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Higher Mortgages, Lower Energy Bills: The Real Economics of Buying an Energy-Efficient Home

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HIGHER MORTGAGES, LOWER ENERGY BILLS: THE REAL ECONOMICS OF BUYING AN ENERGY-EFFICIENT HOME

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ABSTRACT

To measure the *actual* costs and benefits of buying an energy-efficient home, it is necessary to employ a cash-flow model that accounts for mortgage interest and other charges associated with the incremental costs of conservation measures. The ability to make payments gradually over the term of a mortgage, energy savings, and tax benefits contribute to increased cost effectiveness. Conversely, financial benefits are reduced by interest payments, insurance, taxes, and various fees linked to the (higher) sale price of an energy-efficient home. Accounting for these factors can yield a strikingly different picture from those given by commonly used "engineering" indicators, such as simple payback time, internal rate of return, or net present value (NPV), which are based solely on incremental costs and energy savings.

This analysis uses actual energy savings data and incremental construction costs to evaluate the mortgage cash flow for 79 of the 144 energy-efficient homes constructed in Minnesota under the Energy-Efficient Housing Demonstration Program (EEHDP) initiated in 1980 by the Minnesota Housing Finance Agency. Using typical lending terms and fees, we find that the mean mortgage-NPV derived from the homeowners' real cash flow (including construction and financing costs) is 20% lower than the standard engineering-NPV of the conservation investment: \$7981 versus \$9810. For eight homes, the mortgage-NPV becomes negative once we account for the various mortgage-related effects. Sensitivities to interest rates, down payment, loan term, and marginal tax rate are included to illustrate the often large impact of alternative assumptions about these parameters. The most dramatic effect occurs when the loan term is reduced from 30 to 15 years and the mortgage NPV falls to -\$925. We also evaluate the favorable Federal Home Administration (FHA) terms actually applied to the EEHDP homes.

KEYWORDS

Energy Conservation, Economics.

INTRODUCTION

Energy-conservation decisions often hinge on predicted economic benefits of the conservation measures. Economic indicators such as the simple payback time, internal rate of return, and net present value—although often used in the residential buildings sector—do not reflect the homeowner's actual cash flow, since energy-conservation investments are capitalized through a mortgage payment schedule. Considering mortgage effects is important, whether the cost of conservation is financed by means of a home mortgage (for new homes) or a home-improvement loan (for retrofit of existing homes). Components of actual cash flow that increase or decrease due to the conservation measures include: interest, down payment, taxes and tax deductions, insurance, potential resale value, and loan origination fees. Estimates of cost effectiveness derived by accounting for these mortgage-related costs and benefits can differ greatly from standard "engineering" or "societal" estimates of cost effectiveness.

The following analysis illustrates the importance of taking into account mortgage effects when determining benefits to the buyer of an energy-efficient home. We analyze real energy savings and cost-of-conservation data for a number of homes and compare these results with those derived from common engineering economics. Sensitivities to key variables underscore the importance of making reasonable assumptions when evaluating the economic performance of conservation financed through a mortgage.

The influence of mortgage financing on cost effectiveness is relevant to numerous housing concerns. The immediate use of this study can be to improve the process of evaluating the cost effectiveness of residential energy standards, residential energy conservation ordinances (RECOs), lending policy, and home energy rating systems (HERS).

IMPORTANCE OF THE MORTGAGE PERSPECTIVE

Standard economic methods overstate substantially the true financial benefits to the buyer of an energy-efficient home. An analysis that accounts for mortgage effects reveals a very different cash-flow pattern from that resulting from standard engineering analyses. Several variables contribute to the discrepancy between the engineering net present value (E-NPV) and the mortgage net present value (M-NPV). Because an energy-efficient home is more expensive than a standard home, the homebuyer pays incremental costs beyond the direct cost of the conservation features. These costs include one-time payments such as loan-origination fees (points) and title insurance; and they include ongoing costs such as principal and interest on the loan, increased property taxes, and fire insurance. Benefits resulting from mortgage-financing include tax deductions for interest and points and the partial deferral into future years of payments.

Three perspectives are important when considering the difference between M-NPV and E-NPV: those of the homebuyer, lender, and "society". The homebuyer—while paying more than the "sticker price" of the home as a result of interest, taxes, and fees—benefits from the ability to spread payments over a long period. Lenders may see the energy-efficient home as both an asset and liability to their client. The homebuyer's cash flow resulting from the conservation investment will certainly be negative in the first year after purchase because of one-time costs such as increased points, down payment, and title insurance. Ultimately, lower energy bills, tax savings, and resale value may result in positive cash flow, making the client a better risk in the lender's eyes, i.e., the chance of default lessens as the client's net monthly cash flow increases. The societal perspective is equivalent to that indicated by the E-NPV because the incremental "costs" beyond those of the conservation features themselves are simply transfers of money (taxes and insurance) and not true costs.

