

Ninety Years of U.S. Household Energy History: A Quantitative Update

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This time-series analysis measures descriptively the changes in household energy consumption from 1900, thus shedding light upon the events (historical, economic, programmatic and/or technological) that have shaped the energy consumption patterns found.

The updated database (from 1980-1990) allows reporting the amount of energy consumed by the American household for 90 consecutive years. The 10 years of new information continues the previous exploration (see references) of the yearly consumption of fuelwood, anthracite and bituminous coal, electricity, natural gas, fuel oil and LPG (measured in BTU's), as independent energy sources, while also allowing for the calculation of the "sum of all fuels" yearly for households, done in previous work.

Per-household and per-person/per-household analysis of energy consumption over the 90 year period is also included. The measurements for energy and household data are based (in most cases) upon extant databases (see endnotes).

The results of this quantitative update of the history of U.S. household energy consumption, gives evidence that per-household energy consumption has been reduced by 16.7 percent since 1980, in spite of a 13.5 percent increase in the number of households. A perusal of the historical evidence prior to 1980, indicates that overtime the individual American household appears to have become substantially more energy efficient (especially since 1907). And, that is "what we know." Speculations about why this energy reduction has occurred, and a discussion of "energy displacement" to other economic sectors concludes the paper.

Introduction

Two important issues have driven this quantitative U.S. household energy consumption history study since its inception in 1978.¹ The first was a complete lack of an historical perspective, as a context for contemporary household energy research, and the second was the assumption that present day household energy consumption was less efficient than it had been in the past. This assumption was based completely upon a "good old days" folk theory, rather than on factual evidence. Clearly, this assumption romanticizes, even trivializes the past.

For the 1992 ACEEE summer study, two further objectives have given rise to my updating this study. The first is "what do we know now about building (housing) efficiency?" thus, giving the energy research community insight into "where we should be heading?" The answers to these questions should stimulate interesting discussion, if not controversy, as we realize the implications for building science, policy making and human behavior as a result of the findings presented here.

Research Approach

This study is basically a quantitative historical time-series analysis. All of the databases used in this research were compiled from already existent documents. In a few cases where data series were not complete, interpolation methods were used (as per advice from J. Alterman and "other" energy sector experts--see acknowledgements). When the documents I possessed during the compilation of the update (1980-1990) were incomplete, data were even read to me by phone or FAXED (see acknowledgments). The units of measure varied by energy source (i.e., cubic feet, barrels, short tons, etc.) in the data documents (see references); however, as they were transcribed to data sheets for computerization and computation, the units of measure were transformed to British Thermal Units (BTU's) as the common denominator. (The British Thermal Unit allows for comparisons across energy sources overtime).

Operational definitions for each of the energy and household variables used, either followed U.S. Census of

Population or U.S. Department of Energy definitions. This study (including the update to 1990) is therefore a ninety year U.S. household energy history, with energy resources (for seven fuels), and household data recorded year by year. This information allows an examination of the consumption of each energy sources over 90 years; a sum of all fuels consumed, as a measure of total household energy use over the same period; as well as, measures of per-household and a per-person/per-household energy consumption. Patterns of household energy consumption and changes in patterns are examined for trends, consistencies, direction of slopes, and efficiencies found.

U.S. Household Energy Consumption History

The following discussion is an examination of each of the seven household energy sources over time, prior to a discussion of the total household energy consumption over time, as well as, the more individualized per-household and per-person/per-household historical analysis.

Fuelwood²

Prior to 1900 wood use was a very important fuel source for all energy needs (national and household) until sometime between 1875 and 1880 when coal began to out pace wood use at the national level.

