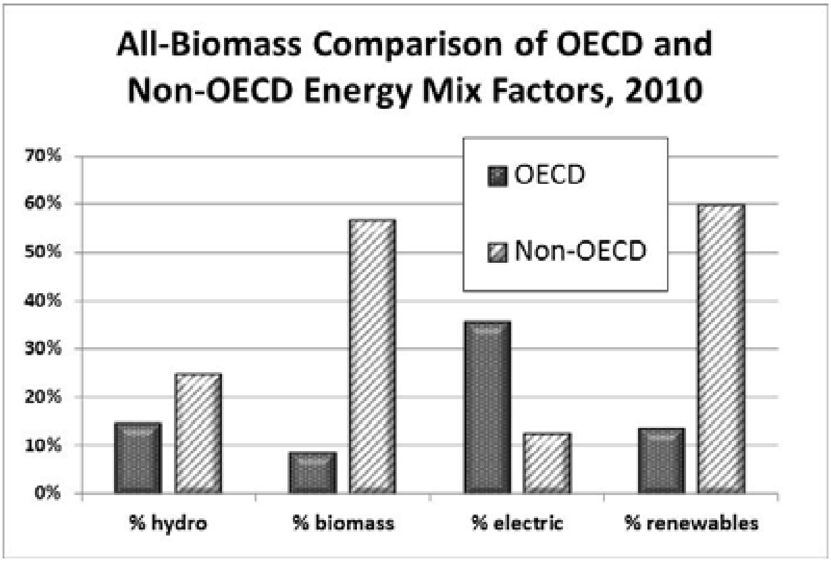


Figure 25. Comparison of residential sector energy mix factors with biomass fuels included

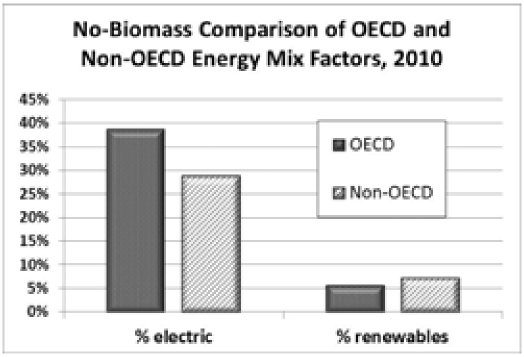


Figure 26. Energy mix factors without biomass

Relative to policy considerations, it may be easier to stipulate the high level of renewables as a given and proceed with policy development based on that underlying high percentage. Similarly, levels of electrification and possible goals for electricity generation using renewables sources may be easier to understand if biomass is not included. Figure 26 shows the comparison of electrification and renewables percentages if biomass is not included. The renewables percentage is approximate here, and based entirely on hydro power, but an important point is that the non-OECD countries' residential sector appears to be doing at least as well as the OECD countries' residential sector in using renewables other than biomass (hydro power is most of the non-biomass renewables energy for both in 2010).

A choice is made here to present the non-OECD residential sector energy use performance indicators with no biomass energy included. This is done based on the idea that policy options for the residential sector will be easier to understand if energy use without biomass included is used for performance measurement and the existing high renewables percentage is stipulated. Figure 27 shows the percentage shares of total non-OECD residential sector delivered energy in 2010 without biomass for non-OECD major regions and some countries.

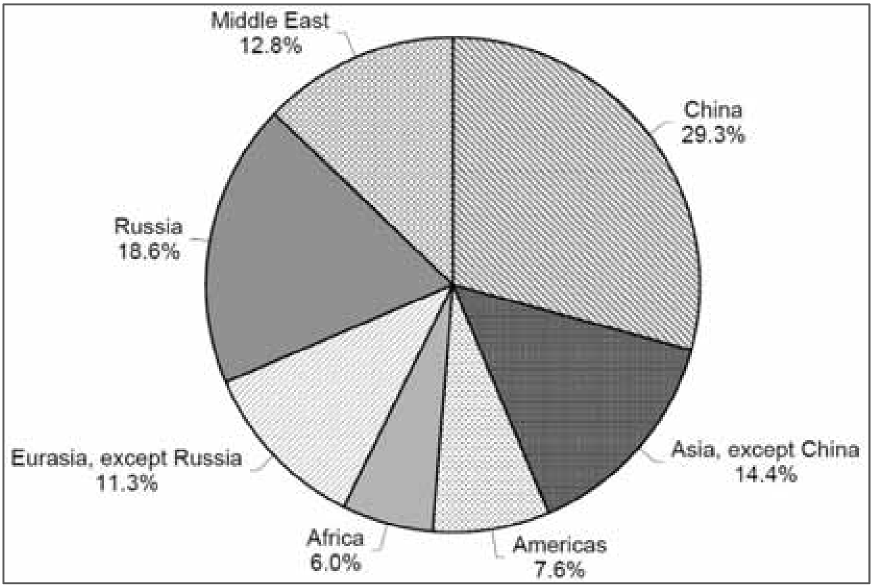


Figure 27. Non-OECD residential sector 2010 delivered energy use shares without biomass included

Rates of growth in Table 3 of residential sector energy use from 2010 to 2040 are high for all non-OECD regions and countries, except Russia, which averages only 0.8%/yr. The Middle East has the next lowest rate of growth, at 1.2%/yr, and the balance of non-OECD Europe and Eurasia countries average 1.3%/yr. Non-OECD Asia averages over

3%/yr, driven primarily by China but also India, while the Americas and Africa are 2%/yr or more. The most important non-OECD targets for shaping residential sector performance over the coming decades are China and Russia — China due to the large use and large expected growth, and Russia because both indicators are high (Figs. 27–28).

Figure 28 maps the two key residential sector energy performance indicators for these regions and countries, without biomass included. The Middle East is expected to see decreasing per-capita growth from 2010 to 2040 (Table 4), so watching developments there may be most useful in the short term. Eurasia, except for Russia, is bound up in the regional complexities of Europe, so there may be need to consider this region as OECD-centric.

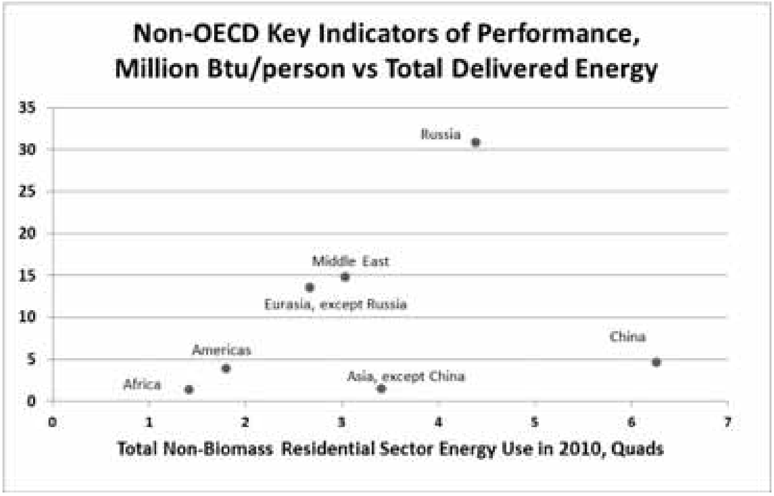


Figure 28. Mapping of non-OECD no-biomass performance indicators for the year 2010

Now the stage is set with the worldwide, regional, country-specific, and US state-specific data presented. Suggestions and recommendations for shaping residential sector performance and beginning to coordinate policies worldwide or regionally will be presented in the next section, with a major change in tone of the presentation.

