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POTENTIAL FOR CARBON DIOXIDE EMISSIONS REDUCTIONS IN BUILDINGS

Vicki Norberg-Bohm

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The Global Environmental Policy Project (GEPP) began in 1989 as a joint effort of the Kennedy School of Government's Energy and Environmental Policy Center (EEPC) and its Science, Technology and Public Policy Program (STPP), and the Harvard Business School Negotiations Project. The Global Environmental Policy Project focuses on four subjects:

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  The analytical tools that we use to evaluate environmental impact and mitigation options were developed to combat problems with local impact and short time frames. These tools are not adequate for the examination of issues, such as global climate change, which are characterized by long-time horizons, tremendous factors of uncertainty, and a broad spectrum of perceptions among nations. The Project is developing a range of analytical techniques for the evaluation of policy options to provide governments with decision rules to assist in their selection among these options.

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  The Project is attempting to develop an executive program to teach senior government officials how to assess and manage global and regional environmental problems.

POTENTIAL FOR CARBON DIOXIDE EMISSION REDUCTIONS IN BUILDINGS

BACKGROUND REPORT FOR

OFFICE OF TECHNOLOGY ASSESSMENT

CLIMATE CHANGE STUDY

by:

Vicki Norberg-Bohm

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Kennedy School of Government
Harvard University

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IV. POLICIES TO REDUCE U.S. EMISSIONS

Reducing CO_2 emissions from buildings is a multifaceted problem. As discussed in Chapter II, in order to achieve net reductions over the 25-year time frame of this study, emissions must be cut in both the residential and commercial sectors, from both new and existing buildings. More efficient equipment, appliances and lighting are required, as well as increased thermal integrity of the building shell. Policies must affect the actions of a large number of decision-makers, including building owners, renters, landlords, architects, engineers, designers, builders, construction workers, manufacturers, retailers, appraisers, building inspectors, and lending institutions. Policies will need to address changes in both purchase and usage decisions. And finally, as will be discussed below, there are a variety of barriers which prevent greater investment in energy efficiency. No single policy will be able to address all of these technical options, decision-makers or barriers. The problem of reducing CO_2 emissions from the buildings sector is amenable only to a combination of solutions. Equally important, many of the policies have synergistic effects, making the whole greater than the sum of the parts.

This section begins with a discussion of the barriers to greater investment in conservation in the buildings sector. It then turns to a discussion of policy options for achieving the potential reductions. The emphasis will be on policy to promote energy conservation, as it provides the greatest opportunity for emission reductions in the near term. This analysis looks specifically at policy tools available to the federal government. The policies which offer the greatest potential for reducing emissions in the buildings sector are end-use taxes, initial purchase taxes, utility least-cost planning, appliance standards, building codes, consumer information programs such as appliance labeling and home energy rating systems, and government sponsored R&D. Additional policies which can contribute

to the reduction of CO_2 emissions from buildings are financial incentives such as loan policies, tax credits and subsidies, energy conservation in federal buildings, technology demonstrations and government procurement. After the discussion of policy options, there is a brief discussion of policy regarding fuel mix. This section ends with a discussion of the relationship between policies to reduce CO_2 emission and other policy goals.

A. Barriers to Investment in Energy Efficiency

Consumer purchase decisions indicate that minimization of first costs is often more important than life-cycle costs. Another way of stating this is that the implicit consumer discount rates are significantly higher than real interest rates or the discount rates commonly used in public decision-making. For example, market discount rates for refrigerators and freezers have been calculated between 78% and 278%.[84] The factors contributing to the high discount rate include: inadequate or unreliable information[85]; the time and effort required to make such investments (i.e., the hassle factor); inadequate capital to cover first costs; uncertainty regarding future energy prices, costs, liability, reliability and marketability; and the choice of products on the market (the trade-offs for energy efficiency require trade-offs on other product characteristics as well).

Similarly, conservation often takes a low priority when competing for corporate funds, for a variety of reasons including the high cost of finance, cash flow concerns,

[84]DOE, November 1988. Draft regulatory impact assessment, p. 5. An analysis of market discount rates by Ruderman et al., 1984, found discount rates ranging from 10% to 200%. High discount rates also bring into question the paradigm of the consumer as a rational actor. Discussions of the problem of using this paradigm to describe or predict consumer action are discussed in Komar and Wiggins, 1987 and 1988-1989, and Hirst. et al., 1986, p. 127-130. This theoretical issue will not be addressed in this paper. For the purposes here, it is sufficient to recognize that the high discount rate implies that issues other than price and operating costs are important, and must be duly considered when formulating policy.

[85]Consumers are often ill-informed about the most cost-effective energy improvements for their homes and have inaccurate perceptions about the major energy users in their homes (Kempton, et. al., 1984).

inadequate expertise for evaluating energy-saving options, the hassle and risk of energy conservation investments, and better use for capital in terms of their bottom line.

The problem of emphasis on first costs is exacerbated by the fact that often builders and owners make purchase decisions while buyers or renters pay the energy bills. Builders' purchase decisions are dependent on first cost, and are most affected by interest rates. They base this on consumer behavior: while consumers say they are concerned with energy conservation, their purchase behavior shows that other, more visible features are more important, including first cost. Builders also share consumers' concern over the uncertainty regarding prices, costs, liability, reliability and marketability. Similarly, landlords have little incentive to invest in energy efficiency if the tenant is paying the utility bills. In addition, because the average tenant stay in U.S. buildings is short, tenants generally have little incentive for investing in energy efficiency.

Financial arrangements that overcome the first cost barrier are not generally obtainable for either new buildings or retrofits. Such arrangements would entail lower down payments based on the fact that higher monthly payments would be affordable with reduced utility bills.

Subsidized housing is a special case in which initial capital costs impose a barrier to energy efficiency. Much of the public housing stock is in need of major rehabilitation, not just energy efficiency improvements. But the financing is not available for major rehabilitation, so energy efficiency improvements are not funded either. This creates a situation where public funds are used for energy subsidies to pay for energy use in inefficient housing. If money could be invested in energy savings, it would reduce energy use and the costs to society in the long run.[86]

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[86]Ritschard and Dickey,

There are also technological constraints on greater residential building energy conservation. The vast majority of the residential construction industry is composed of small and diverse firms. The regulation of the industry is through state and local governments, which results in non-uniform building codes throughout the country. In addition, there are wide swings in demand in the construction industry. These factors prevent investment in R&D, make the training of architects, engineers, builders and construction workers in new techniques of design or construction difficult, and suppress the introduction of techniques requiring high capital investments (such as manufactured housing). Yet investment in research and in manufactured housing could be major factors in creating more energy-efficient housing, as has been the case in both Sweden and Japan.[87]

In the commercial sector there is also a problem with the retraining of design and construction professionals as new products, building methods, and design tools become available.

Finally, energy pricing is a significant barrier to optimal investment in conservation and non-fossil sources. Energy, particularly electricity, is often priced below marginal cost. This prevents consumers from getting the correct price signals. Thus, even if first cost barriers are overcome, if this market failure is not overcome, there could be underinvestment in conservation and renewables. In addition, the costs and risks of CO_2-induced climate change are not adequately represented in market prices. Although difficult, if not impossible, to quantify, including a cost for climate change in energy prices would increase investment in conservation and renewables.

[87]U.S. Congress, OTA, 1986.

B. Policy Options for the U.S.

1. **Energy Use Tax**

Energy use taxes would increase the price of energy, thus bringing the price more in line with the social marginal cost, and accomplishing the goal of lower energy consumption. The experience of the energy price shocks of the 1970s demonstrates that energy price increases, and the belief that prices will stay high or continue to increase, will stimulate energy conservation. Experience also shows that price increases of one fuel relative to another will help determine fuel choices.

Energy use taxes would be a per unit tax on energy consumed, i.e. on a per kWh or per BTU basis. For climate change, it would be best if this tax were based on the CO_2 emissions of various fuels, resulting in a higher tax per BTU of coal than natural gas. In this way, it would create incentives for the choice of fuels as well as the usage level.

One of the great advantages of an energy use tax is that it will affect consumer decisions in both the retrofit and new building markets. Theoretically, it will affect purchase decisions as well as use decisions. If this were a "perfect market," taxes would undisputably be the most efficient method for reducing energy use.

As discussed under barriers to investment, this is not a "perfect market." Taxes do not address the lack of information, uncertainty, divergent incentives between purchasers and user, and the resulting high market discount rate. Thus, they may not be as effective as measures such as initial purchase taxes, appliance standards, and building codes in influencing consumer purchase decisions. The large number of highly cost-effective energy-efficiency investments that are currently not chosen by consumers provide evidence that price alone will not stimulate optimal investment in conservation.

An energy use tax raises significant equity questions. Poor households spend a proportionately larger share of their income on utility bills. They are the same households which are likely to live in less energy-efficient housing and not have the resources to invest in new, more energy-efficient appliances. Any large increase in energy taxes will need to be accompanied by provisions to help low-income households overcome the increased burden.

The amount of energy that will be saved for a given increase in price is often expressed in terms of elasticities. Price elasticity is defined as the percent change in quantity of energy consumed for a given percent change in price. Analogously, income elasticity is defined as the percent change in the quantity of energy consumed for a given percent change in income.

For energy, the ability to respond to price changes differs substantially between the short and the long run. Short-run elasticities are lower than long-run elasticities, as the ability to adjust is more limited. In the short run, opportunities for reducing emissions are mostly from cutting back on usage. This requires new habits and may result in some loss of amenity. In the long term, there is an opportunity for changing capital stock to more efficient buildings and appliances.

Due to these differences in short-term and long-term elasticities, a large energy use tax is least disruptive if it is phased in, i.e., levied in installments over a number of years. This reduces the shock of the tax to consumers by allowing them to plan for higher energy costs in their current purchase decisions. It also gives manufacturers an opportunity to adjust to the new market. The expectation of a continuing rise in prices provides an additional incentive for energy efficiency.

Many studies have been undertaken to measure elasticities. A review of these studies shows a great variance in the elasticity estimates.[88] There are enough independent studies to draw a consensus estimate for the residential sector, but not for the the commercial sector. The residential electricity short- and long-run elasticities are -0.2 and -0.7, respectively. The residential natural gas short and long run elasticities are -0.2 and -0.3, respectively.

Edmonds and Reilly evaluate elasticity estimates for the combined residential/commercial sector. They conclude that the consensus long-term aggregate price elasticity of demand is -0.5, with estimates between -0.3 and -0.9. The long-term income elasticity consensus is 0.9. with estimates ranging from 0.3 to 1.6.[89] Income elasticities for energy are generally around 1.

Using this range of elasticities, several estimates based on different levels of of tax increases and income growth rates are given in Table 21. These estimates demonstrate that large tax increases will be necessary to offset expected income and population growth, and also that the range of elasticities given by Edmonds and Reilly result in very different estimates of the effect of a given tax rate on energy savings.

While the tax needed to achieve substantial savings in energy use may seem unpalatably large, lower taxes will still move the market in the correct direction. Any tax increase can have symbolic value and be part of a package of programs which raise consumer awareness of energy use and energy conservation opportunities.

Forecasts relying on elasticities must be interpreted with great caution. Elasticities are applicable to only a small range of a demand schedule. Thus, large changes in either

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[88]Bohi and Zimmerman, 1984.

[89]Edmonds and Reilly, 1985.

TABLE 21: CHANGE IN ENERGY CONSUMPTION FROM ENERGY USAGE TAX

Price Elasticity	Income Elasticity	Tax Rate (%)	GNP Growth (%/year)	Change in Energy Consumption (b) (after 25 years)
-0.5	0.9	50	2	27
-0.5	0.9	100	2	10
-0.5	0.9	200	2	-10
-0.5	0.9	50	1	2
-0.5	0.9	100	1	-12
-0.5	0.9	200	1	-28
-0.3	0.9	50	2	38
-0.9	0.9	50	2	8
-0.5	0.3	100	2	-18
-0.5	1.6	100	2	56

(a) Income elasticities are assumed to be GNP elasticities which include the effects of both increased personal income and growth in the sector, i.e., increased commercial floorspace and number of households.
(b) Assumes constant elasticity function.

income or price may not be appropriately described by the estimated elasticities. In addition, elasticity estimates are based on historical data and thus incorporate past innovation and technological change. It is fair to ask, is this a good guide to the future?[90]

2. Initial Purchase Tax

An initial purchase tax would place a lump-sum tax on appliances and equipment (and possibly buildings and homes) at the time of purchase. This tax could either be proportional to the amount of CO_2 the product would release in the expected lifetime, or to the energy-efficiency level of the product. A tax based on CO_2 emissions would provide incentives for purchasing less polluting equipment and for choosing lower-CO_2 fuels. A tax

[90]For a discussion of elasticities, see Edmonds and Reilly, 1985.

based on energy efficiency would send signals to conserve energy without targeting the fuel type. The latter would be much easier to implement, as the CO_2 from electricity use is very region-specific, causing diffculties for the labeling and taxing of nationally manufactured items.