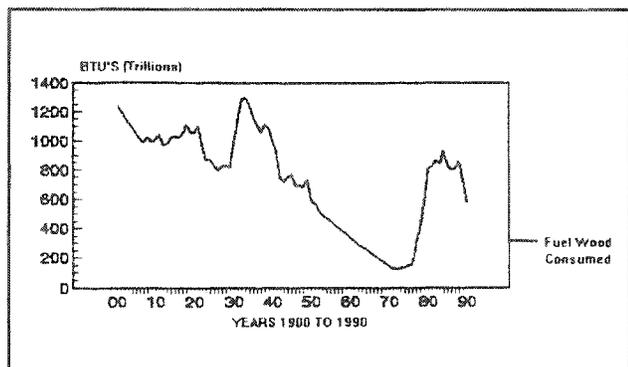


Figure 1. U.S. Household Fuel Wood Consumption. BTU's from 1900 to 1990

The peak year of fuelwood use was 1933. This peak comes after nearly 30 years of declining consumption. There was a 49 percent increase from 1929 to 1933 alone in household fuelwood use. Thus, it would appear obvious that fuelwood was being substituted for other more

expensive fuels during the depression years. During World War II slight increases in fuelwood use were also noted. And further, after nearly 20 years of declining use, fuelwood use was observed once again to be increasing in households, starting in 1973 and ending in 1984; when reductions in use were again measured.

Even as reductions in fuelwood use were being observed especially between 1988 and 1990, levels of consumption were nearly equivalent to levels of use seen in the 1920's, (prior to the depression) and again in the 1940's (during World War II).

Anthracite Coal³

Anthracite coal is a very hard, long burning and clean coal. This form of coal is primarily mined in the State of Pennsylvania and is considered a precious fuel because natural reserves have always been limited.

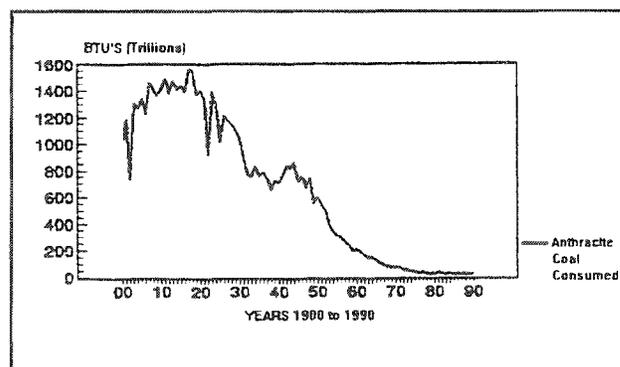


Figure 2. U.S. Household Anthracite Coal Consumption. BTU's from 1900 to 1990

Anthracite has some of the same consumption characteristics as fuelwood. For example there has been a general decline in its use, particularly since 1917-18. Major peaks in anthracite use are related to World Wars I and II. The major sharp declines (unlike fuelwood) are generally related to strikes in the coal mines. Household consumption makes up the largest proportion of anthracite use.

The years of the most substantial declines in household anthracite consumption, were 1902, 1922 and, 1949. The peak years of anthracite use for households were 1917 and 1918, and again in 1944. Between 1941 and 1944 an increase of 21 percent was noted. It is obvious that both major peaks in use of anthracite coal are related to world wars, with the added demands of war production nationally and fuel substitutions at the household level.

Increases in anthracite consumption since the Arab Embargo, 1973, have not been noted. Declines generally have been the case since 1950; therefore, anthracite coal did not become an energy crises substitution fuel (as fuelwood did).

Bituminous Coal⁴

Bituminous coal is a soft coal mined in 26 states.

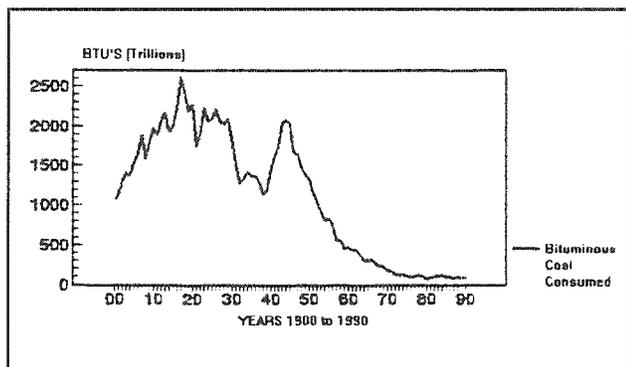


Figure 3. U.S. Household Bituminous Coal Consumption. BTU's from 1900 to 1990

Household bituminous coal consumption has always been a small proportion of the total coal consumed nationally. Although substantial variations in household levels of consumption have occurred, especially in the years to 1945, it is fair to say that there has been a general decline in use since then. The years of greatest household bituminous coal consumption were during the war years of 1917 and 1944.