Key Lessons

1. Energy from biomass must be understood well enough to determine how policy development can be affected by the large worldwide use of biomass in the residential sector
2. Should biomass be included in residential sector energy totals, or not? For OECD and OECD-centric regions or countries, the suggestion here is to include biomass energy and deal with it explicitly in policy development and formulation.
3. For non-OECD countries or regions the major issue facing the world relative to the residential sector is keeping non-biomass energy use at reasonable levels, so policy development may be easier if biomass is not considered directly for several decades yet, and more focus now is placed on keeping non-biomass energy use below some target level, e.g., 7 GJ per capita, for the entire non-OECD zone
4. The most residential sector impact from OECD and OECD-centric regions or countries can came from focusing on the United States and the EU-28, since they have the largest influence on overall worldwide residential sector performance
5. The primary influence on overall sectoral energy in non-OECD regions comes from China and Russia at present
6. Total residential sector delivered energy use (total final in IEA parlance) and per-capita intensities are currently projected to be increasing for the next 30 years in China, Russia, and the EU-28, and per-capita intensity in the United States is projected to be decreasing while total sectoral delivered energy use remains relatively constant over that same time
7. Residential sector energy performance indicators that can be measured and understood from worldwide all the way down to local level have been presented for major world regions and countries, and there is no excuse for continuing to obscure understanding of residential sector energy worldwide by using less coherent and often manipulated factors such as gross domestic product or building floor area

SECTION 6 —

Policies and Policy Development

Blurred Vision

Wittingly or unwittingly, much has been done and continues to be done to obscure measurement and understanding of world energy performance. Political leaders who make empty promises they know cannot or will not be kept, scientific leaders who shut down meaningful discussion and monopolize the dissemination of knowledge to the detriment of true science, central planners who jumble and confuse energy with carbon and weave sustainability and resiliency in mad patterns of attempted autocracy, and news media who do not inform but pander to ideological fixations are all contributors to the muddle. However, the greatest cause of residential sector challenges may be the inherent difficulties of improving energy efficiency in buildings, combined with policy planners' inability to deal effectively with the difficulties.

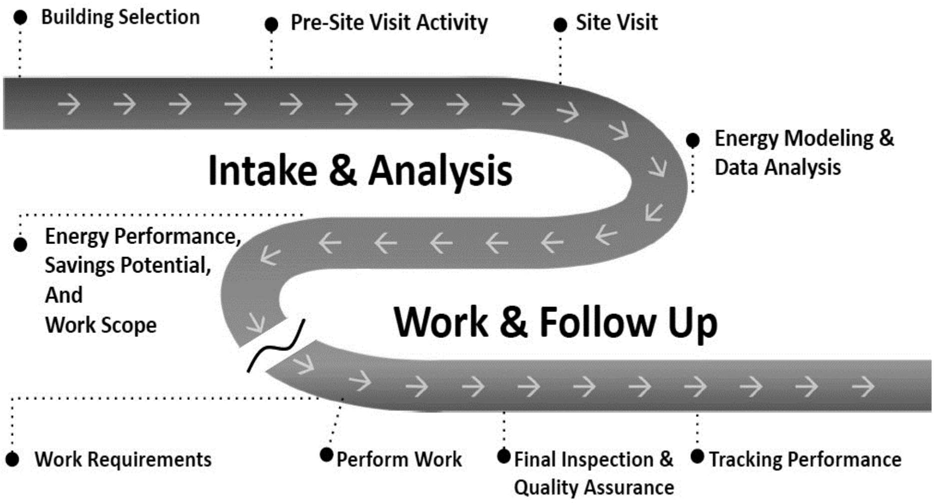
Keep it simple. Keep it measurable. Keep it straightforward. These are worthy requirements for policy recommendations. One more requirement is recommended here to make policy implementation more straightforward: maintain a clear link to the end user.

Will these requirements solve the challenges of overcoming the inherent difficulties? Not directly, so a cautionary note. Solutions need to come at more local levels, and many solutions are known and have been reported. What is lacking to date is manifold, including tracking energy performance separately from carbon performance, having an easily understood energy performance tracking method, maintaining efforts over the long term, and not making absurd promises for short term results.

Absurd promises and goals have dominated for decades now. The measurement of energy performance cannot fix this problematic behavior but may offer some amelioration. This book is aimed at promoting a readily understood energy performance measurement and tracking method for the residential sector worldwide that should be able to be used everywhere, and promoting the idea that sectoral-directed policies are the best way to maintain more clear links of policies to end users. A simplified understandable performance tracking method does offer hope that progress or lack thereof can be measured and those responsible for progress can be held accountable.

Conversion of energy to carbon and tracking carbon performance relative to carbon policy goals should be done separately but can be concurrent. Without distinct, clear energy performance goals, the vision of carbon planning will remain obscured.

The nature and tone of the presentation in the rest of this book are different than previously. No more lessons learned are presented. The lack of progress for decades is a theme. Criticism abounds. Complete solutions are not known. All the political promises sound good, but as presented previously here, the future looks nowhere near as desirable as the promised results.



Reminders

The process for improving energy performance of existing individual buildings is complex, as shown by the snake diagram above. Each item on the twisting path is a sub-process of the overall improvement process, each having multiple parts, and overall there are many potential roadblocks and disconnects.

Although much has been written about this complex process, what is promoted here is the importance of developing policy to primarily aim at sectoral groups of buildings, leaving the individual building details such as those for all the sub-processes in the above figure to be handled as best practice information. Policy goals can be handled at the state or member state level, if a measurement system allows performance to be tracked. Once policy starts to drift into the details at too local a level, the incentives for a state to improve are muddied.

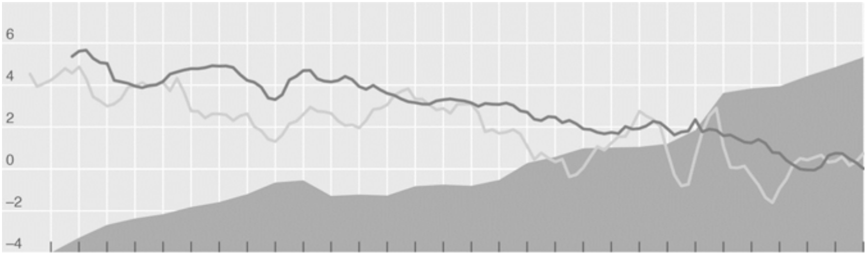
National policy should be as simple as possible while still being measurable. The practices of implementation at the detailed level of individual buildings can be handled at the state or local level, with state-level goals linking the two.