An initial purchase tax could be applied to all equipment and appliances, to only the most polluting, analogous to the "gas guzzler" tax, or on a revenue-neutral basis. A revenue-neutral tax would collect a fee on the most polluting (least efficient) items and provide rebates for the less polluting (more efficient) items, giving even greater incentive for investments in highly efficient technologies.

The great advantage of an initial purchase tax is that it will send the appropriate signals regarding consumer purchasing decisions. Because consumers make decisions based largely on first cost, a tax which is experienced entirely at the time of purchase will have more influence on purchase decisions than a usage tax. This would also send the proper signals to those who make purchase decisions, such as speculative builders and owners of rental property, but who are not the final end-users. It is important to note that this type of tax does not affect use decisions -- i.e., the marginal cost of usage has not changed. Thus, consumers may purchase more efficient appliances but not change their usage. Energy usage could increase; with a more efficient appliance (and no tax on energy use) more energy can be used for the same net cost to the consumer.

The applications of an initial purchase tax to equipment and appliances are relatively straightforward. The application to homes and buildings is a bit more complex, and would require some type of energy audit to determine the CO_2 emissions level. One method for applying such a tax to home and commercial building purchases is through a utility hook-up fee. This could be used for new buildings and for existing buildings at the point of sale

and/or rental.

Measures which increase the purchase price of all equipment may have the effect of keeping older equipment in place longer: i.e., by postponing consumer purchases. On the other hand, if an initial purchase tax is combined with an energy use tax, this problem could be mitigated. Also, a revenue-neutral tax which lowers the price of more efficient appliances may counteract this possiblity.

This tax also raises difficulties for low-income groups. A significant increase in the cost of new appliances and equipment will put them out of the reach of many consumers. Thus, those who are least able to afford new equipment will be burdened with the higher energy costs of older, less efficient appliances. A revenue-neutral tax would overcome the worst aspects of this problem.

3. Utility Least-Cost Planning

Least-cost planning (LCP) refers to a process which evaluates both supply- and demand-side options in determining how to meet electricity needs at the lowest cost to society and rate-payers. Supply-side options refer to all types of electricity generating plants. Demand-side options are energy conservation and load management. Least-cost planning is also known as integrated resource planning (IRP) because it creates an environment where traditional supply technologies must compete with energy conservation, renewables and cogeneration.

Least-cost planning is an excellent method for reducing energy use and the resulting CO_2 emissions in the buildings sector for several reasons:

(1) Many energy efficiency investments are less expensive than new supply, making them economically attractive.

(2) Utilities traditionally have a longer time horizon than consumers (i.e., a lower discount rate), and thus can make investments which are socially desirable but not attractive to consumers.

(3) Utility programs can be aimed at both equipment efficiency and building shell improvements, and at both new and retrofit markets. The ability to reach retrofit markets is particularly attractive because they are difficult to reach through building codes.

(4) Many of the conservation techniques in the buildings sector are proven and can offer the type of reliability desired by least-cost planning. A prime example of this is lighting in commercial buildings.

(5) There is already considerable support for LCP by many state energy offices, state legislatures, and public utility commissions.[91] In addition, some utility companies have recognized the cost advantages of demand-side resources and are supportive of LCP.

Three issues that must be addressed for LCP to stimulate significant investment in conservation are proper incentive structures, methods for incorporating demand side resources into utility planning, and the appropriate price to pay for demand-side resources. Creating proper incentive structures is the most pressing issue. The current cost-of-service regulation provides a disincentive for investment in conservation, as utility revenues and rate-of-return are dependent on the number of kWh's sold. Methods to address this problem include:

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[91] For a discussion of state initiatives in least-cost planning, see Shapiro, L., Marlowitz, P., Hirsh, N., Dec. 1987.

(1) A volume-of-sales adjustment which adjusts retail prices when the level of sales forecasted differs from actual sales (California).

(2) A higher rate of return on conservation investments (Wisconsin).

(3) Shared savings between customers and shareholders (New Jersey Board of Public Utilities).

(4) A performance contract bonus, in the form of increased rate of return, increased prices, or an expanded concept of the rate base.

(5) Comparative bill earnings in which the performance of a utility would be measured by comparison to other utilities in the region, with a higher rate of return available to utilities that are above average.[92]

As regards the appropriate price for utilities to pay for conservation, some argue that it should be the full avoided cost (i.e. the marginal cost of electricity), while others maintain that it should be the difference between the marginal cost of electricity and the average cost of electricity. As regards the method for including demand-side resources, this can be through an integrated bidding scheme which includes both demand and supply resources, through a separate bidding scheme for demand-side resources, or through utility-sponsored programs.[93] The issues to be addressed by any pricing and implementation scheme are how to achieve the most efficient level of investment in conservation, and how to avoid overpayment for conservation and transfers between customers.[94]

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[92]For a discussion of the comparative bill earnings scheme, see Moscowitz, 1988. For discussion of all of these options, see Cicchetti, May 1989.

[93]In 1988, FERC released a NOPR (Notice of Proposed Rulemaking) which called for bidding schemes for supply-side resources and solicited comments on including demand-side resources in these schemes.

[94]For detailed discussion of these issues see Nemzo, 1988 and Cicchetti, 1989.

The regulation of electric utilities is shared by the federal and state governments. The Federal Energy Regulatory Commission (FERC) has jurisdiction over wholesale transactions. This includes any electricity that crosses state lines, thus giving FERC jurisdiction over sales for interstate holding companies and power pools. There is a history of tension over the sharing of jurisdiction for electricity planning. States would prefer minimum interference from FERC. Yet, they recognize that FERC decisions can have a significant effect on state planning.

The Congress can play a powerful leadership role in the direction of utility planning through legislation which guides FERC. This is most apparent in the Public Utilities Regulatory Policies Act of 1978 (PURPA), which required utilities to purchase electricity from qualifying facilities at avoided cost. Qualifying facilities include cogeneration and renewables.

There is currently much state initiative around demand-side planning. Different approaches may be most appropriate to different utilities, states, or regions. We are near the beginning of a learning curve, where it is useful to let diversity flourish. Thus, any federal legislation would ideally be general enough to allow states flexibility in implementation, while specific enough to have a truly positive impact on conservation. This recipe is not easy to find.

Federal legislation to promote utility investment in demand-side resources could take several forms, including:

(1) Require states to formally consider demand-side resources in their planning.

(2) Require least-cost planning for utilities whose projects fall under the jurisdiction of FERC. In other words, require FERC to use planning as well as project approval. This means that when a utility comes to FERC to get a new source of supply

approved, both the selling and buying utility must show that it has considered conservation as an alternative, and rejected it because it was not the least-cost option.

(3) Require all utilities to use least-cost planning.

(4) In addition to requiring least-cost planning, determine a cost for the environmental externalities of supply-side options which is to be used when evaluating least-cost options. Or alternatively, define least cost as the least expensive way of reaching a specified emission reduction.

(5) Require all states to develop a method for making demand-side investments equally attractive to supply-side investments. In other words, resolve the incentive issue.

The potential impact on conservation increases from option (1) to option (4). Option (1) provides a statement of leadership; it shows support for the inclusion of demand-side resources without requiring implementation. For options (2) through (4) to be successful, the legislation must carefully define least-cost planning. This would require a specification of the method for determining the appropriate price for conservation (i.e., avoided cost or marginal cost minus average cost), or a process to be used to establish the appropriate price.

Option (5) is another way of approaching the goal of having all utilities use LCP. It approaches this goal by removing the disincentives to investment in demand-side resources. However, putting supply- and demand-side resources on equal footing may not overcome the institutional resistance to demand-side investment. Option (5) could be used in conjunction with any of the other options.

Regardless of whether Congress mandates some form of utility investment in conservation, the federal government has a key role to play in promoting LCP by helping to resolve the issues of incentive, price and implementation. This can be achieved by providing funding for evaluation of the various approaches and forums for the exchange of ideas between states and utilities which are trying out different approaches.

How much conservation can be achieved through utility programs? Experts give a range of answers to this question. The cost-effective conservation that is achievable will vary depending on the utility. Even for the utilities which are aggressively pursuing conservation, current programs are projected to reduce the rate of growth, but not to reduce electricity sales from current levels. There are at least three explanations for this. The first is the problem with incentive structure as described above. The second is institutional: utilities do not see their mission as selling conservation. Utility planning has traditionally been aimed at adding resources to meet projected demand. The third is that, in many cases, conservation cannot compete with the marginal cost of existing capacity as long as the costs of environmental externalities are ignored.[95] The result is that conservation is most attractive as a way to reduce demand for utilities facing a supply shortage.

Utility least-cost planning can be used quite successfully in conjunction with appliance or building standards. Standards are not likely to be set high enough to capture all of the cost-effective conservation. Thus, standards can be used to establish a floor and keep the least efficient appliances, equipment and buildings off the market. Utility programs can then be aimed at exceeding the standards.

[95]This is not always the case. An analysis of Michigan's demand-side resources indicates that at a 7% discount rate, significant amounts of conservation are less expensive than short-run marginal costs of generating electricity. See F. Krause, et al., 1988.

4. Appliance Standards

As discussed previously, for a variety of reasons, consumers, builders and landlords all emphasize first cost when purchasing appliances. Standards overcome the problem of the consumer's emphasis on first cost by requiring investment in conservation. They also overcome the tendency of manufacturers to give low emphasis to conservation in design trade-offs. Thus, standards benefit society by moving the market closer to minimizing life-cycle costs -- that is, by bringing the market discount rate closer to the social discount rate.

Standards can achieve larger energy reductions than many other policy interventions. A DOE model comparing performance standards to the policy alternatives of tax credits, rebates, enhanced labeling and consumer education, and voluntary energy efficiency targets concluded that performance standards result in significantly higher energy savings than the other methods.[96]

A general concern regarding standards is that they are not economically efficient. This problem is minimized with the current appliance standards for two reasons: (1) The current standards identify a large number of classes of appliances, for example, 10 classes of refrigerators. Standards are set for each class separately. Standards based on this type of market segmentation are unlikely to restrain consumer choice, as they do not prevent higher-amenity appliances, which might use more energy, from being manufactured. (2) The current standards are performance-based (i.e., mandate the level of energy use). This allows for energy reductions to be met in the least costly manner, and thus encourages innovation. For appliances, there is no rationale for prescriptive standards (i.e., mandating specific technologies to be used).

The National Appliance Energy Conservation Amendments (NAECA), which were

[96]DOE, Nov. 1988.

passed in 1988, set minimum energy performance standards for home equipment and appliances. These standards are expected to lower residential energy use by about 0.9 quads by the year 2000.[97] As shown in section II.F., the level of current standards does not come near fully exploiting the potential for emissions reductions through appliance efficiency improvements. NAECA requires a review of standards twice during the 1990s. A review of the standards for refrigerators, small gas furnaces and television sets is currently under way. Reviews provide an opportunity to obtain further energy reductions through more stringent standards.

The current standards are set based on a payback of 3 years.[98] More stringent standards could be adopted if equipment prices fall or energy prices rise, thus making more efficient equipment cost-effective under the current 3-year payback rule. Alternatively, a longer payback or a life-cycle costing rule could be used to set the standard. Because the current economic analysis does not include the costs of environmental externalities, more stringent standards could be justified as a way of reflecting these social costs.

In their current form, standards are used to set a floor which keeps the least efficient appliances off the market. In order to achieve the potential emission reductions from appliances, it is necessary to beat this floor. One possibility is more stringent standards, as discussed above. However, it is very difficult to pass standards with paybacks greater that 3 years. Another approach is to use standards to get the worst energy-guzzlers off the market, and then provide incentives to beat the standards through utility programs,

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[97]Geller, 1988b.