A small increase of 6 percent was observed in household bituminous consumption between 1973 and 1974. This was the only increase observed since 1953; therefore, bituminous coal did not become a fuel source of substitution or transition in households since the energy crisis of 1973.

Natural Gas⁵

For many years after its initial discovery in 1821, natural gas was considered dangerous (explosive) and, basically a waste product of petroleum production. Not until the 1920's was it accepted as a cooking fuel in households. It took the development of vast pipelines and related technology, mainly after the second World War, for natural gas to become a popular, cheap, clean, substitute for coal and wood for cooking and heating in households.

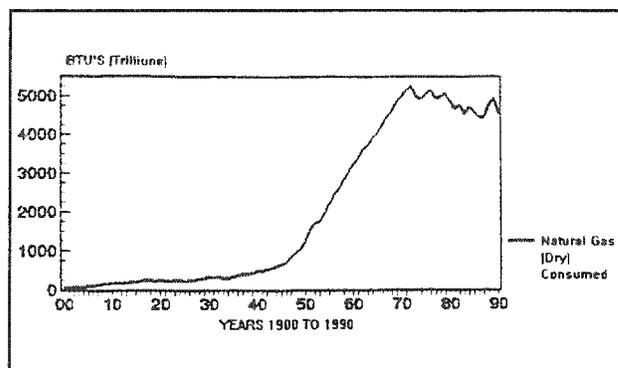


Figure 4. U.S. Household Natural Gas Consumption. BTU's from 1900 to 1990

Once natural gas was fully accepted, its use increased at the household level at near exponential rates. Until 1973 there was only one year of a decline of more than 6 percent. That year was 1921 when a decrease of 14 percent was noted. Since the peak year of 1972 substantial fluctuations in consumption of natural gas by households have been recorded. Changes in natural gas pricing (especially since deregulation in 1985), as well as, the energy crisis period (1973-1979) had an obvious, unsettling effect on natural gas use in households. By 1990, natural gas was 44 percent of all energy sources used by households, and this was a reduction from the 49 percent recorded in 1970.

Electricity⁶

Electricity is the only energy source that is not a primary fuel but rather a power source generated by other fuels (including coal, hydro, fuel oil, natural gas, nuclear and even wood). Electricity is generated at central utilities, then transmitted to the place of use.

Conversion and transmission losses account for approximately 70 percent of the total energy in electrical production, 30 percent is thus useful as an energy source directly.

The measure used within this study is the direct measure of electricity. This was done for reasons of compatibility with other energy sources used in this report. All the other sources of energy consumption in this paper are measures of direct uses; therefore, they do not reflect losses in production and transportation to the place of use.

Generally, electricity consumption (since the earliest records of use: 1903 nationally and 1910 for households) has been observed to increase at near exponential rates, with a few exceptions.

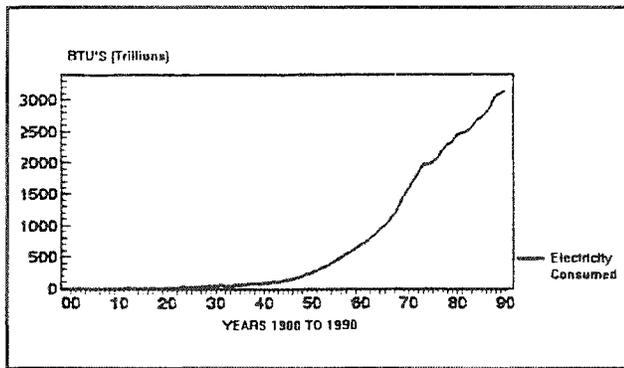


Figure 5. U.S. Household Electrical Consumption. BTU's from 1900 to 1990

Household level electrical energy uses have increased continuously since 1910. The only reduction (2 percent) in use came in 1933 during the Depression. Growth rates were particularly high in the period after World War II, between 1944 and 1954.

The peak year for household electrical use was 1990 after a slight hesitation between 1973 and 1974 (percentage increase of less than one percent) during that energy crises. By 1990 there had been a 37.2 percent increase in electrical energy consumption by households from the 1973-1974 hesitation.