Tracking energy performance can be handled many ways, but the use of the simple indicators here is recommended as a way to be able to link all the location domains shown in Figure 4, if needed, and even link to individual buildings.

The focus must be maintained on the residential sector as an existing set of buildings. Energy performance must be tracked for existing buildings. The promise of zero-energy or fantabulous new construction *must* be handled separately, unless one wants to confuse and obscure the real sectoral performance. Excessive focus on new construction has hobbled residential performance improvement in both Europe and the United States for decades now. New-construction-based focus is acceptable IF and only if 100-yr or longer timetables are acceptable for achieving results.

Most of the world can be handled reasonably well using delivered energy (or total final consumption), without including electricity losses. However, in highly electrified states having ability to increase electric capacities without excessive economic strains (such as the United States), basing goals only on delivered energy will tend to drive residences toward increased electrification, since electricity has an advantage (see the list in the sub-chapter on *Lessons from Massachusetts*). If electricity is highly based on renewables, such as in Norway, this tendency may be desirable.

In addition, if more advanced performance measurement approaches are desired, primary energy may have to be used. Sectoral energy performance can be tracked using both primary and delivered energy goals, if needed. For the United States, national policy linked to state-level goals may need to be based on primary energy, while policy linkage to regional or worldwide goals will likely need to be based on delivered energy, in order to have the best effects within country while still remaining harmonized with worldwide goals. Delivered energy can be used if increased electrification is considered acceptable.



Economic Issues

Malaise in the global economy is problematic. In the Bank for International Settlements *85th Annual Report* for the financial year ending March 2015 (http://www.bis.org/publ/arpdf/ar2015_ec.pdf), the observation is made, "economic expansion is unbalanced, debt burdens and financial risks are still too high, productivity growth too low, and the room for manoeuvre in macroeconomic policy too limited."

In this report, the BIS calls for some major restructuring in "national and international policy frameworks" to, among other changes, "abandon the debt-fuelled growth model that has acted as a political and social substitute for productivity-enhancing reforms." The growth of "financial vulnerabilities" worldwide has raised concerns about potential "long-term pain" if the debt-fueled growth policies continue.

Economic upheavals will probably cause major slowdowns in energy use, so these BIS observations are mentioned to indicate that economic issues can cause current trends to change, possibly a lot.

Other policy issues of importance related to economics are whether to use tax policies or regulations like cap-and-trade to achieve energy or carbon goals. These topics cannot be covered here, but the view here is that use of cap-and-trade or tax policies does not foster the "industry" of energy efficiency (including incentivizing development of a qualified workforce) but does add additional economic pressures against the middle classes (middle 60% of the population), which are in addition to the "debt-fueled" pressures already reducing the wealth and income of this large segment of the population of developed countries.

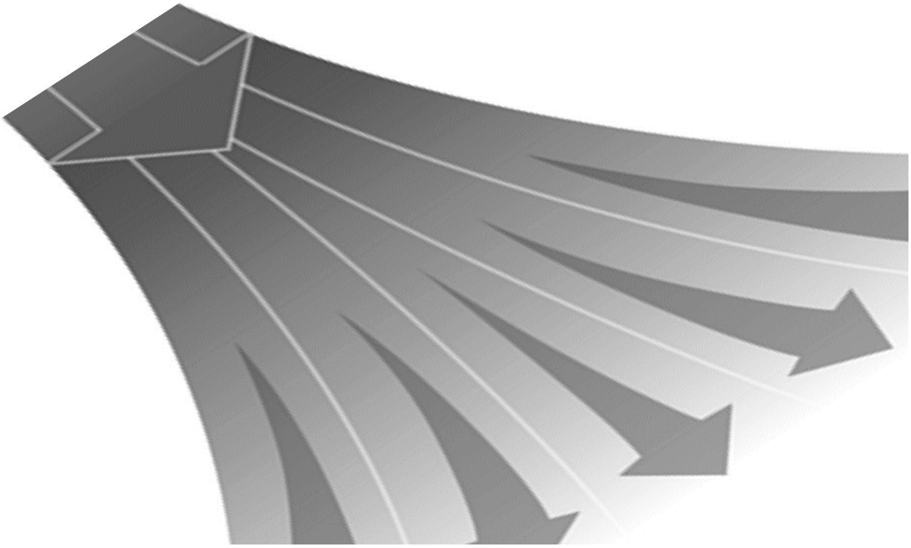
Financing is considered one of the key enablers of energy- or carbon-reduction projects worldwide. The debt-fueled growth model primarily fuels feverish development of new technologies, market manipulations, and financing of growth in prices of existing assets (toward the cliff of long-term pain mentioned by the BIS). Financing for refinement of existing assets in ways that may not be understood easily or are considered more risky (such as needed for energy or carbon reduction projects) mostly disappears. Incentives are needed to move financing in the directions needed, and this is a case where national or supra-national policies may be needed to make the incentives work. Incentives for the residential sector based on measurement of the key indicators here may be the most effective.

End-use sectors are the demand side of the energy equation, and investment in demand side efficiency improvements is usually much lower than needed to meet political goals that are set. Due to the entrenched focus on future-based policies, reasonable order of magnitude numbers on the actual investment needed to shape residential sector energy performance — which must be focused on existing buildings to achieve results in a time frame where results can actually be measured — are limited.

Investment requirements for the residential sector can be linked to energy goals by determining the cost to save a specific amount of energy. Unfortunately, if delivered energy is used, costs can vary a lot, so in order to have stability of cost (pricing) data, primary energy must be used. Also, regional variations can be dramatic. End-use energy prices in Europe tend to be twice those in the United States.

Aggregate residential sector data from the United States (based on primary energy) will be mentioned briefly as examples of potentially useful data:

- Total asset value is $25–30 Trillion
- Total energy cost is about $230 Billion/yr (~$720 per capita)
- Primary energy average price is $11-12 Billion/quad ($11–12 per Million Btu, $11–12/GJ)
- Cost of saving existing buildings energy, $100 Billion per quad/yr



Diversions

Crippling energy or carbon reduction activities with excessive regulations or requirements is a natural continuance of the regulatory maze imposed on all economic activities in the developed world. While all such diversionary effects cannot be mentioned here, a few common ones will be mentioned briefly.

Following the economic theme of the last chapter, the first major diversion is the unfortunate fixation on obscuring basic cost savings and implementation costs by requiring complicated time-value-of-money quantities like net present value or savings-to-investment ratio without also mandating that total costs of implementation and total annual cost savings be reported and understood. While the complicated economic quantities have value, the basic totals are essential for planning and policy purposes. Adjustments to policy over the short term cannot be based easily on 20-yr or 30-yr integrated values, while the basic totals can be understood readily and permit the possibility of on-the-fly adjustments to implementation methods and policies.