[98]The NAECA amendments define all energy-efficiency improvements with a payback of 3 years or less as economically justified. Any paybacks greater than 3 years must be shown to be economically justified.

appliance labeling, and tax schemes.

By creating a market for beating the standards through utility and consumer information programs, standards can be tightened over time without great hardship, as much of the market will have already beaten the existing standards. In this way, standards can continue to play the role of removing the least efficient equipment and appliances from the market, while other policies are used to encourage innovation.

Standards are currently set based on energy consumption. In considering the problem of climate change, standards based on CO_2 emissions would be more desirable, as they would establish incentives regarding both fuel choice and energy efficiency. However, this approach is entirely impractical. Different utilities have different fuel mixes, making a national standard nearly impossible for electric appliances. Thus, national appliance standards are not an appropriate instrument for addressing the question of fuel choice.

Finally, appliance standards are not effective in consumer usage decisions. In fact, if more efficient appliances translate into lower utility bills, there may be some increase in energy use.

5. Building Energy Codes

Building energy codes serve a function analogous to that of appliance standards by preventing the least efficient buildings from being constructed. Similar to appliance standards, they work well with other policies such as utility programs, building rating systems, and tax schemes. Building energy codes are an important component of policy for reducing CO_2 emissions because they capture what would otherwise be a lost opportunity. Retrofitting buildings is much more expensive and less effective than incorporating efficient

designs in new buildings.[99]

For energy efficiency in buildings, it is important to have a choice between performance and prescriptive standards. Performance standards mandate the level of energy use. A performance standard encourages innovation and economic efficiency, as there is an incentive to look for the least expensive method of meeting the requirements. Prescriptive standards mandate that specific technologies be used. For example, in buildings they might specify the thickness of insulation for walls and roofs. In the buildings sector, prescriptive standards are easier to implement and enforce. For many common homes and buildings, it is less expensive to use standard specifications than to customize and meet a performance standard. Perhaps more significantly, the capability to implement performance standards does not currently exist for many builders, designers and inspectors.

Building codes have traditionally been under the jurisdiction of states and localities. During the 1970s, there was some interest in a standardized code as a response to the differences in codes passed at the state level. Many thought that these varying codes damaged the national market for building components and that each state could not be developing the best standards. In 1975, the National Council of States Building Codes Standards (NCSBCS) asked the National Bureau of Standards (now the National Institute for Science and Technology) to develop a uniform national building code. In 1976, Congress enacted legislation which required the development of the Building Energy Performance Standards (BEPS), a mandatory national code based on performance standards. In 1983, prior to DOE releasing a final version of BEPS, the law was modified

[99]For example, the incremental costs in new construction for electronic ballasts (two 4 ft. lamps), high efficiency A/C (7.5 tons), and high efficiency motors (20 HP) are $1800/KW, $500, and $190, respectively. The retrofit cost for these measures is substantially higher: $5000, $4250, and $1100, respectively. From Armond Cohen, based on Xenergy Research for New England Electric Systems C&I New Construction Program.

to be a mandatory code only for federal buildings. (It is voluntary for non-federal buildings, although DOE is mandated to encourage its adoption by states and localities.) In January 1989, DOE placed its proposed standards in the Federal Registry.[100] These standards are both performance- and prescriptive-based.

The DOE shares leadership in building energy code development with the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). The proposed federal building code is nearly identical to the soon-to-be-released ASHRAE standards. ASHRAE previously released standards in 1975 and 1980. All 50 states have adopted all or a portion of the ASHRAE standards. The 1980 standard was estimated to result in energy reductions in commercial buildings of 12% to 29% compared to buildings constructed in the late 1970s. The new standard is expected to provide 20% to 25% energy savings in commercial buildings over the existing code.[101] In contrast, the residential portion of the ASHRAE standards of 1975 and 1980 are significantly lower than the average energy efficiency of new homes in most states.[102]

HUD also plays a role in building codes through its regulation of manufactured housing (mobile homes).[103]

The just-released federal code can have an impact in two ways. The first is through its direct effect on reducing energy consumption in new federal buildings. This will be

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[100]U.S.Department of Energy, Assistant Secretary, Conservation and Renewable Energy Building Equipment Division, 1988.

[101]Geller, 1988a.

[102]Hirst, et al., 1986.

[103]For a detailed discussion of regulation of manufactured housing, see U.S. Congress, Office of Technology Assessment, 1986.

small, as new federal buildings represent only a small portion of the nation's building stock. The second is through its leadership role as a model code which can be adopted by states and localities.

There are several changes in building code policy which could achieve even greater savings than are possible under the current situation. These include: establishment of a uniform national code, development of a more stringent national code, and greater resources for implementation and enforcement.

A uniform national building code has the potential for greater energy savings than a voluntary code, as it will bring all states up to a minimum level. A uniform national code can be established either by mandating compliance or by creating incentives for states to adopt the national code.[104] In the residential sector, incentives could take the form of requiring homes to meet the federal code in order to qualify for Federal Housing Authority (FHA) or Federal Veterans Authority (FVA) loans. Other possible incentives include linking direct funding, government purchasing or tax incentives to states' adoption of the energy-efficient code.

An added benefit of a national code is that it would remove a significant barrier to innovation in the residential market. The present system of codes inhibits technological innovation indirectly by fragmenting the market. A national building code would create a national market for building components, making investment in R&D more rewarding. It would also be hospitable to manufactured housing components. Manufactured housing can achieve better energy efficiency through the quality control that is available in factory conditions. If a national building code helped to promote manufactured housing, it could

[104]See U.S. Congress, Office of Technology Assessment, 1986 for a discussion of how a uniform code might also be developed through state or private initiative.

indirectly help increase the energy efficiency of homes. In addition, acts which encourage manufactured housing in the near term may put the U.S. housing industry into a better competitive position for the future, as the Japanese and some European nations have already developed a manufactured housing industry.[105]

A nationally mandated code would impose federal jurisdiction over an area traditionally under the jurisdiction of states and localities. There is considerable opposition from states and the construction industry to a mandatory national building code.

Some objections to a uniform national code are based on the question of technical feasibility due to the climate variations across the country. This technical problem could be reasonably resolved by specifying an appropriate number of climate zones, and specifying appropriate standards for each zone.

A more serious concern is that a mandatory federal code would displace state initiative. Over the last decade, some states have taken the lead in mandating energy efficiency through building codes. The lead states have created a market for energy-efficient products and designs. A national mandatory building code is likely to preempt this state initiative (even if it grandfathers existing state codes). Therefore, for a national code to be beneficial to energy conservation, it must be more than a "least common denominator" code. Any federal code should have provisions for periodic updating, in order to provide the leadership that was once given by the states.

Whether voluntary or mandatory, a building code is only the first step. Implementation and enforcement are absolutely necessary for a building code to move from paper to energy savings. Therefore, the federal role must include: (1) support and guidance in training state and local inspectors, regulatory officials, architects, engineers,

[105]U.S. Congress, Office of Technology Assessment, 1986.

designers, and builders, and (2) the development of equipment to test and monitor standards, including software which gives states and localities the capability to evaluate buildings which have chosen to use performance standards.[106] Adequate resources are required to carry out these functions.

6. **Consumer Information and Marketing**

Lack of information and uncertainty have been identified as key barriers to greater investment in energy conservation. The federal government can play a role in overcoming these barriers by providing information about opportunities to increase energy efficiency. Information dissemination is as a key element of several of the policy options discussed above, including appliance standards, building codes and utility planning. In addition, there are several consumer information and marketing programs whose sole purpose is information dissemination, including energy rating systems (particularly for homes), home energy audits, appliance labels and general information campaigns.

Information and marketing programs work synergistically with taxes and standards to promote conservation. They provide consumers with the information they need to make appropriate choices when presented with price-based incentives from energy taxes. Labeling and ratings can also help create a market where buildings and appliances compete to beat the standards as part of their marketing strategy. In this way, labeling and rating systems can provide the competitive environment for further advances while standards can insure the adoption of proven technologies.

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[106]See U.S. Congress, Office of Technology Assessment, 1986 for a discussion of the potential federal role in building codes.

a. *Energy Rating Systems*

Home energy rating systems (HERS) can be used to overcome the lack of information that home buyers have about cost-effective conservation investments, and provide them with an ability to shop comparatively for homes based on their energy characteristics. If widely adopted, ratings set up a competitive system in which builders strive for low ratings as part of their marketing strategy. Ratings can be used in conjunction with standards to provide an incentive for builders to exceed the minimum standards as a selling point for their homes. In addition to their direct impact on program participants, HERS can have indirect impact by encouraging non-participants to build to higher standards and developing consumer awareness of energy use. HERS can also provide lenders with the information they need to give larger loans to buyers of energy-efficient homes, thus helping to overcome the first-cost barriers to investment in energy efficiency.

An evaluation of data from a national survey found that energy savings for HERS range from 15% to 50%.[107] The average market penetration for all programs surveyed was 40%, but successful programs had much higher penetration rates, including several with rates at 60% or higher, and a couple with rates of 100%. The worst penetration rate was 2% for manufactured homes (mobile homes). Penetration levels for HERS are significant because higher participation levels will create a larger market for energy-efficient homes. As this demonstrates, HERS have not had an effect on the low-income segment of the housing market because the increased cost of energy-saving features is prohibitive. Also, HERS have not as yet been applied to the resale market.

Only recently have energy rating system programs been introduced in the commercial sector. No data is yet available on these programs.

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[107] Vine et al., 1987a.

The federal government has been involved in HERS through its role in the mortgage market. As will be discussed in more detail in the section on financial incentives, federal involvement has basically had the effect of legitimizing, and thus expanding, the use of HERS in many areas. The federal government could play a further role by developing a uniform energy rating system for both residential and commercial buildings. There are important technical considerations in developing such a system, as it would need to be tailored to the specific requirements of different regions, including climate and housing types.[108] A further step would be to require the use of energy rating systems. This option could provide states with the option of either using a uniform federal standard or developing their own energy rating system.

b. *Home Energy Audits*

The Federal Residential Conservation Service (RCS) was created in 1978 to provide consumers with information on energy conservation for their homes. It mandated that gas and electric utilities provide their customers with on-site energy audits. This program was designed to overcome the barrier of inadequate information. As with the HERS, this program could affect energy use beyond that of the participating households.

The program was implemented starting in 1981. There has been very little evaluation of the program, and little reliable information has been kept on its success in reducing energy consumption. From a study based on the limited available data, Hirst concluded that the programs' contribution to national energy savings was small.[109] In general, participation rates were low, energy savings were modest and costs were high.

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[108]For a discussion of the technical considerations in developing HERS, see Rosenfeld and Wagner (1985).

[109]Hirst, 1985.

However, some of the state programs worked well, suggesting that home energy audits could be a successful part of a home energy conservation policy. Suggestions for improvement of RCS include: limiting audits to the most useful features; wider marketing, especially to low-income groups; operating through non-profit organizations; and combining audits with contracting, financing and inspection.

c. *Appliance Labels*

Appliance labels have the same goals as home rating systems: to inform consumers about energy savings and to create competition among appliances based on energy efficiency. The U.S. requires labels on seven products: refrigerator-freezers, freezers, room air conditioners, clothes washers, dishwashers, and electric and gas water heaters. Early studies indicated that labels had little effect on consumer behavior but may have pushed manufacturers to produce more efficient models.[110] A more recent consumer survey suggests that labels contributed to consumer awareness of energy costs and affected appliance purchase decisions for up to half of the consumers surveyed.[111]

d. *Information Campaigns*

The federal government funds a state-implemented information service called the Energy Extension Service (EES). The purpose of the EES is to serve as a local source of information on energy use and efficiency. Discussions with state energy officers indicate that generalized advertising was their least effective tool. They found on-site workshops, auditor training and campaigns targeted to a specific group to be their most effective

[110]Hirst et al., 1986.

[111]Dyer, 1986.

activities.[112] In general, information campaigns conducted through existing social networks and combined with feedback are most effective.

7. Research and Development (R&D)

There are major barriers to private investment in R&D in the buildings sector, including the fragmented structure of this sector and the short-term perspective of many of the decision-makers. Thus, the federal government has a key role to play in funding R&D for this sector.