Two of the most important factors to the buyer and lender are the term of the loan and resale value (Holt, 1984). The typical "residence time" for owner-occupied buildings is roughly seven years. Resale value is partly a function of the second buyer's expectations about future energy prices, yet little is known about how the housing market values conservation. For many homebuyers, energy-related value is a function of energy savings *and* other amenities—such as decreased drafts—resulting from the conservation measures. A study of the resale value of conservation amenities in the 1979 Knoxville TN housing market found that a one-dollar reduction in the annual fuel bill increases the resale value of the house by roughly 20 dollars, implying a low buyer discount rate (Johnson and Kaserman, 1983).[1] The Knoxville data come from a time of keen national awareness of energy use and the value of conservation; resale value no doubt varies with current energy prices and the popularity of energy issues.

The mortgage perspective on energy efficiency is slowly finding a place in the housing market. Lower interest rates and higher debt-to-income ratios (the ability to qualify for a more expensive home on a set income) are available from several lending institutions to buyers of energy-efficient homes. Mortgage-based analysis is also being used in the development and evaluation of thermal standards. The Northwest Power Planning Council and the Bonneville Power Administration are using mortgage cash flow to evaluate the cost effectiveness of their proposed Model Conservation Standards (Bonneville, 1986) and others have used this perspective to evaluate existing construction codes for manufactured and site-built homes (Balistocky *et al.*, 1985).

Perhaps more noteworthy, Sweden has encouraged extensive use of energy-efficiency features in new homes via an exceptionally favorable mortgage-financing system. Initially, the interest rate is set very low (5.5% in the first year) and then rises, at the rate of ½% per year, to the normal interest rate. In addition, to lessen negative cash flow in the first year of home ownership, the down payment is set at only five percent. During the past two decades, virtually all Swedish apartments and 85 to 90% of single-family homes have been built under this system (Schipper *et al.*, 1985).

[1] The Knoxville data reflect an upper bound on the valuation of conservation in the housing market. Such analyses are problematic owing to their reliance on regression techniques to determine the value of home amenities. The variable for conservation can unfairly "take credit" for factors such as quality of construction or tree-shading, both of which increase the home resale value but not all of which save energy.

DATA SOURCES AND METHODOLOGY

The Lawrence Berkeley Laboratory (LBL) has compiled energy and cost data for 107 of the 144 homes constructed and monitored under the MHFA Energy-Efficient Housing Demonstration Program. The construction strategies used in the program emphasized super-insulation and passive-solar design (Nelson *et al.*, 1986). The homes analyzed here represent the subset of 79 homes for which energy savings and incremental cost data of sufficient quality were available. The energy data are derived from the first year of monitoring. In a subsequent year, space heating energy use was sub-metered for 47 homes. Of this group, only 24 homes with both sub-metered heating energy also had usable cost data, a far cry from the initial 144-home sample.

The methodology employed at LBL computes savings in *annual furnace output*, thereby isolating the effects of building-envelope efficiency from those of the heating system (Busch and Goldman, 1986). Incremental costs for efficient heating systems are not included in the cost data. The baseline used to compute heating energy savings was developed using computer simulations of homes built according to typical construction practice and levels of thermal integrity as reported by the National Association of Homebuilders' (NAHB) survey of builders in the region.

Using measured energy savings, a "mortgage net present value" (M-NPV) is calculated based on the annual pattern of "after-tax net cash flow" (ATNCF) due to the investment and the resulting energy savings, or:

$$\text{ATNCF} = \text{Energy Savings} + \text{Tax Savings} + \text{Resale Value}$$
$$- \text{Down Payment} - \text{Points} - \text{Insurance} - \text{Taxes} - \text{Interest} - \text{Principal}$$

where the down payment, points, and title insurance costs occur only in the year the home is purchased. By projecting the ATNCF over a desired time horizon, we can evaluate an M-NPV that can be compared to the engineering net present value (E-NPV) which simply deducts a initial lump-sum payment from the discounted energy savings over that same time period.