Health and safety requirements must be handled in some fashion, and there are many potential health and safety issues that can shut down attempts to achieve energy or carbon reduction via modifications to existing homes. The primary challenge is to find ways to deal with the important issues while not imposing unreasonable requirements that homes be made totally safe according to sometimes arbitrary definitions of what “safe” is. One major issue relates to current engineering standards that promote ventilation requirements based on supposedly “consensus” judgments that require highly transformative ventilation of residences under the presumption that the existing homes are not or will not be “safe” or “healthy” — to the point of claiming life or death concerns, but also in the vein of dictating whether odors in my bathroom and kitchen must be removed more effectively and in a shorter timeframe (scatological comment withheld). Economic concerns are many here.

The need is there to develop clear and firm policies on health and safety issues before starting large scale efforts to make modifications to homes. Some buildings may have vermin or asbestos issues, and older homes with knob and tube wiring may be too risky to modify without a wiring upgrade, so a wide range of issues must be addressed.

Regulations have run amok in the developed world, so some effort will be needed to circumvent excessive restrictions that may ensue from unreasonably strict application of all potential regulatory (sometimes conflicting) requirements. Clear and firm policies on regulatory issues should be developed partially before large-scale efforts are started, and methods for quick adjudication on-the-fly are also probably needed.

Imposing excessive energy upgrade requirements, such as requiring improvements to existing residences to comply with new construction energy efficiency standards, is also likely not a wise use of resources and should be considered a diversion from effective progress.

Similarly, imposing renewable energy requirements on existing homes may not be a wise use of resources, although suggestions on renewables can be useful.

Political consensus building and creation of new executive posts to provide ombudsman-type services for large-scale implementation efforts are likely needs to circumvent or minimize the diversions.

Shaping Policy

Only the briefest overview on high-level points of policy can be covered here, and while use of the key performance indicators is offered as a step forward for the residential sector, this book is not about a complete solution. National and supra-national policies on shaping the energy performance of the residential sector should be kept as simple as possible. Responsibility for success must be pushed to the state and local level, and goals should be set with state and local agreement on what is to be achieved. Indeed, initial efforts should probably request states to set their own goals, since current efforts are ongoing and time is needed to adjust to the realities of what it means to have a real performance measurement system in place. Achieving agreement from the most favorable locations — those that have the most potential to improve national or international performance — should be the first priority.

Only five or six countries in Europe are critical to achieving important results for Europe overall, and these can be considered for the first wave of large-scale sectoral implementation. Only 10–20 states in the United States are needed for reaching initial goals likely to be agreed upon, and only 4–10 states should be pilots for testing methods to move to larger-scale residential sector improvement efforts. China and Russia will need to be addressed at some point, but not in the first wave. Heavy focus on renewables energy for China could be an important first wave effort though.

If a goal to keep non-renewables residential sector energy use in the non-OECD countries below 7 GJ per capita overall is adopted internationally, strategies can be based on increasing renewables resources while also assuring efficiency in new construction. China and India should be the initial primary focus of these efforts, but methods and approaches developed there should be used both as examples and as leverage to help other countries benefit from what is learned.

Russia is unique in that per-capita and total energy use are high, and needed improvements are likely similar to what is needed in many East European countries. The IEA has found that large potential for energy savings exists in the Russian residential sector, primarily in heating. Possibly Russia can be given goals for efficiency improvement and then see if they wish to take a leadership role for demonstrating effective large-scale residential sector implementation approaches for countries that have building systems, climates, and societal subsidies like theirs.

Devising methods to move financing where needed is a priority, and since amazing means of increasing sovereign debt, bundling sub-prime debt, and swapping risks in order to allow even more questionable debt to be accumulated have been developed by financiers and promoted by politicians, pressure should be brought to bear on politicians and the worldwide financial community to use the lessons on debt growth to also develop financing and property valuation methods that permit needed energy projects.

Data

National energy balances are now available to such an extent that implementation of a worldwide residential sector energy performance measurement system using the key indicators discussed here is readily accomplished.

The IEA energy balances provide region- and country-specific end user sectoral breakouts for industry, transport, residential, commercial and public services, agriculture/forestry, and fishing. The industrial and transportation sectors have additional detail. Eurostat has similar detail for the EU-28 and a few other countries. Additional national energy balance data are available from individual countries. The EIA has extensive data on sectors down to the state level for the United States. Data are available that would allow policies to be linked directly to the major end-use sectors. This book focuses on the residential sector to start the consideration of such linkages.

Worldwide recommendations on energy have become highly obscured by jumping from energy policy needs to carbon data and reduction goals instantaneously. Although the two are highly related, there are many potential disconnects and deviations, and the transformational relationships are not readily understood by most people. This practice is a major vision problem. Policies on energy must be discrete from carbon reduction policies, if one wants to be effective at impacting energy use. Discrete energy policies do not rule out concurrent carbon accounting and impact analyses.

Similarly, energy security policies should be discrete from policies aimed at improving energy efficiency performance, but interactions can still be analyzed concurrently.

Required population data are readily available in a more timely fashion than energy data. More timely energy data are needed if performance tracking is to be done closer to real time. The current lag time on energy use estimates is about two years, so some increase in timeliness may be needed. In addition, methods for obtaining data at more local levels may be needed.

Promises, Promises

Worldwide energy use has increased about 50% from 1990 to 2010, despite all climate protocol promises, which demonstrates almost total lack of ability to achieve what is promised (except by those who obtained special treatment). Current projections are that worldwide energy use is going to increase 50% more from 2010 to 2040 (Table 1), which would be 225% of 1990 energy use, so there is a lot of uncertainty about the value of any current climate promises. World leaders have been ineffective for 20 years, and current projections indicate they will remain ineffective for 30 more years.

Major changes in current approaches are needed. Empty promises are the result of not having any understanding of what is needed to achieve desired goals while continuing to foster future-based policies intended to obscure memories over time.

Still, there are a few hopeful signs, such as increasing efforts to finance renewable energy projects in the non-OECD zone. However, much more is needed. Some scoping on the residential sector is next.

Large-Scale Scoping

If we want to obscure all understanding of what is needed to achieve energy or carbon reductions across large regions or worldwide, we will perform complex carbon analyses that almost nobody can understand and then report the carbon results in a report too long for most people to read. On the other hand, if we want to be clear about what is needed and report what is needed in simple terms that most people can understand, policy discussions can engage the wider population.

Complex carbon analyses and complex computer models are a conundrum for most people. Dissociating carbon from energy is a missing link in the chain of evidence needed to make a case for action. While complex analyses and carbon reporting might make some policy people content, the average person is caught in the information wars that must be fought over the areas of disagreement. If the perceived need for energy use reductions and the requirements to meet energy reduction goals are stated in terms that all can understand, at least the average person can understand what the desired policy for energy reductions is.