Electricity was the only energy source analyzed where growth has been continuous with very few exceptions; and further, it was an energy source which has not been affected in any substantial way by wars, depression or the energy problems of the 1970s. It would appear that electricity has become the energy source of choice, capturing 31 percent of the household market by 1990 (a 16 percent increase since 1970).

Fuel Oil⁷

Petroleum consumption at the national level includes crude oil, natural gas liquid, condensate, imported oil and other products. Petroleum is not just an energy source but it is also a resource used for the production of many products.

Of all the energy sources analyzed, petroleum has become of particular importance during the period since 1973. The Arab embargo was an embargo of oil imported to the United States and other nations.

The United States produced only 12 percent of the world's crude oil in 1990, (down 3 percent from 1980). Since domestic crude production has not kept pace with U.S. consumption, imports make up the important short falls.

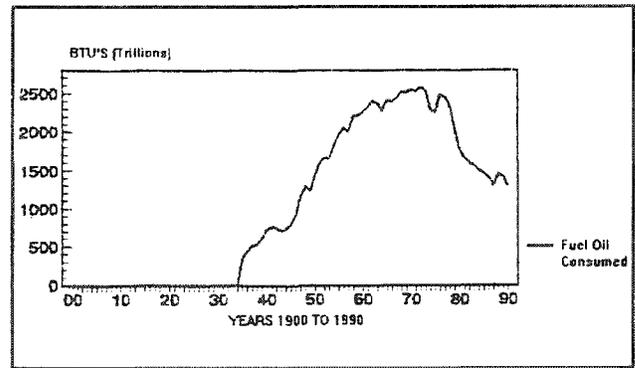


Figure 6. U.S. Household Fuel Oil Consumption. BTU's from 1900 to 1990

By 1990, petroleum imports were 42 percent of the national consumption, (although down from the 1977 peak of 47 percent).⁸ The United States is still particularly vulnerable to cut-offs or fluctuations in imported petroleum supplies as demonstrated by the advent Gulf War in 1991.

Household level petroleum consumption includes only heating oil (distillates #1, 2 and 4), residuals and kerosene, plus range oil (in the early years, 1930s to 1950s). These fuels are mainly used for heating and cooking. Household petroleum consumption generally increased up to 1972. However, reductions of household petroleum use were recorded during World War II. Reductions were also recorded after the Arab embargo, with a very substantial reduction of 50 percent occurring between 1972 (peak year) and 1990.

Liquid Petroleum Gas (LPG)⁹

Liquid Petroleum Gas is a product obtained in the processing of natural gas. Thus, this energy source is the by-product or usable waste product of natural gas cycling and fractionation. For the purposes of this study, the liquefied petroleum gases (LPG) including propane, butane, and propane-butane mixtures were measured.

Liquid petroleum gas consumption was not measured until 1922. Household use of liquid petroleum gas has been mainly limited to heating and cooking needs especially in rural areas, (also in vacation and mobile homes). Household use has increased dramatically overtime, though never more than 6 percent of total household energy use, when all fuel sources are considered. The peak year of use for households was 1979, which increased 9 percent over the initial peak year of 1973. LPG was apparently used by households, as a substitution energy source during the energy crisis period. Since 1979

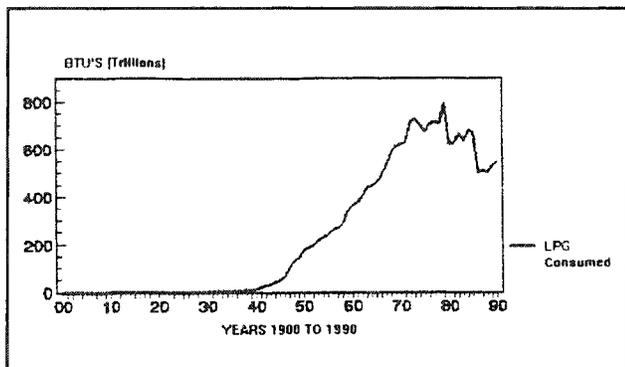


Figure 7. U.S. Household LPG Consumption. BTU's from 1900 to 1990

LPG consumption has fluctuated considerably, with 1989 and 1990 indicating a modest increase in use; however, this was an average 13.7 percent reduction in use from the 1979 peak.