The federal government has actively supported research, development and commercialization of energy-saving technology. R&D investment in energy conservation for all sectors has netted a return of fifty-to-one in the past decade.[113] R&D investment contributes to other social goals as well, including competitiveness, reducing the trade deficit, and improving national security.

The U.S. government currently spends a negligible amount on housing research. In contrast, Sweden, with a population of only 9 million, spends more on research for home construction than the U.S.[114] In countries such as Sweden and Japan, R&D spending has been part of their trend toward manufactured housing, which has contributed to the energy efficiency of their homes through standardization of energy-saving features, and quality control in the design and manufacture of building components. If the home construction industry in the U.S. market moves toward manufactured housing, as is the case in Sweden and Japan, this lack of investment in R&D may put the U.S. at a competitive disadvantage.

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[112] Hirst et al., 1986.

[113] Geller, Harris et al., 1987.

[114] U.S. Congress, OTA, 1988.

Research is necessary not only for energy-efficiency technologies, but also for the most promising on-site renewable technologies and technologies, such as absorption refrigeration, that will make cogeneration more applicable in buildings.[115]

In addition to R&D on building technologies, there is a need for better energy end-use data for energy planning. Information on commercial building energy use is less available than residential energy end-use data, and is worth further study, particularly because energy use is growing faster in this sector than in others.

8. Financial Incentives

a. *Loan Policies*

Changing lending policy to accurately assess the monthly costs of home ownership is one way to overcome the barrier of higher initial costs. Because the monthly utility bills are lower on energy-efficient houses, owners can afford higher monthly house payments. Thus, the debt-to-income ratio for an energy-efficient home can be higher than for a typical new home. Lenders generally use standard formulas for determining debt-to-income ratios. In order for lenders to consider lower down payments in exchange for higher monthly payments, they need to be able to accurately assess the monthly utility costs for any given house. Reliable home energy rating systems (HERS), as discussed above, can provide this information. If lending policies were changed to reflect this ability to make higher monthly payments on more efficient houses, not only could more people afford the extra first cost of energy-efficient homes, but it would open the market for home ownership to people who previously could not qualify for a loan.

The Federal National Mortgage Association (Fannie May) and the Federal Home

[115] See Oak Ridge National Lab, Dec. 1988 for discussion of promising R & D opportunities.

Loan Mortgage Corporation (Freddie Mac) have endorsed this concept and approve HERS for qualification in the secondary mortgage market. The Federal Housing Administration and the Veterans Administration have their own set of qualified HERS, creating a diverse situation in the secondary market. Up to this point, there has been only minimal participation by the first mortgage market in making higher loans to energy-efficient homes. Thus, the endorsements by Fannie May and Freddie Mac have helped improve energy efficiency mostly indirectly by helping HERS market their programs. A uniform HERS in the secondary market could change this situation by increasing the acceptance in the first mortgage market of higher loans for energy-efficient homes. Also, the transaction costs (i.e., the costs for lending agencies to include the energy costs in their evaluation of mortgages) may be unacceptably high if ratings are not standardized.

Another loan policy for encouraging energy efficiency is reduced mortgage rates for energy-efficient homes.

b. *Tax Credits*

The federal government passed legislation which provided solar and conservation tax credits for the years 1978 through 1985. The credit rates were 15% for energy conservation measures, with a maximum credit of $300, and 40% for solar measures, with a maximum credit of $4000. The 1986 tax reform act allowed the energy conservation tax credits for residential use to expire. The residential solar tax credits and some commercial energy conservation tax credits were extended. Studies on the impact of these credits are inconclusive. Some say the credits were too low to affect homeowners' behavior. Studies of state programs show that larger tax credits led to greater use of the credit. However, another study indicates that the level of the tax credit may not be as important as its

presence.[116]

The conservation tax credits raise equity questions. Low-income groups accounted for less than 1% of the households claiming credits. A way of resolving the equity issue is by providing subsidies to low-income households for energy conservation investments.

c. *Subsidies*

The federal government has funded three programs involving subsidies. The Institutional Conservation Program (ICP) pays for audits and half the conservation investment in schools and hospitals. The ICP program has proved successful. State officials rate this program as more successful than other federally funded programs such as the Energy Extension Service (EES), the Weatherization Assistance Program (WAP), the Residential Conservation Service (RCS), and the Solar Energy and Energy Conservation Bank (SEECB). WAP pays for energy conservation in low-income housing. WAP has a mixed performance record. SEECB helps finance energy conservation and cost-effective solar in low- and moderate-income housing and in commercial buildings owned by non-profits. The federal government provides funding to states, which then provide matching grants and loan subsidies. The program got off the ground in 1984, and initial evaluations were positive.[117]

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[116]Hirst et al., 1986.

[117]Hirst, 1986.

9. Energy Conservation in Federal Buildings

Energy use in federally-owned buildings is currently about 0.9 quads.[118] This represents about 2% of the total energy used in the buildings sector. Thus, major cuts in energy use in federal buildings cannot have a large direct effect on emissions from this sector. But there are opportunities for indirect effects. The philosophy of getting one's own affairs in order first is a strong one. Aside from setting an example, retrofitting of federal buildings provides a testing ground for technologies, building codes, software, and institutional arrangements.

Federally owned buildings are currently required to retrofit to improve energy efficiency and minimize life-cycle costs. The required target for 1985 to 1995 is to reduce energy consumption by 10% (on a per-square-foot basis). As discussed in section II.D., studies of retrofits show even greater potential for cost-effective reductions. It is worth considering what would be necessary to exceed the 10% goal.

10. Technology Demonstrations

Government-sponsored demonstration projects can prove the reliability and marketability of energy-efficient buildings, thus providing evidence to overcome the perception held by builders and consumers that energy-efficient technologies are risky. Results from an evaluation of demonstration projects show that energy-efficient homes are not significantly more expensive than typical new homes, and that energy-efficient commercial buildings can actually reduce initial costs.[119] In addition, there is evidence that demonstration projects help create new markets, change standard building techniques, train

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[118] U.S. Department of Energy, 1987.

[119] Vine and Harris, 1988.

builders who then continue to build innovative energy-efficient structures, serve as models for other communities, and serve as a basis for developing standards, labeling, and funding guidelines.

11. Government Procurement

Government procurement can play a role by setting energy-efficiency standards for all buildings, equipment and appliances purchased by the U.S. Government. The federal building code serves this purpose for new buildings. Guidelines could also be developed for purchases for retrofits as part of a program for reducing energy use in federal buildings. This type of program can serve the same role as demonstration programs in overcoming the private sector's fears about first-of-a-kind projects and new technologies. Government procurement programs can also stimulate producers to take risks in development by assuring a market for their product.

The potential drawbacks of government procurement programs are that they can sustain an economically inefficient industry, constrain competition and freeze innovation beyond the level of the standards. These problems can be overcome through competitive bidding and the phasing out or updating of programs in a timely manner.

C. Policy Regarding Fuel Mix

While the above analysis looks at several important ways to save energy in buildings, it does not directly address a key issue for reducing CO_2 emissions: namely, the fuel mix. In the short term, CO_2 emissions could be reduced by substituting natural gas for fuel oil, and for electricity in those regions of the country where electricity is produced largely by fossils, especially coal. While there may not be enough savings to justify retrofitting, this

is definitely a consideration for new buildings. In the long run, it is unclear whether gas or electricity will be the preferred fuel. If gas is produced through the sustainable use of biomass, it is preferred over fossil-fuel-generated electricity. On the other hand, non-fossil electricity is preferable to natural gas. In addition, the relative efficiencies of gas and electric appliances must be considered. These questions are raised because of the longevity of buildings. Thus, if buildings are all electric today, changes to gas in the future will be costly. The point to be made is that a long-term plan for moving away from fossil fuels can point us toward the best short-term choices. Without considering the long-term energy supply situation, we may lock ourselves into an undesirable future.

The problem of climate change puts a premium on the use of fossil fuels. When considering fuel mix, it is also necessary to evaluate which sectors and end-uses are best suited for which fuels -- in other words, which end-uses can most easily substitute non-fossil fuels for their current fossil fuel consumption. In the buildings sector, there is already limited experience with using renewables. Increased funding of R&D for on-site use of renewables in buildings could help prepare us for a switch away from fossils.

D. The Relationship Between Policies to Reduce CO_2 Emissions and Other Policy Goals

Reductions in CO_2 emissions in buildings must compete with the other goals and purposes of buildings. In other words, when building policy is considered, goals such as affordable housing and urban renewal are likely to be at the top of the agenda. When consumers think about building investment, they are concerned with comfort, aesthetics, and reduced costs. If energy conservation can contribute to reaching some of these goals, policy for buildings is more likely to include measures for energy conservation.

Similarly, policies for energy conservation in buildings are more likely to be implemented if they also serve other societal objectives, such as economic development, national security, competitiveness, and reduction of other environmental externalities such as acid rain. Thus, as policies are considered for reducing CO_2 emissions in the buildings sector, their ability to contribute to other policy goals could enhance their desirability.

1. Economic Efficiency

Energy-efficiency programs can contribute to economic efficiency. Schipper estimates that conservation policies carefully imbedded in the policies that already affect homes and buildings can, in the long run, squeeze inefficiency out of the economy on the order of 2% to 4% of GNP.[120]

2. The Effect of Chlorofluorocarbon Reductions on Energy Efficiency

Chlorofluorocarbons (CFCs) are a major cause of both ozone depletion and climate change. The recently negotiated Montreal Protocol calls for a freeze on CFC-11 and CFC-12 at 1986 levels by 1989, followed by cutbacks of 20% in 1993 and 50% (from 1986 levels) in 1998.

CFCs have played a significant role in energy-efficiency improvements in the buildings sector through their use as refrigerants and in foam insulation. With this in mind, the question of how reductions in CFCs will affect building energy use is important. A 1988 study estimates that the elimination of CFCs from refrigerators in the U.S. will result in a 0.4 quad increase in energy use with current technology, but could result in a 0.2 quad

[120] Schipper, 1987.

decrease with technological advances including vacuum panels and new refrigerants.[121] For comparison, 1985 refrigeration energy use was 1.41 quads.

In the commercial sector, the main concern is for centrifugal chillers which use CFC-12. It is estimated that switching to CFC-22, which has a low ozone depletion potential, would reduce efficiency by 5%.[122] Technological advances could offset this loss of efficiency.

3. Indoor Air Quality

A major component of building energy conservation has been a reduction in the level of outside air or infiltration. This has been accomplished by plugging leaks around doors and windows, and by reducing the outside air intake in HVAC systems in commercial buildings. Over the past decade, there has been a growing concern about indoor air quality, as there are reports of "sick building syndrome." This concern legitimately raises the question of whether efforts to improve indoor air quality will result in greater energy use.

In response to concern over energy conservation, in the early 1980s, ASHRAE dropped their requirements for indoor air in commercial buildings to 5 CFM per person. However, in 1986, in response to concerns over indoor air quality, it was proposed that this standard be raised to 15 to 20 CFM per person. This suggestion is controversial and has not been passed by ASHRAE. It is estimated that a change from the current 5 CFM to a 20 CFM standard would raise energy use by 0% to 8% for heating, 1% to 14% for cooling, and about 2% for auxiliary HVAC equipment such as fans and pumps. These

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[121] Statt, 1988.

[122] Fisher et al., 1987.

ranges are the result of modeling the change for buildings in several different climates.[123]

There are several reasons why these increases may be an overestimate: (1) air-to-air heat exchangers could be used to recapture the heat in the exhaust stream, (2) technologies are being developed which can monitor indoor air quality, making it possible to have higher ventilation rates only when needed, thus avoiding the need for a higher standard, and (3) the guidelines may be ignored.[124]

E. Summary of Policies to Reduce U.S. CO_2 Emissions in the Buildings Sector

Reducing CO_2 emissions from the buildings sector is a multifaceted problem. It requires implementing numerous technical options, influencing the behavior of many decision-makers, and overcoming a variety of barriers to investment in energy conservation. Significant reductions of CO_2 emissions are attainable only through the implementation of a combination of policies.

This section focused on policy to promote energy conservation because it provides the greatest opportunity for emission reductions in the buildings sector in the near term. The most promising policy options are: energy use taxes, initial purchase taxes, utility least-cost planning, appliance standards, building codes, consumer information and marketing, and research and development. Other policies with more limited impact include: financial incentives, energy conservation in federal buildings, technical demonstrations and government procurement.