Currently in the United States, national policy development is going along the path of <<the federal government will dictate how the world is to be saved by reducing air emissions whether you [the people of Amerika] like it or not>>. Needless to say, litigation rules at the moment, and it is *not* clear that current proposed regulations will have much of an impact anyway. The main points relative to policy development are that heavy-handed complex regulations are likely *not* going to win the day, and most people cannot understand what is going on or why.

On a more local level though, several states and cities are trying to understand how to best improve sustainability while at the same time trying several different approaches to reducing energy. Even with these efforts though, the need to develop and report simple data for measuring and tracking energy performance is mostly not recognized or addressed.

What will be attempted here is to provide examples of how simplified data can allow scoping of requirements on a larger scale, and also allow understandable reporting of policy goals and resources needed. With simplified data and reporting, the need for improvement and resources required should be able to be understood by most.

EU-28

Total residential sector delivered energy use for the EU-28 in the year 2012 is only 6% higher than it was in 1990, so it could be argued that the residential sector there is not the main issue relative to worldwide energy use. However, from an energy security and carbon reduction standpoint, a lot of savings potential exists, making it hard not to have the residential sector as a target. In addition, projected growth rates for Europe (Table 3) from 2010 to 2040 indicate an increase of 15–20% or more in residential sector energy use.

From the group of 14 top residential sector energy consumers in the EU-28 mentioned previously, only six states used more than 25 Million Btu per capita in 2010: Belgium, Germany, France, Austria, Finland,

and Sweden. Although current economic difficulties may preclude much action at present, this group of six will be used for the first example of large-scale scoping. Possibly Russia could also be coaxed to be part of this policy group in some way, but that possibility is for the future.

The implied simple policy is something like, "the [initial] EU goal is to have all members out of the 14 largest energy-using states with a per capita index of more than 25 GJ per capita in the residential sector in the year 2012 reduce residential sector energy use to 25 GJ per capita by the year 2025." In order to give understandable substance to this goal, some simplified large-scale scoping is required.

Data quantities of potential interest are:

- Total residential sector energy use for the initial six target states in the year 2012 is about 5 quads (126 Mtoe)
- Total residential sector energy reduction by the year 2025, relative to the 2012 energy use, if all six states can reach the goal of 25 GJ per capita, is approximately 12 Mtoe/yr (0.5 quads/yr)
- Total investment required to achieve the reductions, based on €6 Billion per Mtoe/yr savings (€150 Billion per quad/yr) for the residential sector is estimated to be €70–75 Billion for all six states combined

Detail on each of the six states could follow in a real program planning effort.

Estimated residential sector energy use for each state if they meet the goal is simply projected population times 25 GJ per capita. Savings is estimated 2025 energy use less 2012 energy use. The investment value (index) is guesstimated based on US experience of $100 Billion per quad/yr for primary energy and a fair amount of hand waving after that. The energy use values and costs above are for delivered energy and not primary energy, and the investment costs required for saving delivered energy are higher than for primary energy. Anyway, the cost index values are guesstimates, but hopefully the value of such quantities for policy development and program planning can be seen.

Other potential goals can also be considered, such as a 10–20% per capita reduction for the largest energy users. Or an additional goal could be related to states that use less than 25 but more than 20 GJ per capita. Also, possibly France and Belgium could be pushed to move toward 20 instead of 25. Renewables percentages might also be factored in.

Progress toward the goals can be measured each year once the residential sector energy use estimate is available. Evaluating investment requirements involves more complicated study, but total investment and total per capita and sectoral reductions can be tracked to measure progress and develop refined investment indexes.

However, large-scale residential energy improvement programs would have to be established somehow in order to attempt to reach any goals, and the substantial investment required must somehow be directed toward achieving the goals. Of course this is nontrivial, and extensive negotiations are likely needed to move states toward adopting any such goals. The initiative is that with a workable performance measurement system in place, and simple means of scoping and presenting goals and requirements established, progress of any programs toward shaping sectoral performance can readily be tracked and compared to policy goals.

United States

Total residential sector delivered energy use for the United States in the year 2012 is only 8% higher than it was in 1990. In addition, projected growth rates (Table 3) from 2010 to 2040 are very low. However, with the high per-capita energy use (Figures 7 and 8) in the United States and the large potential for savings, pursuit of large-scale savings would be justified if a need for energy use reductions were a policy goal.

The investment index value of $100 Billion per quad/yr of primary energy is derived from results of the most recent retrospective national evaluation of the DOE Weatherization Assistance Program (WAP) and previous work on capital cost requirements for achieving energy savings:

- WAP national evaluation reports and publications are at: http://weatherization.ornl.gov/evaluation_nr.shtml
- Previous analysis from the 1994 ACEEE Summer Study: http://aceee.org/files/proceedings/1994/data/papers/SS94_Panel7_Paper13.pdf

As indicated previously, total residential sector energy use in the United States is on track to remain relatively constant for the foreseeable future, and if current trends hold will remain constant for the next 100 years.

The energy-savings potential for the US residential sector is large, and has remained large for over 50 years, despite promised efforts to achieve reductions following development of the Kyoto protocol. A national energy strategy was developed (1993) that was aimed at reducing total buildings sector energy use by 15 quads of primary energy compared to EIA projections by the year 2030. In 2010, buildings sector energy use had followed the EIA base case projections almost exactly (the base case means business as usual). The national energy strategy fed a Climate Change Action Plan (1993) that was going to lead the way in keeping energy use at 1990 levels. The political posturing was extensive. But the end result is that the EIA base case prevailed and no reductions relative to the base case were achieved. The Climate Change Action Plan is now a worthless footnote in history.

Residential sector savings potential in the United States remains high, at least if extensive recent studies by McKinsey & Company and the National Academy of Sciences are any indication.

In 2009, the median annual cost of household energy (all types of residences, but not including transportation) was $1,800, while median household income was about $50,000, so energy cost was about 3.5% of income before taxes.

Median household primary energy use was 167.5 Million Btu in 2009 (average of 182 Million), and median cost per Million Btu was about $10.80 (average of $11.40). For an investment index of $100 per Million Btu/yr saved ($100 Billion per quad/yr) of primary energy, in order to achieve 15% savings for a median household, a median investment estimate of $2,500 is indicated. Investing $2,500 is estimated to save $270/yr (9.3 year simple payback).

Convincing a household to invest $2,500 of their own money is challenging, since 9-yr simple paybacks are not attractive when struggling to pay all the other bills, but if this type of investment has creative means of inducing financing, with payback from energy bills in some fashion, action might be initiated.

Increasing the portfolio of efficiency loans, in a manner that risks are treated and reliability of payments is increased, would help even more. Discussion of risks cannot be attempted here, but the primary roadblock in the United States appears to be the difficulty in trying to assign equity value to such financing while also mitigating risks. Most energy efficiency improvements are difficult to repossess. Creative solutions are needed for both owner-occupied and rental properties (and quantitative easing has demonstrated immense creativity exists).