RESULTS

Table 1 presents the base-case assumptions for ATNCF, the first-year costs associated with each variable, and the degree to which each component contributes to the total M-NPV. Figure 1 shows the relative impact of each variable. The engineering and mortgage net present values are compared in Table 2 where one can readily see the importance of cost components neglected by the engineering net present value. In addition, the patterns of cumulative cash flows also differ for the two calculation procedures (see Figure 2). The resulting annual cash flow for the mean case ± one standard deviation is plotted in Figure 3. Mortgage net present values and selected building characteristics for each of the 79 homes are shown in Appendix-A.

Under the base-case assumptions, the mean M-NPV for the 79 homes is \$7981, 20% lower than the standard engineering method indicates. This result is primarily due to the high interest charges paid through the mortgage. Not only does E-NPV overestimate the financial benefits but it also fails to reveal the negative benefits resulting from extra mortgage-related costs in 8 of the 79 homes. High electricity prices (relative to gas) generally result in larger net present values.

A central objective of energy-efficient homebuilding demonstrations, such as the Minnesota program, is to identify correlates of building characteristics and the cost of conservation with cost-effectiveness. Unfortunately the relation is often rather weak. In particular, the correlation between hand-calculated heat loss coefficients (HLC) and M-NPV is low (due in part to the substantial role of solar gains). However, incremental costs and energy savings show some correlation to the M-NPV (see Figures 4 and 5, the outliers are homes with electric heating).

Sensitivity Analysis

As shown by the sensitivities in Table 3, interest rates and loan term are extremely important variables. An interest rate of 12% or term of 20 years reduces the M-NPV to \$6781 or \$1852 (69 and 19% of the E-NPV), respectively. Figure 6 shows M-NPV versus E-NPV for each of the homes for the case of a 15-year loan term. Applying the very favorable terms (down payment=5%, points=2%, and interest rate=7%) available through Federal Home Administration (FHA) loans to the buyers of the Minnesota homes, increases the M-NPV from the base case value of \$7981 to \$8640. A very long payment schedule (35 years) under typical lending terms yields a significantly greater improvement in M-NPV.

In our base-case scenario, a single owner is assumed to occupy the home for the duration of the loan period and resale value, if any, is ignored. However, the nature of resale value presents some interesting questions. If resale occurs in year seven, the approximate resale value required for the first owner to break even is the unpaid balance of the loan less the 7-year M-NPV, or \$7000 for the Minnesota base case. Resale value must be adjusted for transaction costs such as realtor commission and capital gains tax. For a given real energy price escalation rate (1%/year in the base case), the E-NPV is unchanged by varying the nominal discount rate; however, the present values of multi-year mortgage payments and tax savings are highly sensitive to the assumed discount rate.

CONCLUSIONS

Investigation of the mortgage NPV reveals that the financial benefits of buying an energy-efficient home depend on factors neglected by simplified calculations such as the engineering net present value. Except in the most favorable cases, benefits are lower than indicated by conventional engineering analyses. For the 79 homes in our sample, however, mean benefits are still positive. As long as this is the case, lenders may be able to justify offering more-favorable financing and/or relaxing loan-qualification criterion to reflect the improved financial position of the buyer of an energy-efficient home. In cases where the M-NPV is negative and the E-NPV is positive, subsidies may be necessary to encourage investment in energy-efficiency that is socially beneficial although not necessarily so for a given buyer. The wide range in sensitivity results suggest that any accurate application of mortgage-based analysis of conservation must begin with project-specific data and lending assumptions. Resale value or lending terms can make or break the cost-effectiveness of an energy-efficient home.

RESEARCH NEEDS

There are numerous ways in which the after-tax net cash flow methodology presented here may be applied to valuing energy efficiency in the housing market, yet many questions remain unanswered. The following list suggests promising applications and avenues of research.