The synergisms that are possible between taxation, regulation, incentive, information, and R&D programs are keys to reducing emissions. Taxation sends the necessary pricing

[123]Eto and Meyer, 1987.

[124]Geller, 1988a.

signals for reducing energy consumption. Regulation can be used to get the least efficient equipment, appliances and buildings off the market. Incentive and information programs can be used to create a market for beating the standards. Information programs also provide consumers with the information needed to make energy-conserving choices in response to price signals from taxation. Finally, government-sponsored R&D is necessary to support innovation in an industry which is too fragmented to make capital-intensive and risky investments.

Avenues for further research into the policy options include more quantitative modeling on the potential for emission reductions from implementation of the policy measures (both individually and in packages), developing the costs of these policy options, and determining the time frame required for implementation of these options.

V. U.S. POLICIES FOR GLOBAL CO_2 EMISSIONS REDUCTIONS

Policies the U.S. can pursue to achieve international reductions in greenhouse gases include international conventions and protocols for emission reductions, bilateral and multilateral research and information programs, influencing developing countries' energy policies through development banks and U.S. AID, and trade policies. The specific application of these policies in the residential and commercial sectors is discussed in this section.

A. Conventions and Protocols

International conventions or protocols which are not sector-specific would be the most efficient form of agreement. They would allow each nation to decide how best to reduce its own emissions. In this case, sector-specific information might inform the debate and determine what levels of emissions are obtainable for various countries. End-use information such as that developed in this report could be important in making this determination.

Undoubtedly, international negotiations will include some debate over what emission level to use as a starting place in each society. Although this analysis indicates that even a country like Sweden has room for energy-efficiency improvements in its buildings, these may be more costly than improvements for a society that has not yet had market saturation of the most basic energy conservation measures. This raises questions of equity and economic efficiency. Could emission reductions be traded?

International appliance labeling and/or appliance standards are a type of international accord which could be aimed specifically at the buildings sector. Labeling

would serve the purposes mentioned previously: providing consumers with information and creating a situation where appliances compete based on energy efficiency. Standards would remove the worst energy-guzzlers from the market. It is doubtful that international agreements could be reached on standards that are technology-forcing. International appliance labeling and standards would require internationally agreed-upon measures of efficiency. In addition, standards could require technical assistance so that all countries which manufacture appliances could meet the requirements.

B. Research and Information Programs

Research programs for reducing emissions will necessarily be looking at potential reductions from specific sectors. Because of the great potential in the buildings sector, it should figure prominently in such studies. International research programs could help develop a consensus on the level of potential reductions as well as act as an avenue for technology transfer. For the LDCs, methods for improving the efficiency of wood stoves and/or moving more quickly to modern fuels are areas particularly in need of attention.

C. Programs of the Development Banks and AID

Through the World Bank, the Inter-American Bank and AID, the U.S. can finance conservation and renewables, influence LDCs' utility planning to include least-cost planning, and provide technical assistance for conservation, standards and labeling. These institutions can also help build the institutions that LDCs will need to successfully pursue climate change policies.

D. Trade Policies

Many countries have trade policies which discourage energy efficiency by imposing import duties on energy-saving equipment. The U.S. may be able to influence these policies through multilateral or bilateral trade agreements.

APPENDIX

APPENDIX

TABLE A1: CO_2 EMISSION REDUCTION POTENTIAL
BASED ON SOLAR ENERGY RESEARCH INSTITUTE STUDY, 1981
page 1

ANNUAL ENERGY USE (QUAD BTU) (a)

			CONSERVATION		CONSERVATION & SOLA	
	1980 ELECT	1980 FUEL	2000 ELECT	2000 FUEL	2000 ELECT	2000 FUEL
RESIDENTIAL SECTOR						
exist heat & cool	2.65	7.04	0.88	1.95	0.66	1.37
new heat & cool			0.92	0.74	0.81	0.54
water heat	1	1.29	1.26	0.75	0.92	0.55
appliances	4.16	0.47	4.13	0.43	4.13	0.43
RESIDENTIAL TOTAL	7.81	8.8	7.19	3.87	6.52	2.89
COMMERCIAL SECTOR						
exist bldgs	4.4	5.6	1.57	2.44		
new bldgs			0.16	3.09		
COMMERCIAL TOTAL	4.4	5.6	1.73	5.53		

CO_2 EMISSIONS (MILLION METRIC TONS CARBON) (b)

			CONSERVATION		CONSERVATION & SOLA	
	1980 ELECT	1980 FUEL	2000 ELECT	2000 FUEL	2000 ELECT	2000 FUEL
RESIDENTIAL SECTOR						
exist heat & cool	47	113	15	31	12	22
new heat & cool	0	0	16	12	14	9
water heat	18	21	22	12	16	9
appliances	74	8	73	7	73	7
RESIDENTIAL TOTAL	139	141	126	62	115	47
COMMERCIAL SECTOR						
exist bldgs	78	92	28	40		
new bldgs	0	0	3	51		
COMMERCIAL TOTAL	78	92	30	91		

APPENDIX
TABLE A1: CO_2 EMISSION REDUCTION POTENTIAL
BASED ON SOLAR ENERGY RESEARCH INSTITUTE STUDY, 1981
page 2

EMISSION REDUCTIONS FROM 1980

	CONSERVATION		CONSERVATION & SOLAR	
	% end-use	% total (c)	% end-use	% total (c)
RESIDENTIAL SECTOR				
heat & cool	53%	17%	65%	24%
water heat	11%		35%	
appliances	2%		2%	
RESIDENTIAL TOTAL		33%		42%
COMMERCIAL TOTAL		29%		

NOTES:

(a) On-site solar is accounted for as energy savings.

(b) 1980 electricity fuel mix from U.S. Energy Information Administration, 1980 data. Year 2000 electricity fuel mix assumed same as 1985 fuel mix. Year 1985 fuel mix from U.S. Energy Information Administration, 1986. Does not include cogeneration. Emission factors from Rotty and Masters, 1985.

(c) This calculation is based on the percent of emission reductions that would be possible if energy-saving measures were taken for heating and cooling, but not for water heating and appliances. The BNL base case was used to determine emission growth for water heat and appliances in the absence of energy-saving measures.

APPENDIX

TABLE A2: CO_2 EMISSION REDUCTION POTENTIAL BASED ON ENERGY DEMAND SCENARIOS FROM WRI (GOLDEMBERG, ET AL., 1988)

page 1

ANNUAL END-USE ENERGY (EXAJOULES)

	1980 ELECT	1980 FUEL	2020 ELECT	2020 FUEL
RESIDENTIAL SECTOR				
space heat	0.29	6.02	0.19	1.93
A/C - central	0.24		0.37	
A/C - room	0.09		0.04	
hot water	0.33	1.64	0.14	0.67
refrig/freezer	0.56		0.25	
freezer	0.16		0.24	
range	0.12	0.28	0.12	0.4
dryer	0.16	0.06	0.14	0.33
lights	0.29	0.13		
miscellaneous	0.34		0.34	
RESIDENTIAL TOTAL	2.58	8	1.96	3.33
COMMERCIAL TOTAL	2.03	4.34	1.8	1.4

	CO_2 EMISSIONS (million metric tons carbon) ASSUMES 2020 ELECTRICITY GENERATING MIX SAME AS 1985				EMISSION REDUCTIONS FROM 1980
	1980 ELECT	1980 FUEL	2020 ELECT	2020 FUEL	% end-use saved
RESIDENTIAL SECTOR					
space heat	16	91	10	28	64
A/C - central	13	0	20	0	-55%
A/C - room	5	0	2	0	55%
hot water	18	25	8	10	59%
refrig/freezer	30	0	13	0	55%
freezer	9	0	13	0	-51%
range	6	4	6	6	-16%
dryer	9	1	8	5	-31%
lights	16	0	7	0	55%
miscellaneous	18	0	18	0	0%
RESIDENTIAL TOTAL	138	122	105	49	40%
heating and cooling	33	91	32	28	51%
appl., lights, misc.	105	30	73	21	31%
potential reductions for heating and cooling only (c):					8%
potential reductions for appliances, lights, misc. only (d):					7%
COMMERCIAL TOTAL	109	68	97	22	33%

APPENDIX
TABLE A2: CO_2 EMISSION REDUCTION POTENTIAL
BASED ON ENERGY DEMAND SCENARIOS FROM WRI
(GOLDEMBERG, ET AL., 1988)
page 2

	CO_2 EMISSIONS (million metric tons carbon) BASED ON WRI ELECTRICITY GENERATION SUPPLY SCENARIOS				EMISSION REDUCTIONS FROM 1980 % end-use saved
	1980 ELECT	1980 FUEL	2020 ELECT	2020 FUEL	
RESIDENTIAL SECTOR					
space heat	16	91	4	28	70%
A/C - central	13	0	8	0	38%
A/C - room	5	0	1	0	82%
hot water	18	25	3	10	70%
refrig/freezer	30	0	5	0	82%
freezer	9	0	5	0	40%
range	6	4	3	6	21%
dryer	9	1	3	5	17%
lights	16	0	3	0	82%
miscellaneous	18	0	7	0	60%
RESIDENTIAL TOTAL	138	122	42	49	65%
heating and cooling	33	91	13	28	67%
appl., lights, misc.	105	30	29	21	63%
potential reductions for heating and cooling only (c):					15%
potential reductions for appliances, lights, misc. only (d):					24%
COMMERCIAL TOTAL	109	66	38	21	44%

NOTES:

(a) Uses 1985 U.S. Energy Information Administration data for supply mix for electricity generation. CO_2 emission factors from Rotty and Masters.
(b) Electricity-generating fuel mix from WRI (Goldemberg, et al., 1988). For this analysis, all cogeneration in supply mix assumed to be used by industry.
(c) These calculations are based on the percent of emission reductions that would be possible if energy-saving measures were taken for heating and cooling only while all other end-uses were allowed to grow according to the BNL base case scenario.
(d) These calculations are based on the percent of emission reductions that would be possible if energy-saving measures were taken for appliances and lighting only, while heating and cooling were allowed to grow according to the BNL base case scenario. (note: BNL base case scenario ends in year 2010.)

APPENDIX

TABLE A3: POTENTIAL EMISSION REDUCTIONS FROM SPACE CONDITIONING IN RETROFITS VERSUS NEW HOMES IN THE RESIDENTIAL SECTOR

Based on SERI Scenario

SERI SCENARIO	CO_2 EMISSIONS (million metric tons carbon) (d)		
		cons.	cons. + solar
Emissions	1980	2000	2000
Existing Heat and Cool	160	47	34
New Heat and Cool	----	28	23
Total Space Conditioning		75	67

ASSUME NO RETROFITS, BUT EFFICIENT NEW HOMES (a)

		cons.	cons. + solar
Emissions	1980	2000	2000
Existing Heat and Cool	160	122	122
New Heat and Cool	---	28	23
Total Space Conditioning		150	145

CONCLUSION: Compared to 1980, space conditioning emission reductions of 10 to 15. This is compared to an expected growth in the sector from 1985 to 2000 of 34 (c). No net reductions.

ASSUME RETROFITS, WITH NEW HOMES BUILT TO BASELINE STANDARDS (b)

		cons.	cons. + solar
Emissions	1980	2000	2000
Existing Heat and Cool	160	47	34
New Heat and Cool	---	57	57
Total Space Conditioning		104	91

CONCLUSION: Compared to 1980, space conditioning savings of 56 to 69. Expected growth in sector from 1985 to 2000 is 34 (c). This results in net emission reductions of 22 to 35, 8% to 12%.

Notes:

(a) Fraction of existing housing standing in year 2000 equals 76%. Emissions without efficiency improvements are calculated as (160 *.76) = 122. This is an overestimate as there will be some emission reductions from replacing equipment as it wears out.

(b) Based on SERI baseline estimates for new homes between 1981 and 2000 of 28.9 million new fuel homes using a total of 1.59 quads and 14.8 million new electric homes using 2 quads primary energy.

(c) Based on BNL scenario (Brookhaven National Laboratory).

(d) Year 2000 electricity fuel generating mix and non-electric fuel mix between gas and oil assumed to be the same as 1985.