If the year 2005 is established as a new climate baseline, the US residential sector is almost already there on a delivered energy basis. Alternatively, if earlier baselines are chosen, savings of 1–2 quads/yr are needed.

To save one quad/yr of primary energy is estimated to require an investment of $100 Billion. If the average required investment per home is in the neighborhood of $2,500, then 40 million homes (out of about 120 million) have to be improved to achieve one quad/yr savings. The average savings would be about 15% of annual use. Increasing the technological sophistication of energy improvements might lead to 20% average savings, but the cost index might also increase to $120–140 Billion per quad/yr.

In addition, $100 Billion would generate about 4.5 million job-years of work, counting direct, indirect, and induced job creation effects (based on 45 job-years per $1 Million expended on this type of building energy efficiency improvement work). Over 10 years that would be 450,000 jobs (and hopefully continuing after that).

Large-scale scoping is important for understanding what the resource requirements and scope of activities are. Complicated economic quantities and projection models are of no use in understanding the basic scoping. Large-scale scoping is also needed on creative financial methods, but real commitment from politicians and financiers is needed there first.

Large-Scale Programs

If you just read the previous material on the United States and were startled by the mention of 40 million homes, you should be. If there were knowledge about how to improve the efficiency of four million homes or residences per year over a 10-yr period, that knowledge would be valuable. No residential improvement program achieving 15% or more savings per residence has ever approached even one million residences per year. During the period of "stimulus funding" in the United States, DOE's Weatherization Assistance Program installed efficiency improvements in 340,000 homes over a year, which is probably the largest-scale residential sector improvement effort ever.

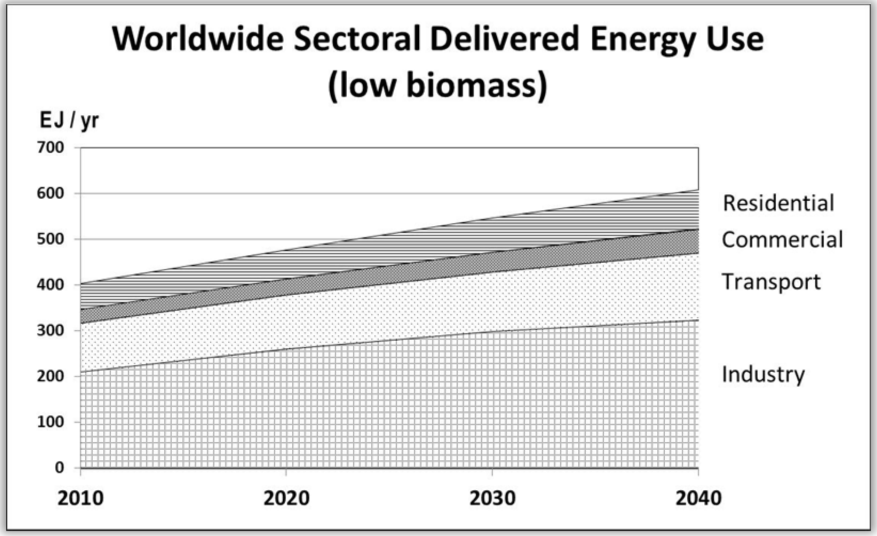
One of the reasons climate protocol promises and building energy performance directives keep failing to accomplish what is needed or promised is that capabilities for actually running large-scale efficiency improvement programs have never been truly developed. Boom-and-bust efforts — at a scale that is still much less than needed — have followed fervently fluctuating policies over the past 40 years, such that not only are needed capabilities for program execution not developed, but the potential workforce has been hammered with unstable hiring and firing. Negative aura reigns, and some needed resources do not exist.

In order for larger-scale efficiency improvement programs to become reasonably stable and continue to function over the long term, unreasonable demands that the world be saved from climate disaster in a short period of time cannot be the driver of efficiency efforts. Unfortunately, the operational mode for decades has been to flip back and forth between "crisis" management and uncaring neglect.

So in the short term, a critical need for large-scale residential energy efficiency programs is to steadily build the capacity to accomplish efficiency improvements in existing buildings, while also recognizing that some reasonably optimal capacity should exist for the long term.

Large-scale policy scoping is needed to start to move development of multiple resources in this direction, but the challenges are many and formidable.

SECTION 7 — Conclusion



Quo Tendimus

Where is world energy use headed? In considering the potential shaping of residential sector energy use, the overall trend for the world should be remembered. Major efforts to impact industrial and transport energy use must occur also, if there is a need to reduce worldwide energy use. The total world delivered energy use is projected by the EIA to increase from about 400 EJ/yr (an exaJoule is 5.5% less than a quad) to a little over 600 EJ/yr in 2040. The EIA projections only include a small part of total biomass energy.

Should world energy efficiency and carbon reduction efforts focus on countries? Or is a sectoral focus a better way to link policies to end use? A focus on the residential sector in this book allows one to see the unique facets of trying to shape sectoral performance, and one initial choice facing worldwide policy is whether each country must develop means to shape residential sector performance on their own, or whether the sector should be addressed on a larger scale.

Many strategies are being considered worldwide. Most mentions of "large-scale" energy efficiency programs are relatively small compared to the scale presented here. Conversely, plans for the "decarbonisation" of Europe discuss investment levels of trillions of €uros per year, which is of the scale needed. Plans for massive development of renewable energy electricity supply also call for investments of trillions of US dollars. The scale of investment required is recognized, but there does not seem to be a path to reach these large scale efforts.

Most analyses of the paths to reaching energy or carbon reductions indicate that energy efficiency improvements should be part of the foundation of any initiatives to achieve reduction goals. But pressures to invest in energy supply infrastructure often prevail over any needs to develop large-scale efficiency programs. Those same pressures also push toward investment in renewables energy supply, so needed efficiency improvements may once again be bypassed for renewables energy supply infrastructure, which is likely more costly but may be more politically correct. (See recent Fraunhofer study for instance:
http://www.climateworks.org/wp-content/uploads/2015/11/Report_How-Energy-Efficiency-Cuts-Costs-for-a-2-Degree-Future.pdf)

One of the considerations here is that large-scale energy efficiency programs are probably more effective than large-scale energy infrastructure investments at making the overall economy better functioning and increasing the economic well-being of 80% of the population, while still moving toward energy reduction goals. Analyses usually indicate efficiency is less costly. The challenge is how to move economic activity in this direction, given the political pressures to do otherwise.