- *Simplified tools for lenders/builders/buyers/appraisers:* Within, for example, the framework of home energy rating systems (HERS), builders and appraisers can use mortgage cash flow to inform lenders and buyers of the annual financial impact of the conservation investment. Higher debt-to-income (D/I) ratios increase the pool of qualified buyers and the ability of a given buyer to purchase a larger or higher-quality home. Mortgage cash flow analyses may be used to determine appropriate D/I increases as a function of climate, building type, etc.
- *Alternative mortgage instruments:* There are many ways of structuring mortgages. Each has a different effect on ATNCF and thus the size of the M-NPV. Although energy is not a key factor in determining mortgage terms, the differences in outcomes based on these terms can be significant. The FHA approach is one example of improving cost effectiveness by using alternative mortgage terms.
- *International comparisons:* Mortgage-financing incentives used abroad, notably in Sweden, can encourage increased investment in energy efficiency.
- *Relationship of M-NPV to societal NPV:* Direct societal benefits may be determined by following a procedure similar to that presented here for the engineering net present value, most likely using a lower discount rate. If M-NPV is negative, yet the societal NPV is positive, there is need for subsidy or assistance in making payments for the efficient home. Utilities may find this cost analysis approach useful in determining appropriate conservation program rebates or incentives.
- *Standard-setting:* Wider use can be made of mortgage analysis in identifying optimal energy-performance standards for homes and their appliances.
- *Existing residences:* Measured pre- and post-retrofit data may be evaluated by applying the methodology presented here to the case of home-improvement loans (usually with less-favorable terms). From the research perspective, retrofit analysis, when annual consumption is normalized to long-term average weather conditions, provides an especially reliable baseline from which savings may be computed.
- *Correlates of high M-NPV:* The Minnesota experience, and others as well, have shown that simple indicators of thermal efficiency do not correlate well with the M-NPV. Techniques for identifying reliable indicators of cost effectiveness as a function of selected conservation features, construction costs, or energy savings, are needed by all participants in the housing market.

- *Field data:* Well-controlled studies of energy-efficient homes bought and sold on the market would help quantify the value that is actually placed on conservation at the time of home resale.

ACKNOWLEDGEMENTS

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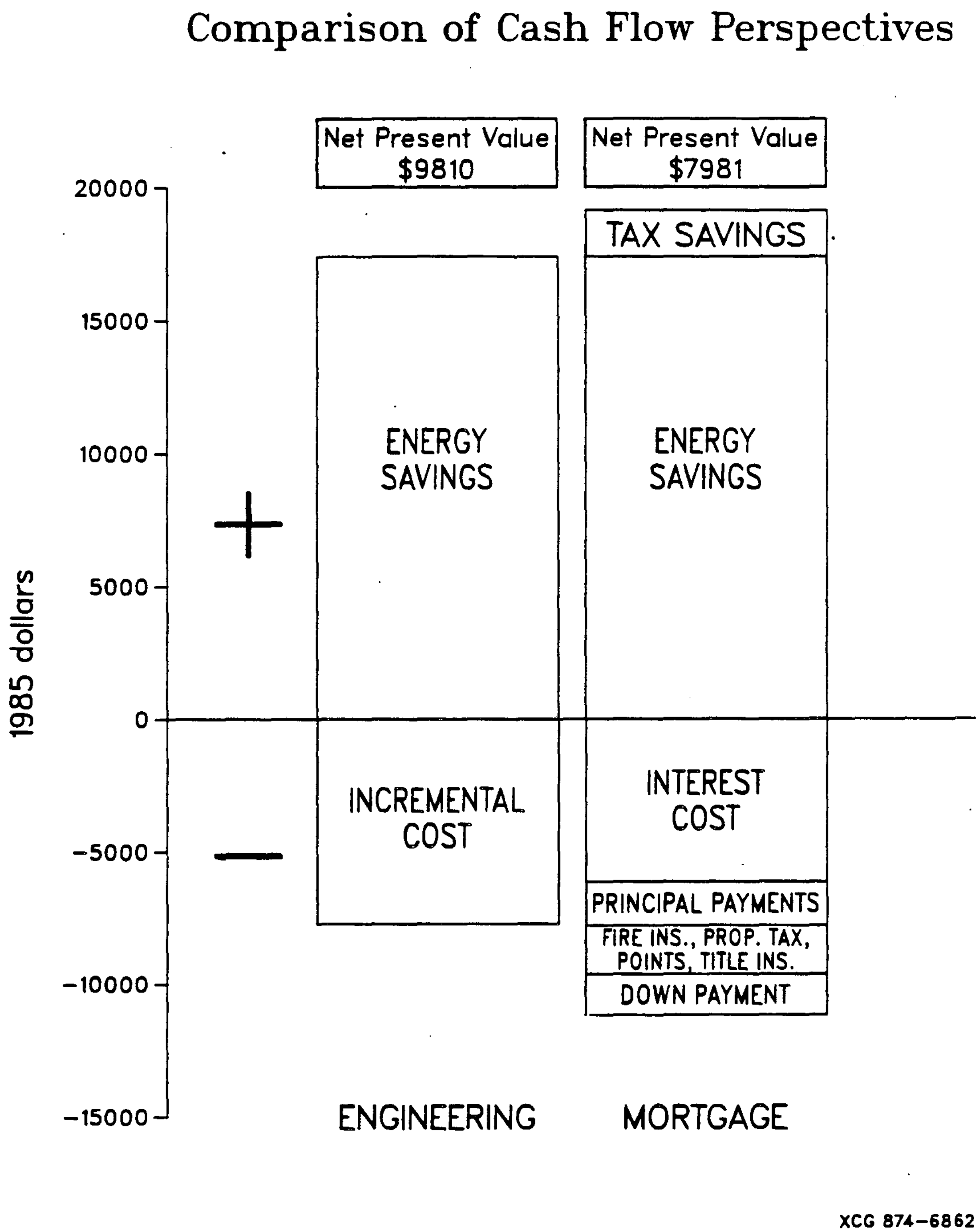