APPENDIX
TABLE A4: SCENARIOS OF RESIDENTIAL SPACE HEATING BASED ON WRI SCENARIO (GOLDEMBERG ET AL., 1988)

NUMBER OF HOMES

Vintage	1980 fuel	1980 elec(a)	1980 total	2020 fuel	2020 elec(a)	2020 total
pre-1981	67.3	14.3	81.6	41.4	8.7	49.8
1981-1990				7.2	7.2	14.4
1991-				27.5	27.5	55
total			81.6			119.2

	Scenario: retrofit and new home efficiency			Scenario: retrofit existing homes, with new homes at 1981-1990 standards			Scenario: new homes highly efficient, no retrofits (b)		
	fuel	elec(a)	total	fuel	elec(a)	total	fuel	elec(a)	total
SPACE HEATING (EJ)									
pre-1981	1.55	0.06	1.61	1.55	0.06	1.61	3.70	0.18	3.88
1981-1990	0.18	0.06	0.24	0.18	0.06	0.24	0.18	0.06	0.24
1991-	0.22	0.08	0.30	0.68	0.21	0.90	0.22	0.08	0.30
TOTAL	1.94	0.19	2.14	2.41	0.33	2.74	4.10	0.31	4.41
SPACE HEATING (QUADS BTU)									
pre-1981	1.47	0.06	1.52	1.47	0.06	1.52	3.51	0.17	3.68
1981-1990	0.17	0.05	0.22	0.17	0.05	0.22	0.17	0.05	0.22
1991-	0.21	0.08	0.28	0.65	0.20	0.85	0.21	0.08	0.28
TOTAL	1.84	0.18	2.03	2.28	0.31	2.60	3.89	0.30	4.18
CO_2 EMISSIONS (MILLION METRIC TONS CARBON)									
pre-1981	23	3	26	23	3	26	55	9	64
1981-1990	3	3	6	3	3	6	3	3	6
1991-	3	4	7	10	12	22	3	4	7
TOTAL	29	10	39	36	18	53	61	17	77

NOTES:
(a) Measured as end-use, not primary. Converted to primary in emissions calculation.
(b) Assumes no efficiency improvments in existing homes. This is an overestimate of emissions from existing homes, as expected replacement of equipment will result in some reduction in emissions.

APPENDIX

TABLE A5: CO_2 EMISSION REDUCTIONS FROM APPLIANCE EFFICIENCY IN RESIDENTIAL SECTOR

page 1

CO_2 Emissions in Million Metric Tons Carbon
1985 Estimates (a)

RESIDENTIAL SECTOR

	Elec.	Gas	Oil	Other(b)	Total
Space Heating	31	42	20	8	101
Water Heating	28	12	2	1	43
Refrigerators	25				25
Lighting	18				18
Air Conditioners	19				19
Ranges/Ovens	11	3		1	15
Freezers	8				8
Other	20	8			28
TOTAL	159	65	22	10	256

Fraction of Energy Use With More Efficient Appliances,
Compared to 1986 Average (c)

	NAECA		1986 Best		Advanced Technologies	
	Elec.	Gas	Elec.	Gas	Elec.	Gas
Space Heating		0.8		0.7		0.5
Water Heating	0.8	0.9	0.4	0.7	0.3	0.5
Refrigerators	0.7		0.5		0.3	
Lighting			0.7		0.4	
Air Conditioners	0.8		0.5		0.4	
Ranges/Ovens		(d)	0.9	0.6	0.6	0.4
Freezers	0.6		0.4		0.2	

CO_2 Emissions in Year 2010
(Million Metric Tons of Carbon)
Assumes 100% Replacement

	NAECA		1986 Best		Advanced Technologies	
	Elec.	Fuel	Elec.	Fuel	Elec.	Fuel
Space Heating	31	75	31	65	31	52.1
Water Heating	31	17	15	15	12	9.6
Refrigerators	23		18		9	0.0
Lighting	18		16		10	0.0
Air Conditioners	24		17		13	0.0
Ranges/Ovens	11	4	13	3	9	1.9
Freezers	7		4		3	0.0
Other	20	8	20	8	20	7.8
TOTAL	165	103	135	91	107	71.3

APPENDIX
TABLE A5: CO_2 EMISSION REDUCTIONS FROM APPLIANCE EFFICIENCY IN RESIDENTIAL SECTOR
page 2

	MILLION MT CARBON	% REDUCTION FROM 1985
TOTAL 1985	256	
TOTAL NAECA	269	-5%
TOTAL 1986 BEST	225	12%
TOTAL ADV. TECH.	178	30%

NOTES:
(a) Based on energy use estimates from Brookhaven National Laboratory, July 1988. Based on emission factors from Rotty and Masters, 1985. Electricity fuel generating mix based on U.S. Energy Information Administration.
(b) Coal and LPG.
(c) Based on Geller, 1988b. NAECA refers to National Appliance Efficiency Act Standards. Advanced Technologies are efficiency improvements expected to be available in 1990's.
(d) Standard bans use of pilot lights in ranges and ovens with an electrical supply. No estimate of energy savings.
(e) Growth rate based on BNL prediction of 118.5 million homes in the year 2000, compared to 86.9 million in 1985.

Assumes all fuel appliances improve at same rate as gas appliances.
Assumes mixture of fuel and electric remains constant.
Assumes growth in penetration of air conditioning of 1% per year.

APPENDIX

TABLE A6: SCENARIOS FOR EMISSION REDUCTIONS IN COMMERCIAL SECTOR COMPARING SAVINGS FROM NEW BUILDINGS AND RETROFITS

1. BASED ON WRI SCENARIO (GOLDEMBERG ET AL., 1988)

VINTAGE	1979	2020	baseline energy intens. (GJ/sq. m.)		year 2020 energy intens. (GJ/sq. m.)	
	million sq. meters		fuel	elec	fuel	elec
Pre -	4.13	2.59	0.92	0.46	0.46	0.23
1980 - 1990		0.9			0.10	0.43
1991 - 2020		2.88			0.04	0.28
TOTAL		6.37				

	CO_2 EMISSIONS (million metric tons carbon)	
	baseline (a)	2020
Pre-	110	50
1980 - 1990		22
1991 - 2020		45
TOTAL		117

Retrofits save (110 - 50) = 60 million metric tons carbon.

Total saved in sector = 58 million metric tons carbon.

CONCLUSION: Without retrofits, will not have positive savings in sector.

Assume retrofit, but all new buildings built to 1980 - 1990 standards in WRI scenario.

Retrofit emissions = 50

New building emissions = 93

Total emissions = 143, compared to 1980 emissions of 176.

CONCLUSION: Retrofits and new buildings to WRI 1980 - 1990 energy intensities result in some emission reductions. However, WRI 1980 - 1990 energy intensities are lower than those achieved by the new buildings reported in the BECA results (Lawrence Berkeley

Labs, 1986), suggesting that unless these newer buildings are also retrofit, retrofits alone may not result in positive net emission reductions.

2. BASED ON SERI SCENARIO (SOLAR ENERGY RESEARCH INSTITUTE)

1980 - 31 billion sq. ft.

2000 - 27.5 of 31 billion still standing = 89%.

Baseline CO_2 emissions for existing buildings in 2000 are (.89*170) = 151

CO_2 emissions in SERI scenario, with retrofits, are 68.

Savings from retrofits = 83

Total savings in sector = 49

CONCLUSION: Without retrofits, will not have positive savings in sector.

NOTES

(a) This assumes no retrofits to existing buildings. Based on (2.59/4.13)*176. In other words, the percent of 1980 stock still standing multiplied by 1980 emissions.

APPENDIX

TABLE A7: POTENTIAL CO_2 EMISSION REDUCTIONS FROM FUEL SWITCHING
page 1

	ANNUAL PRIMARY ENERGY USE (QBTUs) (a)			
	1986	1990	2000	2010
RESIDENTIAL				
Electricity	9.2	10.0	1.7	13.9
Gas	4.4	4.6	4.4	4.2
Oil	1.1	1.0	0.7	0.6
other (coal and LPG)	0.5	0.5	0.4	0.4
total	15.2	16.1	17.2	19.1
COMMERCIAL				
Electricity	8.3	9.6	12.6	15.6
Gas	2.4	2.4	2.3	2.2
Oil	0.9	0.9	0.8	0.7
other (coal, LPG, gas)	0.3	0.3	0.3	0.3
total	11.9	13.2	16.0	18.8

	CO_2 EMISSIONS (MILLION METRIC TONS CARBON)(b) ASSUME FUEL MIX CONSTANT AT 1986 VALUES			
	1986	1990	2000	2010
RESIDENTIAL				
Electricity	162	176	206	244
Gas	64	67	64	61
Oil	22	20	14	12
other (coal and LPG)	10	10	8	8
total	257	272	291	325
COMMERCIAL				
Electricity	146	169	221	274
Gas	35	35	33	32
Oil	18	18	16	14
other (coal, LPG, gas)	6	6	6	6
total	205	227	277	326

	CO_2 EMISSIONS (MILLION METRIC TONS CARBON) (b) ASSUME ALL ON-SITE FUEL USE IS NATURAL GAS			
	1986	1990	2000	2010
RESIDENTIAL				
Electricity	162	176	206	244
Gas	64	67	64	61
Oil	22	14	10	9
other (coal and LPG)	10	7	6	6
total	257	264	285	319
COMMERCIAL				
Electricity	146	169	221	274
Gas	35	35	33	32
Oil	18	13	12	10
other (coal, LPG, gas)	6	4	4	4
total	205	221	271	320

APPENDIX
TABLE A7: POTENTIAL CO_2 EMISSION REDUCTIONS FROM FUEL SWITCHING
page 2

CO_2 EMISSIONS (MILLION METRIC TONS CARBON) (b)
ASSUME ALL ON-SITE FUEL AND
ELECTRICITY OIL IS NATURAL GAS

	1986	1990	2000	2010
RESIDENTIAL				
Electricity	162	173	203	241
Gas	64	67	64	61
Oil	22	14	10	9
other (coal and LPG)	10	7	6	6
total	257	262	282	316
COMMERCIAL				
Electricity	146	167	219	271
Gas	35	35	33	32
Oil	18	13	12	10
other (coal, LPG, gas)	6	4	4	4
total	205	219	268	317

CO_2 EMISSIONS (MILLION METRIC TONS CARBON) (b)
ASSUME 20% REDUCTION IN USE OF FOSSIL FUEL FOR
ELECTRICITY GENERATION

	1986	1990	2000	2010
RESIDENTIAL				
Electricity	162	141	164	195
Gas	64	67	64	61
Oil	22	20	14	12
other (coal and LPG)	10	10	8	8
total	257	237	250	276
COMMERCIAL				
Electricity	146	135	177	219
Gas	35	35	33	32
Oil	18	18	16	14
other (coal, LPG, gas)	6	6	6	6
total	205	194	232	271

APPENDIX
TABLE A7: POTENTIAL CO_2 EMISSION REDUCTIONS FROM FUEL SWITCHING
page 3

EMISSION FACTORS	(Million Metric Ton Carbon/Quad BTU, primary)
electricity	17.57 (for 1985 fuel mix)
	17.34 (for oil replaced with gas)
	14.05 (for 20% reductions from 1985)
natural gas	14.46
liquid fuel	20.02
solid fuel	26.37

NOTES:
(a) Energy use scenarios based on Brookhaven National Laboratory Projections, 1988.
(b) Emission factors from Rotty and Masters, 1985.

Electricity fuel generating mix from U.S. Energy Information Administration, 1986.

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REFERENCES

Akbari, H., et al., "The Impact of Summer Heat Islands on Cooling Energy Consumption and Global CO_2 Concentration," to be presented at the ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, August 1988.

American Council for an Energy-Efficient Economy, The Most Energy-Efficient Appliances (Washington, D.C.: American Council for an Energy-Efficient Economy, 1987).

American Council for an Energy-Efficient Economy, Proceedings from the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Volume 8, Planning and Forecasting (Washington, D.C.: American Council for an Energy-Efficient Economy, 1986).

American Council for an Energy-Efficient Economy, Proceedings from the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Volume 3, Large Building Technologies (Washington, D.C.: American Council for an Energy-Efficient Economy, 1986).

American Council for an Energy-Efficient Economy, Proceedings from the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Volume 2, Small Building Technologies (Washington, D.C.: American Council for an Energy-Efficient Economy, 1986).