Households and Energy Consumption

Household Energy Consumption Changes

Over the ninety years of this study, household energy consumption patterns have changed. Table 1 is a comparison by decades of the various energy sources as a percentage of total household consumption.

In 1900, 99 percent of the energy use was provided by coal and wood. Natural gas accounted for 1 percent.

By 1940, a greater variety of energy sources had become available to households, although coal still dominated the energy mix.

In the post-World War II years of the 1950s, the energy mix for households changed once again with the addition of LPG, the proportions within the mix also changed quite drastically. In 1950, for example, total coal accounted for 35 percent, fuelwood, 10 percent, natural gas and fuel oil became dominate for the first time at 48 percent, electricity had increased to 4 percent and LPG to 3 percent.

The 1960 household energy consumption mix, however, showed the greatest single change in proportional energy source uses. By 1960, coal (combined anthracite and bituminous) only accounted for 9 percent and wood 4 percent, whereas, natural gas by itself had increased to

43 percent, fuel oil to 30 percent. Electricity had increased in household use to 9 percent and LPG to 5 percent.

The last year of the study, 1990 finds coal almost non-existent as an energy source in households; it had been reduced from its all time high of 74 percent to just over 1 percent. Fuelwood use had increased to 6 percent by 1990. Natural gas use decreased by 1990 to 44 percent of total household use from the 1970 high of 49 percent. Electricity appears to be becoming an energy source of the future for households, capturing 31 percent of total household use. Fuel oil consumption was reduced to 13 percent of total household use by 1990, matching the level of use found in the 1930s. Fuel oil has been the energy most affected by the increasing energy prices and threats to a stable supply since the Arab oil embargo; thus households were finding substitutes for it, or simply using less of it through conservation practices. Household consumption of liquid petroleum gas (LPG) had decreased to 5 percent of total household consumption by 1990, dropping 1 percent from 1970 and 1980.

Households

Household numbers have continuously increased since 1900. Between 1900 and 1990 there was a 584 percent increase in household numbers in this country.

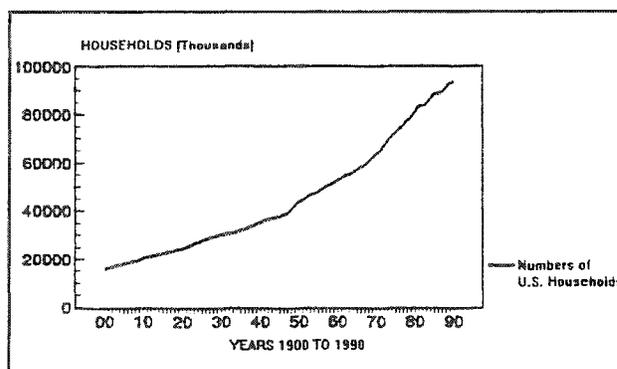


Figure 8. U.S. Households Numbers from 1900 to 1990

The years after World War II, particularly between 1947 and 1958, were years of notable increases in household numbers (baby boom). However, 1970 and 1971 were the years of the largest percentage increase in household numbers on a yearly basis (both years increased 12 percent). This trend was noted in the late 1960's and continued through 1990.

Table 1. U.S. Household Energy Consumption, By Decades, 1900 to 1990: Each Energy Source As A Percentage Of Total Household Energy Consumption

Decades	Sources						
	Anthracite Coal %	Bituminous Coal %	Fuelwood %	Natural Gas (Dry) %	Electricity (Direct) %	Fuel Oil %	Liquid Gas (LPG) %
1900	30	32	37	1	--	--	--
1910	31	43	22	3	--	--	--
1920	28	46	21	5	--	--	--
1930	25	44	23	7	1	--	--
1940	16	32	23	10	2	16	--
1950	11	24	10	22	4	26	3
1960	3	6	4	43	9	30	5
1970	1	2	1	49	16	25	6
1980	.26	1	8	46	23	17	6
1990	.22	1	6	44	31	13	5

Percents may not equal 100 due to rounding

Source: U.S. Household Energy History: 1900-1990. Data compiled by Bonnie Maas Morrison in 1979 and 1992.