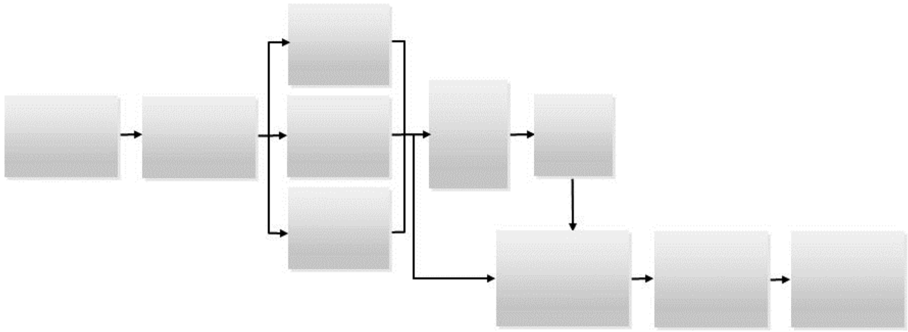
Another key part of the foundation for any energy reduction program is the ability to measure energy performance. The performance measurement methods here are intended to allow readily understandable large-scale measurement of the energy performance of the residential sector. Use of these methods would allow initial development of a program foundation for achieving large-scale energy use reductions in the residential sector. Or at least to begin to speak clearly about energy performance on a wider scale. The residential sector is unique in many ways, so sector-directed methods are needed to make progress.

Will carbon reduction programs be successful over the next 25 years? Are results of the 2015 climate conference just more “Promises, Promises?” In 25 years, will non-biomass residential sector energy consumption be following the EIA trend? Time will tell.

America is often criticized for not following through on needed actions to achieve carbon reductions, but almost all countries have failed to follow through to the levels supposedly promised. Since the climate debate is highly politicized, many accusations are made. One accusation here is that future-focused policies allow political posturing and mostly baseless promises to win out over efforts to actually start large-scale energy and carbon reduction programs.

Trying to grasp what is happening in a specific sector is difficult enough, but promising to change the energy use or carbon emission profile of a whole country is an invitation to blurry vision and obscure strategies. The information in this book allows fairly specific means of targeting the residential sector. Other sectors should also be targeted, but using different means and methods.

Quo tendimus? Probably right along the EIA projection path, unless changes are made in policy approaches, such as suggested here for the residential sector to allow a foundational starting point. Following that, some entity has to take responsibility for program development, which will by nature require major adjustments in economic activities.



Program Development

As of today, a truly large-scale residential sector energy efficiency improvement program is a phantom. How can such a thing develop? Several challenges have to be addressed:

1. If federal or state governments become too involved, political roadblocks are more likely to develop, so special care is needed to keep governmental policy simple and mostly detached from actual program management and implementation
2. Governmental oversight is needed though, and energy performance measurement and reporting should be a government function
3. Government involvement in establishing initial incentives for program development is necessary also
4. Some means of assuring initial program longevity is needed, probably 10 years minimum to begin, but hopefully ongoing after
5. Program policies and goals should be tied to energy performance measurement
6. Since much needs to be learned about how to make such programs function effectively, pilot programs should be run at a smaller scale to allow methods and policies to be tested and refined
7. Extinction of energy suppliers should not be a goal, so care is needed to establish a framework where existing regulatory requirements impacting energy supply and suppliers are adjusted slowly or factored into policy adjustments as most appropriate, while also setting the stage for energy use reductions

8. Existing programs that are considered “large-scale” can be evaluated to see which aspects most readily allow scaling up to truly large scale
9. Workforce development will be a major issue, and training will be needed
10. Incentives to move financing into the energy efficiency market are needed, but the nature of the best incentives are still unclear, and the real commitment of the financing community is also unclear
11. Means of financing that minimize complexity of end user decisions (meaning as simple as possible) are needed
12. Net costs to end users probably need to be near zero for most, but the cost issue is part of the overall incentives complex and strategies must be linked to the savings variability risks mentioned below, to provide some type of net cost guarantee to end users
13. Insurance and indemnification issues are nontrivial, and new risk amelioration strategies may be needed
14. Savings risk is also nontrivial and needs to be pooled in some fashion so that aggregate savings are achieved without excessive concern over savings at the individual residence level
15. Since truly large-scale efficiency programs will be a nontrivial alteration of a country’s economy, startup incentives, ongoing costs, valuation of benefits achieved, and need for ongoing incentives will all need to be tracked and evaluated
16. Large-scale cultural and political motivation will be required
17. Too much distraction coming from renewables quotas or directives is counter-productive

This list is not meant to be definitive but only illustrative of challenges facing development of truly large-scale residential energy efficiency improvement (carbon reduction or whatever) programs. (Health, safety, and regulatory control challenges were mentioned previously.)

If clear goals on the simple indicators can be set at some governmental unit level, means of measuring the key indicators at the appropriate levels will be needed. The effectiveness of pilot programs will likely need to be measured using data that is more local than is readily available.

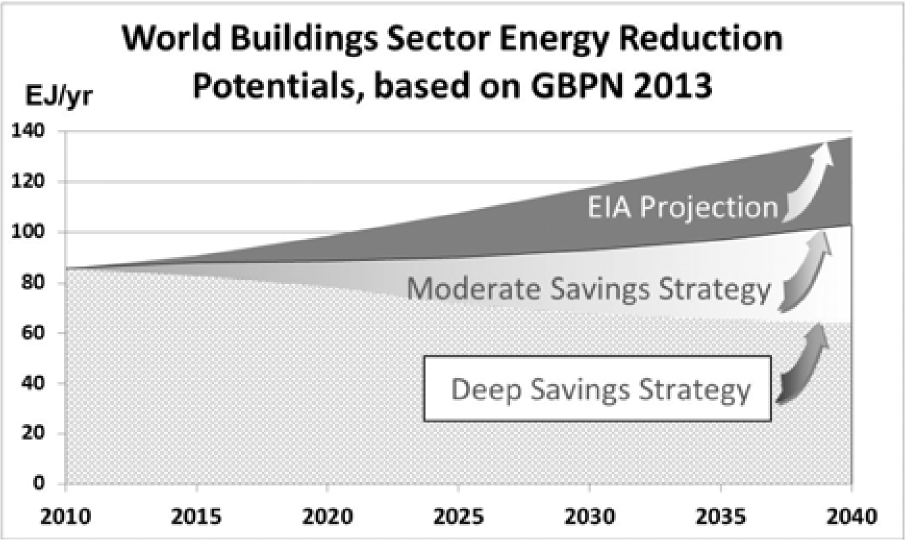
Fortunately, a workforce should be available to conduct pilot programs. Efforts to scale the workforce up can begin while pilot programs are in progress.

Means of funding the pilot programs will have to be determined. Forcing energy suppliers to run such programs is probably not a good approach, due to conflicting interests (meaning poor motivation to perform, but large incentive to appear to perform). On the other hand, energy suppliers are already used to being forced to pay for efficiency improvement programs, so they are a potential source of some funding and also potential billing recovery of costs.

The array of challenges gives an indication of why most directives on building energy efficiency have performed less well than expected. Economic "crises" tend to be much better at reducing residential sector energy use. Tax-based approaches also tend to be successful at achieving reductions in the short term, although the long-term effects are less certain. Unfortunately, tax approaches are difficult to use during economic crises, and once an economic crisis has passed, the notion of taxes is often unpalatable. As mentioned previously, energy or carbon tax approaches are not expected to lead to more beneficial economic activity, while large-scale energy efficiency improvement programs should.