American Council for an Energy-Efficient Economy, Proceedings from the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Volume 1, Appliances and Equipment (Washington, D.C.: American Council for an Energy-Efficient Economy, 1986).

American Council for an Energy-Efficient Economy for Pacific Gas and Electric Company, "Residential Conservation Power Plant Study, Phase 1 -- Technical Potential" (Washington, D.C.: American Council for an Energy-Efficient Economy, 1986).

Andrews, J.W., P. Aalto, T.C.J. Gleason, A.J. Skalafuris, "Modular Cogeneration in District Heating and Cooling Systems" (U.S. Department of Energy, December 1987) BNL 52133.

ASEAN, Proceedings of the ASEAN Conference on Energy Conservation in Buildings (Singapore: Sponsored by United States Agency for International Development, May 29 - 31, 1984).

Berrie, T.W., "Policy Issues in Improving Energy Efficiency," Energy Policy, 15: 529-533 (December 1987).

Bohi, D.R. and M.B. Zimmerman, "An Update on Econometric Studies of Energy Demand Behavior," Annual Review of Energy (Palo Alto, California: Annual Review Press, 1984).

Brookhaven National Laboratory, "Analysis and Technology Transfer Annual Report -- 1987," prepared for Office of Buildings and Community Systems, U.S. Dept. of Energy, (Upton, New York: Brookhaven National Laboratory, July, 1988).

Brown, Ian, "Administering Energy Saving: Four Years On," Energy Policy, 15: 534-537 (December 1987).

Busch, J.F. and A.K. Meier, "Monitored Performance of New, Low-Energy Homes: Updated Results from the BECA-A Database," LBL-18306, Lawrence Berkeley Laboratory, August 1984.

Brown, Marilyn, "Technology Transfer and the Buildings Industry," Oak Ridge National Laboratory Review, 20(3): pp. 27-28 (1987).

Cavanagh, Least-Cost Planning Imperatives for Electric Utilities and Their Regulators, 10 Harvard Environmental Law Review, 299, 322-24, 330-42 (1987).

Chandler, William U., "Assessing the Carbon Emission Control Strategies: The Case of China, Climatic Change, 1988.

Chandler, William U., Atmospheric Methane Emissions: A Summary of Sources and Policy Issues, Battelle, Pacific Northwest Laboratories, Draft, December 21, 1988.

Ching, Wong Wai, "Energy Conservation in Buildings in Singapore," in Proceedings of the ASEAN Conference on Energy Conservation in Buildings, Singapore, May 1984, sponsored by U.S. AID.

Cicchetti, C.J., "Incentive Regulation: Some Conceptual and Policy Thoughts" (Cambridge, MA: Energy and Environmental Policy Center, Kennedy School of Government, Harvard University, May 1, 1989).

Cicchetti, C.J. and S.M. Curkendall, "Conservation Subsidies: The Economist's Perspective," in Electric Potential, Vol. 2, No. 3.

Cicchetti, C.J. and S.M. Curkendall, "Are Energy-Efficiency Programs Worth It?" (Cambridge, MA: National Economic Research Associates, Inc.).

Cicchetti, C.J. and W. Hogan, "Including Unbundled Demand-Side Options in Electric Utility Bidding Programs," Discussion Paper (Cambridge, MA: Energy and Environmental Policy Center, John F. Kennedy School of Government, Harvard University, Aug. 1988).

Clinton et al., "Review of Government and Utility Energy Conservation Programs," 1986.

Cogan, Douglas and Williams, Susan, Generating Energy Alternatives: Conservation, Load Management and Renewable Energy at America's Electric Utilities (Washington, D.C.: Investor Responsibility Research Center, Inc., 1983).

Cohen, Armond, "Utility/State Energy Program Options to Reduce CO_2: A New England Perspective," Conservation Law Foundation of New England, 1989.

Council on Development Choices for the '80s, The Affordable Community (Washington, D.C.: Urban Land Institute, 1981).

Devault, B. "State-of-the-Art of Residential Thermally Activated Heat Pumps," presentation at the First National Conference on Appliance Efficiency, sponsored by the American Council for an Energy-Efficient Economy, Washington, D.C., Oct. 1987.

Dyer, Robert F., "A Longitudinal Analysis of the Impact of the Appliance Energy Labeling Program" (Washington, D.C.: Office of Impact Evaluation, Federal Commission, November, 1986).

Edmonds, Jae and John M. Reilly, Global Energy (New York, Oxford University Press, 1985).

Eto, J.H. and C. Meyer, "The HVAC Costs of Fresh Air Ventilation in Office Buildings," (Berkeley, CA: Lawrence Berkeley Labs, 1987). LBL-24135

Fisher, S.K., Creswick, F.A., and Diechman, J., "Energy-Use Impact of Chlorofluorocarbon Restrictions in Refrigeration and Buildings Applications," draft report (Oak Ridge, TN: Oak Ridge National Laboratories, Nov. 1987).

Geller, Howard S., "The Potential for Electricity Conservation in Brazil" (Sao Paulo, Brazil: Companhia Energetica de Sao Paulo, 1984).

Geller, Howard S., "Progress in Energy Efficiency of Residential Appliances and Space Conditioning Equipment," pp. 270-298 in Energy Sources: Conservation and Renewables, edited by David Hafemeister, Henry Kelly and Barbara Levi (New York: American Institute of Physics, 1985), AIP Conference Proceedings, Number 135.

Geller, Howard S., "Energy-Efficient Residential Appliances: Performance Issues and Policy Options," IEEE Technology and Society Magazine: 4-10 (March 1986a).

Geller, Howard S., "Improving End-Use Electrical Efficiency: Options for Developing Countries", Energy Department Paper, World Bank, June 1986b.

Geller, Howard, "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the U.S. Economy," p 357-395 in Annual Review of Energy, Volume 12, 1987, edited by Jack M. Hollander, Harvey Brooks and David Sternlight (Palo Alto, CA: Annual Reviews Press, 1987a).

Geller, Howard, "Energy and Economical Savings from National Appliance Energy Standards," (Washington, D.C.: American Council for an Energy-Efficient Economy, 1987b).

Geller, Howard, "Commercial Building Equipment Efficiency: A State-of-the-Art Review," written under contract to the Office of Technology Assessment, Contract Number H3-6705.0, 1988a.

Geller, Howard, "Residential Equipment Efficiency: A State-of-the-Art Review," written under contract to the Office of Technology Assessment, Contract Number H3-6705.0, 1988b.

Gellings, C.W. and Limaye, D.R., Electric Utility Conservation Programs (Westport, CT: Greenwood Press, 1986).

Gibbons, John H. and William U. Chandler, Energy, The Conservation Revolution, Plenum Press, New York, 1981.

Goldemberg, Jose, et al., "An End-Use Oriented Global Energy Strategy," pp. 613-688 in Vol. 10, Annual Review of Energy, 1985 (Palo Alto, CA: Annual Reviews Press, 1985).

Goldemberg, Jose and Williams, Robert H., "The Economics of Energy Conservation in Developing Countries: A Case Study for the Electrical Sector in Brazil," pp. 33-52 in Energy Sources: Conservation and Renewables, edited by David Hafemeister, Henry Kelly and Barbara Levi (New York: American Institute of Physics, 1985), AIP Conference Proceedings, Number 135.

Goldemberg, Jose, et al., Energy for a Sustainable World (Washington, D.C.: World Resources Institute, September 1987a).

Goldemberg, Jose, et al., Energy for Development (Washington, D.C.: World Resources Institute, September 1987b).

Goldemberg et al., Energy for a Sustainable World (New Delhi, India: Wiley Eastern Limited, 1988).

Goldman, C.A., "Measured Results of Energy Conservation Retrofits in Residential Buildings," presented at 1986 ASHRAE Winter Meeting, San Francisco, CA, Jan. 19-22, 1986, LBL-20950.

Hagler, Bailly & Company, Financing Energy Conservation in Developing Countries (Washington, D.C.: Hagler, Bailly & Company, 1987), prepared for the Office of Energy, Bureau for Science and Technology, U.S. Agency for International Development.

Herendeen, R.A., "Notes and Comment on the Energy Cost of Building Construction," in Energy and Buildings, 1 (1977) 95-96 (The Netherlands: Elsevier Sequoia S.A., 1977).

Hirst, Eric, "Improving Energy Efficiency of Existing Homes: The Residential Conservation Service," in State Energy Policy: Current Issues, Future Directions (Westview Press, 1985).

Hirst, Eric, Deanne Clinton, Howard Geller, and Walter Kroner, Energy Efficiency in Buildings, Progress and Promise (Washington, D.C.: American Council for an Energy-Efficient Economy, 1986).

Hirst, Eric, Robert Marlay, David Greene, and Richard Barnes, "Recent Changes in U.S. Energy Consumption: What Happened and Why," in Annual Review of Energy (Palo Alto, CA: Annual Reviews Press, 1983).

International Energy Agency, Energy Balances of Developing Countries, 1971 - 1982 (Paris, France, International Energy Agency, 1984).

International Energy Agency, Energy For Buildings (Paris, France, International Energy Agency, 1986a).

International Energy Agency, Energy Balances of OECD Countries, 1970 - 1985 (Paris, France, International Energy Agency, 1986b).

Keepin, W., I. Mintzer, and L. Kristoferson, "Emission of CO_2 into the Atmosphere," in B. Bolin, B.R. Doos, J. Jager, and R.A. Warrick, eds., The Greenhouse Effect, Climatic Change and Ecosystems (Chichester and New York: John Wiley & Sons, 1986).

Keyes, Dale L., "The Influence of Energy on Future Patterns of Urban Development," in Solomon, Arthur P. (ed.), The Prospective City: Economic, Population, Energy and Environmental Development (Cambridge, MA: The MIT Press, 1980).

Komar, P.S. and Wiggins, L.L., "Energy Conservation Behavior: A Critique of the Cost-Minimization Model, and a Review of Some Alternative Models," J. Environmental Systems, V. 18(1), (1988-1989).

Komar, P.S. and Wiggins, L.L., "Predicting Conservation Choice: Beyond the Cost-Minimization Assumption," Energy, V. 13, No. 8, pp. 633-645 (Great Britain: Permagon Press, 1988).

Krause, F., et al., Final Report: Analysis of Michigan's Demand-Side Electricity Resources in the Residential Sector, Vol. I - III (Berkeley, CA: Lawrence Berkeley Laboratory, April 1988) LBL-23026.

Lawrence Berkeley Laboratory, "Buildings Energy Use Compilation and Analysis Project," March 6, 1986.

Leach, Gerald, Lorenz Jarass, Gustav Obermair, and Lutz Hoffman, Energy and Growth, A Comparison of 13 Industrial and Developing Countries, Butterworth Scientific, Guildford, England, 1986a.

Leach, Gerald, Household Energy in South Asia (London: International Institute for Environment and Development, May 1986b).

Least-Cost Planning: A State Survey, Public Utilities Fortnightly, at 38-41 (May 1987).

Ledbetter, Marc, "Energy Efficiency: An Overlooked Environmental Protection Strategy," paper presented at Alliance to Save Energy's conference on Preparing for the Energy Challenges of the 1990s, January 28, 1988.

Levine, M.D., J. Koomey, H. Ruderman, P. Craig, J. McMahon, and P. Chan, "Economics of Efficiency Improvements in Residential Appliances and Space Conditioning Equipment" in American Institute of Physics, 1985.

Loveland, J.E. and Brown, G.Z., "Impacts of Climate Change on the Energy Performance of Buildings in the United States," Contract Number J3-4825.0, Office of Technology Assesment, U.S. Congress.

Lovins, Amory, The Expanding Potential for U.S. Energy Efficiency, Abstract of Invited Testimony by Amory B. Lovins, Director of Research, Rocky Mountain Institute, to the Subcommittee on Energy and Power, Committee on Energy and Commerce, House of Representatives, U.S. Congress, Oversight Hearings on Energy Conservation, November 4th, 1987.

MacDonald, J.M., "A Research Plan for Commercial Sector Retrofits," Proceedings from the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Vol. 3.

Manzoor Alam, Joy Dunkerley, K.N. Gopi, William Ramsay, and Elizabeth Davis, Fuelwood in Urban Markets, Naurang Rai, New Delhi, India, 1985.