Figure 1. Components of E-NPV and M-NPV.

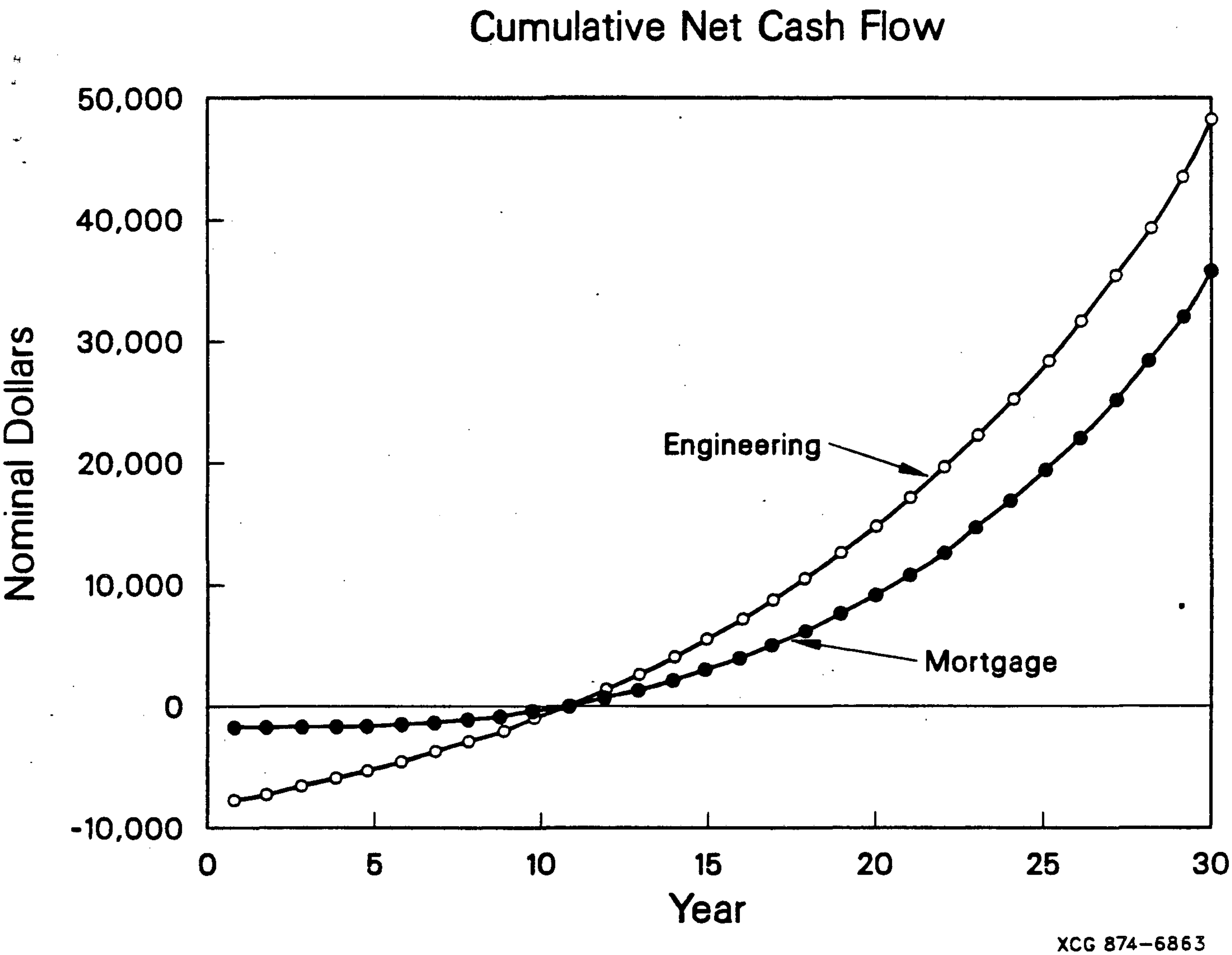

Figure 2. Comparison of *cumulative* undiscounted cash flow for the mortgage and engineering net present value calculations: base case assumptions.