Energy Consumption by All Households

Energy consumption by the aggregate number of households increased 325 percent between 1900 and 1979 (peak year). After the first peak in total household energy use in 1917, a more or less steady decline in use was noted until 1932. Levels of total household energy consumption by 1932 had declined to levels approximating levels of consumption in the early part of the century. After 1932, total household energy consumption increased with few exception. The 16 years from 1957 to 1973 was the longest unbroken trend of increases in total household energy consumption over the ninety year period.

Since 1970, fluctuations in total household energy use have ranged in and around the mean of 10,460 trillion BTU's level.

Energy Consumption Per-Household and Per-Person/Per-Household ¹⁰

Energy consumption of all fuel sources analyzed on a per-household, and a per-person/per-household basis concludes the analysis of the history of U.S. household energy consumption.

As mentioned in the initial statements in this paper, an assumption of continuous growth in household energy consumption has prevailed (the "good old days" folk theory).

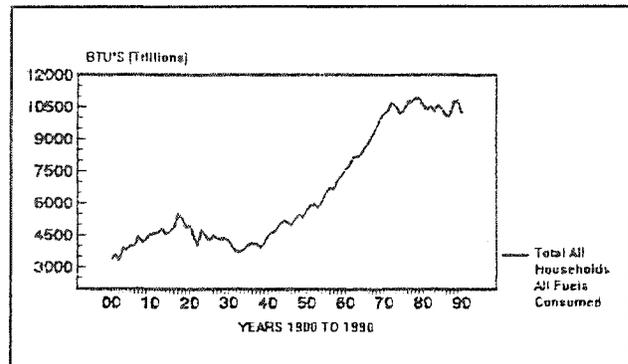


Figure 9. Total U.S. Household Energy Consumption. BTU's from 1900 to 1990

This assumption was partially refuted by the data presented in Figure 9 which indicated that substantial fluctuations in total household energy uses have occurred, particularly between 1900 and 1930. And, further that the road to the peak energy use by households in 1979, was not without valleys along the way. Between 1979 and

1990, household energy consumption has fluctuated in and around a mean of 10,460 trillion BTU's.

On a per-household basis, however, the assumptions about growth in energy consumption was completely unsupported.

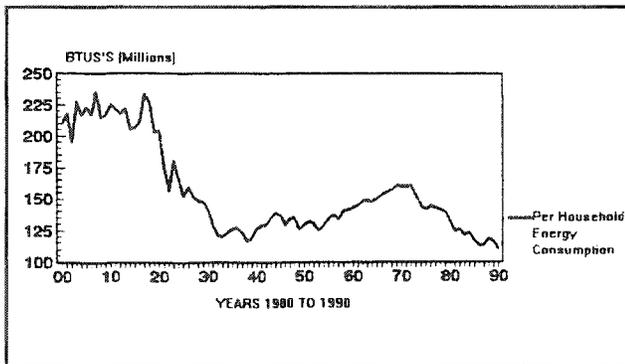


Figure 10. Per Household Energy Consumption. BTU's from 1900 to 1990

It becomes apparent that on an individual household level, energy consumption has been substantially reduced since the early parts of the century and, further, that energy consumption on a per-household basis is still far below the peak uses found in 1907 (236 million BTUs) and 1917 (234 million BTUs), even when secondary peak use in the late 1960s and early 1970s were reached (161 million BTU's in 1969 and 1972).

Total energy consumption on a per-household level decreased 52 percent between 1907 and 1938, and nearly 51 percent between 1917 and 1938. Nineteen-thirty-eight is the year of least per-household energy consumption with 116 million BTUs measured. The peak total per-household energy consumption levels of 1969 and 1972 (161 million BTUs) were still 31 percent below the all-time peak of 1907. In fact, it was about the same level of energy consumption noted in 1924. By 1980, per-household total energy consumption was reduced even further from the 1969 and 1972 peaks, mirroring levels observed in 1951.

The most amazing observations from this update of U.S. household energy consumption are: 1. that the individual household energy consumption was reduced 16.7 percent between 1980 to 1990, and 2. that a 53 percent reduction was observed between 1907 (peak year) to 1990.