Markowitz, Paul and Joseph Kriesberg, "Least-Cost Electrical Planning: Is There Really A State Movement?" (Washington, D.C.: Public Citizen, Critical Mass Energy Project, Dec. 1985).

McMahon, James E., "The LBL Residential Energy Model: An Improved Policy Analysis Tool," Energy Systems and Policy, Volume 10, Number 1, 1987.

McMahon, James E., "Validation of the LBL Residential Energy Model," presented at the ACEEE 1986 Summer Study.

Meyers, Steven, "Energy Consumption and Structure of the US Residential Sector: Changes Between 1970 and 1985," pp. 81-97 in Annual Review of Energy, Volume 12, 1987, edited by Jack M. Hollander, Harvey Brooks and David Sternlight (Palo Alto, CA: Annual Reviews Press, 1987).

Mixon, William, Michael Karnitz, and Michael MacDonald, "Improving Energy Efficiency in Homes and Commercial Buildings," Oak Ridge National Laboratory Review, 20(3): pp. 46-52 (1987).

Moscovitz, David, "Will Least-Cost Planning Work Without Significant Regulatory Reform?" presented at the Least-Cost Planning Seminar, National Association of Regulatory Utility Commissioners, Aspen, CO, Apr. 12, 1988.

Mueller Asociates, Inc., "Market Potential for Small Scale (15 kW to 500 kW) Cogeneration Systems" (U.S. Department of Energy, MAI Project No. 84-228-10, Nov. 27, 1985). DOE/CE/40716-T1.

National Audubon Society, The Audubon Energy Plan, Vol. 1 and 2, Second Edition (New York, NY: National Audubon Society, 1984).

Nemtzow, David, "Competing for Demand-Side Resources" (Cambridge, MA: Kennedy School of Government, Harvard University, 1988).

Northwest Power Planning Council, Northwest Conservation and Electric Power Plan (Portland, Oregon: Northwest Power Planning Council, 1986).

Northwest Power Planning Council, 1989 Supplement to the 1986 Northwest Conservation and Electric Power Plan (Portland, Oregon: Northwest Power Planning Council, 1989).

Oak Ridge National Laboratory, "Energy Technology R&D: What Could Make a Difference?", draft (Oak Ridge, TN: Oak Ridge National Laboratory, Dec. 1988).

OECD, Energy Balances of OECD Countries (Paris, France: International Energy Agency, 1987).

Prindle, William R. and Michael W. Reid, Energy Efficiency: A Key to Affordable Housing, paper presented at Alliance to Save Energy's conference on Preparing for the Energy Challenges of the 1990s, January 28, 1988.

Reddy, Amulya Kumar N., An End-Use Methodology for Development-Oriented Energy Planning In Developing Countries, With India as a Case Study, PU/CEES Report NO. 181 (Princeton, N.J.: Center for Energy and Environmental Studies, Princeton University, February, 1985)

Resources for the Future, Trend in Energy Use in Industrial Societies, EPRI EA-1471, 1980.

Ritschard, Ronald and Dorothy Dickey, "Energy Conservation in Public Housing: It Can Work," in Energy Systems and Policy, V. 8, No. 3, 1984.

Rosenfeld, Arthur H. and David Hafemeister, "Energy Conservation in Large Buildings," pp. 148-168 in Energy Sources: Conservation and Renewables, edited by David Hafemeister, Henry Kelly and Barbara Levi (New York: American Institute of Physics, 1985), AIP Conference Proceedings, Number 135.

Rosenfeld, Arthur H. and David Hafemeister, "Residential Energy Efficiency: Progress Since 1973 and Future Potential," in Energy Sources: Conservation and Renewables, edited by David Hafemeister, Henry Kelly and Barbara Levi (New York: American Institute of Physics, 1985), AIP Conference Proceedings, Number 135.

Rosenfeld, Arthur H. and David Hafemeister, "Energy-Efficient Buildings," Scientific American, 258(4): 78-85 (April 88).

Rotty, R.M. and C.D. Masters, "Carbon Dioxide from Fossil Fuel Combustion: Trends, Resources, and Technological Implications," in Trabalka, John R. (ed.), Atmospheric Carbon Dioxide and the Global Carbon Cycle (Washington, D.C.: U.S. Department of Energy, December 1985), DOE/ER-0239.

Ruderman, H., et al., "Energy Efficiency Choice in the Purchase of Residential Appliances," Doing Better: Setting an Agenda for the Second Decade, (Washington, D.C.: American Council for an Energy-Efficient Economy, 1984).

Sathaye, Jayant, Andre Ghirardi, and Lee Schipper, "Energy Demand in Developing Countries: A Sectoral Analysis of Recent Trends," pp. 253-281 in Annual Review of Energy, Volume 12, 1987, edited by Jack M. Hollander, Harvey Brooks and David Sternlight (Palo Alto, CA: Annual Reviews Press, 1987).

Sathaye, Jayant and Stephen Meyers, "Energy Use in Cities of the Developing Countries," in Annual Review of Energy, 1985.

Schipper, L., "Energy conservation in OECD homes: Permanent or reversible?", Energy Journal, Volume 6, October 1985.

Schipper, Lee, "Energy Conservation Policies in the OECD. Did They Make a Difference?" Energy Policy, 15: 538-548 (December 1987).

Schipper, L. and A. Ketoff, International Comparison of Residential Energy Use. Part One: The Data Base (Berkeley, CA: Lawrence Berkeley Lab, 1980), LBL-11703.

Schipper, L. and A. Ketoff, "Oil Conservation: Permanent or Reversible? The Example of Homes in the OECD" (Berkeley, CA: International Energy Studies, Lawrence Berkeley Laboratory, Oct., 1984) NTIS publication. LBL-17785, UC-95d.

Schipper, L. and A. Ketoff, "Explaining Residential Energy Use by International Bottom-up Comparisons," in Annual Review of Energy, edited by Jack M. Hollander, Harvey Brooks and David Sternlight (Palo Alto, CA: Annual Reviews Press, 1987).

Schipper, L., A. Ketoff, S. Meyers, and D. Hawk, "Residential Electricity Consumption in Industrialized Countries: Changes Since 1973," Energy, 12 (12): 1197-1208 (1987).

Schipper, L., S. Meyers, and H. Kelly, Coming in From the Cold, Energy-Wise Housing in Sweden (Cabin John, Maryland: Seven Locks Press, 1985).

Schipper, L., S. Meyers, and A. Ketoff, "Energy Use in the Service Sector: An International Perspective," Energy Policy, 14: 210-218 (June 1986).

Shapiro, Lisa, Paul Markowitz, and Nancy Hirsh, "A Brighter Future: State Actions in Least-Cost Electrical Planning" (Washington, D.C.: Energy Conservation Coalition, Environmental Action Foundation, December 1987).

Silas, Adrien L., Appliance Standards: Summary of National Appliance Energy Conservation Act of 1987 (Washington, D.C.: Congressional Research Service, July 2, 1987), CRS Report 87-578.

Sissine, Fred J., Energy Conservation: Technical Efficiency and Program Effectiveness (Washington, D.C.: Congressional Research Service, September 29, 1987), Issue Brief, Order Code IB85130.

Solar Energy Research Institute, et al., A New Prosperity, Building a Sustainable Energy Future, The SERI Solar/Conservation Study, Brick House Publishing, 1981.

Statt, T.G., "The Use of Chlorofluorocarbons in Refrigeration, Insulation, and Mobile Air Conditioning in the United States," Poster Paper Abstracts at Conference on Substitutes and Alternatives to CFCs and Halons, Cosponsored by the Conservation Foundation, the U.S. Environmental Protection Agency, and Environment Canada, January 13-15, 1988.

Stein, R.G., "Energy Cost of Building Construction" in Energy and Buildings, 1 (1977) 27-29 (The Netherlands, Elsevier Sequoia S.A., 1977).

United States Congress, Office of Technology Assessment, Residential Energy Conservation (Washington, D.C.: U.S. Government Printing Office, July 1979).

United States Congress, Office of Technology Assessment, Technology and the Future of the U.S. Construction Industry (Washington, D.C.: AIA Press, 1981).

United States Congress, Office of Technology Assessment, Residential Energy Conservation (Washington, D.C.: U.S. Government Printing Office, July 1979) OTA-E-92.

United States Congress, Office of Technology Assessment, Energy Efficiency of Buildings in Cities (Washington, D.C.: U.S. Government Printing Office, March 1982).

United States Congress, Office of Technology Assessment, Technologies to Sustain Tropical Forest Resources (Washington, D.C.: U.S. Government Printing Office, 1984) OTA-F-214.

United States Congress, Office of Technology Assessment, Technology, Trade, and the U.S. Residential Construction Industry (Washington, D.C.: U.S. Government Printing Office, Sept. 1986).

United States Congress, Office of Technology Assessment, Technology and the American Economic Transition, Choices for the Future, OTA-TET-283 (Washington, D.C.: U.S. Government Printing Office, May 1988).

United States Congress, Office of Technology Assessment, Industrial and Commercial Cogeneration.

United States Congress, Senate Committee on Environment and Public Works, Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances, Ozone Depletion, The Greenhouse Effect, and Climate Change (Washington, D.C.: U.S. Government Printing Office, 1987), S. Hrg 100-3.

United States Congress, House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and the Environment, Hearing, March 9, 1987, Ozone Layer Depletion (Washington, D.C.: U.S. GPO, 1987). Serial No. 100-7.

United States Department of Energy, Market Potential for Small Scale (15 kW to 500 kW) Cogeneration Systems (Washington, D.C.: U.S. DOE, November 27, 1985) DOE/CE/40716--T1.

United States Department of Energy, DOE Assistant Secretary's Review of Office of Buildings and Community Systems (Berkeley: Lawrence Berkeley Laboratory, October 1986).

United States Department of Energy, Assistant Secretary, Conservation and Renewable Energy, "Annual Report on Federal Government Energy Management, Fiscal Year 1987."

United States Department of Energy, Office of Scientific and Technical Information, Buildings Energy Technology (Oak Ridge, TN: U.S. DOE, 1988).

United States Department of Energy, Assistant Secretary, Conservation and Renewable Energy Building Equipment Division, Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators, Furnaces, and Television Sets, including Environmental Assessment (DOE/EA-0372) and Regularity Impact Analysis (Washington, D.C.: U.S. DOE, November 1988) COE/CE-0239.

United States Department of Energy, Office of Conservation and Renewable Energy, "Energy Conservation Voluntary Performance Standards for Commercial and Multi-Family High Rise Residential Buildings; Mandatory for New Federal Buildings; Interim Rule," Federal Register, Vol. 54, No. 18, Monday, January 30, 1989.

United States Energy Information Administration, Annual Report to Congress -- 1980 (Washington, D.C.: Department of Energy, 1981) DOE/EIA-0173(80)/2.

United States Energy Information Administration, Annual Energy Review (Washington, D.C.: Energy Information Administration, 1986, DOE/EIA-0384).

Vine, E., B.K. Barnes, and R. Ritschard, Evaluation of the Implementation of Home Energy Rating Systems (Berkeley, CA: Lawrence Berkeley Lab, 1987), NTIS, PC A02/MF A01.

Vine, E., B.K. Barnes, and R. Ritschard, Home Energy Rating Systems: Program Descriptions (Berkeley, CA: Lawrence Berkeley Lab, 1987), LBL-22919, UC-95d.

Vine, E. and Jeff Harris, Planning for an Energy-Efficient Future: The Experience of Energy Conservation Programs with New Residential and Commercial Buildings (Berkeley, CA: Lawrence Berkeley Lab, July 1988), draft, LBL-25525.

Williams, Robert H., Gautam S. Dutt, and Howard S. Geller, "Future Energy Savings in U.S. Housing," pp. 269-332 in Vol. 8, Annual Review of Energy, 1983 (Palo Alto, CA: Annual Reviews Press, 1983).

Wirtshafter, Robert M., Angela Sorrentino, and Chang Song-ying, "Improving Energy Efficiency in Chinese Housing."

World Bank, China, The Energy Sector: Annex 3 to China Long-Term Development Issues and Options, The World Bank, Washington D.C.
(possibly from a document called World Bank Country Study).

Zhu, Hang, M. Brambley, and R. Morgan., "Household Energy Consumption in the People's Republic of China," in Energy, Vol. 8, No. 10, p. 765.