The approach of forcing electricity generation to achieve needed carbon reductions also has appeal to politicians, since the challenges of transforming an economy are bypassed. However, the impact of achieving all carbon reductions at the electricity generation level is likely to be economically less desirable for most of the population.

Overall, shaping sectoral energy performance is difficult, while other strategies still appear to offer the "magic bullet" to achieve promised goals. Bureaucrats and politicians have been implementing magic bullet approaches for decades now. How has that worked?



Days of Future Passed

Looking at overall buildings sector (residential and commercial) energy savings potentials, the Global Buildings Performance Network (GBPN) released a policy paper in June 2013, *Buildings for Our Future*, that presented results similar to the figure above. Two levels of savings potential were presented: moderate and deep.

(http://www.gbpn.org/reports/buildings-our-future-deep-path-closing-emissions-gap-building-sector-2)

The "deep" path requires zero-energy and net-positive-energy new buildings and is highly future oriented. Given that it will be difficult to even accomplish the "moderate" strategy, one might ask how we are to arrive there? The promised results are off in the future, if only . . .

The IEA released a *World Energy Outlook* special report in 2015 on energy and climate change that is so future-oriented that Promises, Promises slides into days of future passed, never reaching the end.

(https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf)

Carbon fixation leads people to talk about increasing investments in carbon capture and storage and high-cost, big-technology fixes, but the least-cost efficiency improvements — probably the most reliable methods, are mostly ignored. Possibly one reason for ignoring them is that they are ready for implementation here and now, and if promised results are not off in the future somewhere, claiming future results is difficult to do to hide inaction and political posturing that is ineffective.

Future days of the US 1993 *Climate Change Action Plan* have mostly come and gone, with no impact. Future days of the EU 2002 *Directive on the Energy Performance of Buildings* have come and faded into the 2010 *Energy Performance of Buildings Directive* (EPBD) and the 2012 *Energy Efficiency Directive* (EED). In a few more years, the future days of these directives will be mostly behind us, and the EIA projected energy use will probably still be the trend of energy use, meaning all the efforts to follow the directives are not changing the trends much, if at all.

The EED tries to address multiple sectors, while the EPBD tries to address both residential and commercial sectors simultaneously.

The GBPN projected savings potentials sound nice, but no real path is defined for how to reach the potentials. Hopefully the information in this book makes it easier for interested individuals to ask questions about how we are supposed to make it to the promised land of residential carbon reductions and energy reductions.

As hinted at the beginning of this book, the hope of presenting the information here is that residential sector energy performance will start to be tracked by many, and politicians and programs will be held more accountable for what happens to sectoral performance. Additional means of tracking performance of other sectors are needed, and the methods here are a start for the residential sector.

Future days have been passing for decades. For decades this author has been waiting to see evidence of the beginnings of a truly viable large-scale energy efficiency program that could shape the energy performance of an entire end-use sector. Somewhere. Still waiting.

RSVP

Rio. Earth Summit. 1992. UNFCC . . . developed countries are taking the lead . . . by the end of the present decade . . . modifying longer-term trends in anthropogenic emissions . . . to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases . . .

The US 1993 *Climate Change Action Plan* was in response to Rio and the United Nations Framework Convention on Climate Change. How many more worthless footnotes in history are needed?

This book is a call for response — not necessarily grandiose. Activities are happening in the world, but the patterns of activity have not changed much in 25 years. Crisis management flits from climate to economy to security to . . . and back again.

Initial response should be to question all that is happening, especially those who are in a position to question with authority. US policies are to do what? We are going to throw lots of money at new whiz-bang technologies, just like has been promised for the past 40 years, and this is somehow new? How about saying that residential sector per-capita energy use will be lowered to 25 GJ/yr by 2025? What about similar understandable goals for other sectors? How about actually reporting on progress toward reaching understandable goals?

EU policy is to do what? Fundamentally rethinking energy efficiency in order to treat it as a new energy source? Oh, except maybe not? Trillions of €uros/yr will be spent on decarbonisation of Europe? Oh, except maybe we cannot come up with that much, or maybe that is not such a good idea after all.

Energy efficiency action plans that require complicated diagrams to explain the vision and goals are guaranteed to prevent understanding of what is to be accomplished. One response is to demand simplification of goals and at least one simple metric on progress for each end-use sector. Another response is to demand that sectoral energy performance be reported clearly in simple, understandable terms. EPMI will plan to continue reporting performance data.

Another response is to demand sectoral energy performance goals that are distinct and separate from carbon reduction goals. If energy is ignored, then progress is difficult to understand, since energy is complicated enough, but carbon is even more.

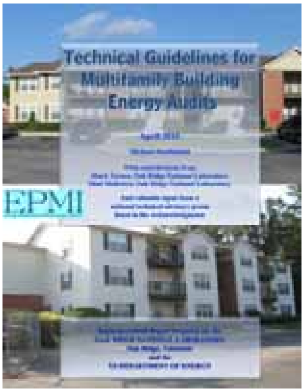
Simplified goals and simplified policies are sorely lacking. True accountability is lacking due to future-based, difficult-to-discern (blurry) goals. What does 2°C really mean? In a very real sense, a 2°C goal buries understandability at least one layer deeper than carbon goals.

RSVP.

Other items on the EPMI website

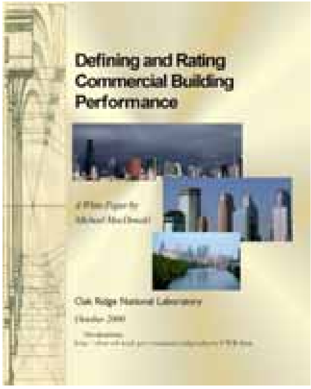
Multifamily Energy Audit Guide

http://epminst.us/mf_audit/MF_audit.htm



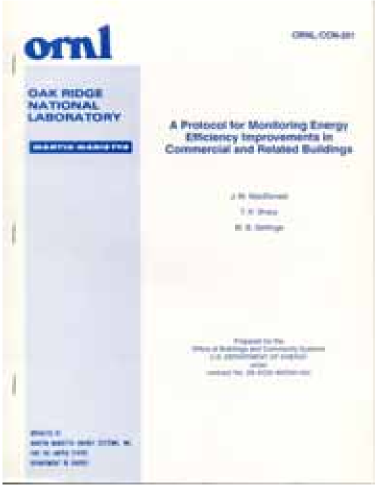
Defining and Rating
Commercial Building Performance

http://epminst.us/ORNLproducts/CWB.htm



Commercial Building Energy
Efficiency Monitoring Protocol

http://epminst.us/ORNLproducts/protocol.htm



Michael MacDonald retired from Oak Ridge National Laboratory after 25 years working on building energy efficiency research, energy assessment methods, and sectoral data analysis. He started the Energy Performance Measurement Institute to continue studying energy performance measurement methods and issues.

EPMI

Energy Performance Measurement Institute