Table 2 also indicates the per-person/per-household energy consumption by decades. On a per-person/per-household basis it was interesting to note that the magnitude of

difference in energy use was not great. It ranges on a per-person/per-household basis from 34.2 million BTUs in 1930 to 50.4 million BTUs in 1970. This amounts to a mean difference of 43 million BTU over the ninety years. The per-person/per-household BTUs consumed in 1990 were near levels consumed in 1960.

Discussion and Some Speculations

"What We Know Now."

"We know" that total U.S. household energy consumption has increased 325 percent over the period from 1907 (peak year) to 1990. That was a 3 fold increase over the ninety years. We also know that since 1980 total household energy consumption has been near steady-state, with fluctuations in and around a mean of 10,461 trillion BTUs. The peak year of total household energy consumption in the U.S. was 1979 (10.9 Quad. BTUs). By 1990 a 6.4 percent decrease (to 10.2 Quad. BTUs) had been observed. This nearly steady-state household energy consumption is not all bad (at least there has not been any drastic overall energy consumption increases). This state of affairs does suggest that perhaps some technologies, programs, and policies (even household energy related behaviors) have "kept the lid on" household energy consumption. But is it enough to just "keep the lid on?" What needs to be done to break through this pattern of household energy consumption, to actual meaningful reduction in overall energy use?

"We also know" that household numbers have increased by 584 percent (nearly 6 fold increase) over the ninety year period, and "we know" that the numbers of persons per-household have decreased from 4.76 to 2.63 in the same period.

And, finally, "we know" that on the individual household level, a 53.6 percent reduction in overall energy consumption has occurred between 1907 (all time per-household energy peak) and 1990. And, this is in spite of the 6 fold increase in households, and the reduction of 2 persons (on average) living in each household. Since 1980, per-household energy consumption has been reduced 16.7 percent, while a 13.5 percent increase in households has been observed.

Does this mean that in spite of a increase in households demanding energy in more and more individual housing units, that the household has become substantially more energy efficient in their purchase decisions, management, and daily activities? Or has the design and implementation

Table 2. U.S. Household Energy Consumption 1900 To 1990: Millions Of Btu's Per-Household And Millions Of Btu's Per-Person/Per-Household

<u>Years</u>	<u>BTUs In Millions</u>		
	<u>Per-Household</u>	<u>Per-Person/ Per-Household</u>	<u>Average Household Size</u>
1900	209	44.0	4.76
1910	225	49.6	4.54
1920	204	47.0	4.34
1930	141	34.2	4.11
1940	126	34.4	3.67
1950	129	38.3	3.37
1960	143	42.9	3.33
1970	160	50.4	3.17
1980	131	47.8	2.76
1990	110	41.6	2.63

Source: U.S. Household Energy History: 1900-1990. Data compiled by Bonnie Maas Morrison, in 1979 and 1992.

of energy efficient technologies (smart thermostats, energy efficient appliances and equipment, etc.) and/or building science breakthroughs created the efficiency evident here? Or, has some of the energy not measured in individual households gone elsewhere? Think of the conveniences required for today's dual-earner,¹¹ single-parent/multi-job holding households.¹² Think of the eating-out phenomenon, think of the pre-packaged, pre-prepared meals (from freezer, to micro-wave, to table, to garbage can, all in one container). Think of the transportation to and from places of work, shopping and leisure demanded by these households. Think of the energy demanded in these places of work, leisure, and retail. Think of the energy demanded to process the waste products of this "convenience."

"Time itself has become a commodity"¹³ and "convenience" has become the oil that lubricates the wheel of time, allowing more activities, to take place either at one time in the same place (i.e., using the cellular car phones while driving), or in a particular time period but in a different place (i.e., doing grocery shopping, while dishes or clothes are machine washed).

In the book, The Overworked American, 1991, Juliet Schor suggests that "U.S. employees currently work 320 more hours—the equivalent of over 2 months—than their counter-parts in West Germany or France."¹⁴ This American lifestyle demands convenience, and that demand

is exercised both inside and outside the household. My speculations are that the reduction in individual household energy consumption overtime, are most likely due to:

1. The non-use of the place of residences, while the household is engaged in work, leisure and/or consumption activities (i.e., shopping).
2. The use of convenience products in the time spent at home (take-out, home delivered/or pre-prepared foods are examples).
3. Some measure of the adaptation and use of energy efficient technologies, equipment and/or building techniques.

All of this leads to the next questions, "where should we be heading?"

I think a major investigation needs to be mounted to understand the "displacement of energy" consumption from the household to "other" sectors of the economy. This needs to be done in order to understand the energy, and yes, even the environmental cost of convenience.

Only when such research is completed will we understand what this U.S. household energy consumption study measured. Was it energy efficiency or displaced energy or both?

Acknowledgments

1. Mertie W. Buckman, whose Professorship I hold, College of Human Ecology, University of Minnesota.
2. U.S. Department of Energy, for the Visiting Scholarship in 1978 and 1979, that made the initial study possible.
3. University of Minnesota and Michigan State University Agricultural Experiment Stations, funded aspects of the analysis.
4. U.S. Department of Energy's Energy Information Administration for publications and expert consultation from Lynda T. Carlson, Wendal L. Thompson, Eugene R. Slatick and Kathleen Cavanaugh.
5. Expert consultants: Jack Alterman, Senior Scientist Resource for the Future (now retired); Donald Davidson and Ray Cairnes, Reading Anthracite Coal Co.; Ken Skog and Robert Phillips, U.S. Department of Agriculture, U.S. Forest Service.
6. Judy Pfaff, expert computer programmer over the 10 years of this research.
7. Marty Haywood, expert manuscript word processor.
4. Bituminous Coal heat conversion factors used were: 26,200 BTU's/short ton, from 1900-1948, then the heat content given in DOE/EIA-0384(90), p. 296 for 1949-1990 was used.
5. Natural Gas heat content was a given in H.S., Vol. I (see references) pp. 587-88 for 1900-1948, then the heat content listed in DOE/EIA-0384(90), p. 294, for 1949-1990 was used.
6. Electrical heat content was 3,412 BTU's per KWH for the whole series. This is a measure of direct electricity only.
7. Fuel oil heat content used the following conversion factors for the whole series:
5,825 million BTU's per barrel for #1, 2 & 4 heating fuel
5,670 million BTU's per barrel for #1 range oil and kerosene
6,287 million BTU's per barrel for residual fuel oil.

Endnotes

1. This research was initially developed during a sabbatical leave from Michigan State University, while a Visiting Scholar in the U.S. Department of Energy's Historian's Office. 1978-79.
2. Fuelwood heat content factor used for the whole series was 258,760 BTU's per cubic feet (a measure of round-wood only) per consultations with Jack Alterman in 1979 and 1992). All roundwood consumption was assumed to be household consumption. (via Alterman and Skog, 1992).
3. Anthracite coal heat content factors were 25,400 BTU's/short ton from 1900 to 1948, as per R.F.F. pp. 511-13. (see references) and as per DOE/EIA-0384(90) p. 296 from 1949 to 1990. Proportion of anthracite consumption allocated to households varied over the series from 60 to 75 percent of retail deliveries, as per personal consultations with Jack Alterman (1979), Herbert Foster, American Coal Association (1979), and Ray Cairnes, Reading Anthracite Coal Co. (phone consultation 3/2/92).
8. The information used to calculate the U.S. proportion of crude oil production in 1990 was DOE/EIA-0384(90), pp. 2, 4 and 259.
9. Liquid Petroleum Gas (LPG) heat content used the following conversion factors; as per DOE/EIA-0384(90) p. 291:
4,326 million BTU's per barrel for butane
4,130 million BTU's per barrel for butane-propane mixture (60%/40%)
3,836 million BTU's per barrel for propane.
10. Per-household energy consumption for the whole series was calculated by dividing the total household BTU's (trillions)/year by the total number of households (millions)/year. Per-person/per-household energy consumption was calculated by dividing the per-household BTU's/year by the average number of persons per household/year.
11. "By 1990, two-thirds of married American women were participating in the labor market," p. 25 in Schor (see references).
12. Senauer, et. al., 1991 (see references), pp. 2-5, and 106-111.
13. See Le Goff in references.
14. Schor, op. cit., p. 2.

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