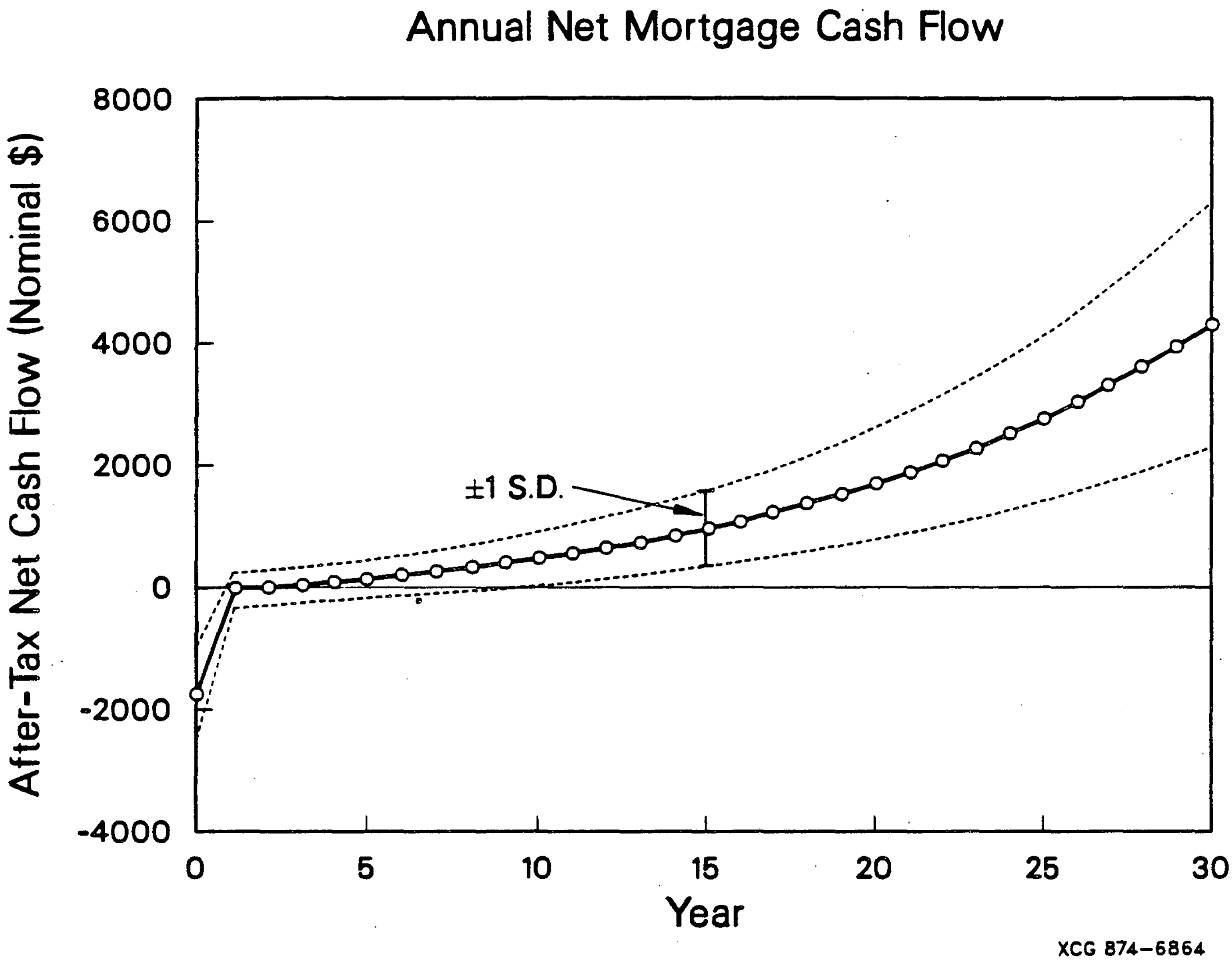

Figure 3. Annual after-tax net cash flow for the mean base case. The M-NPV is simply the sum of the present value of these cash flows and the discounted resale value, if any.

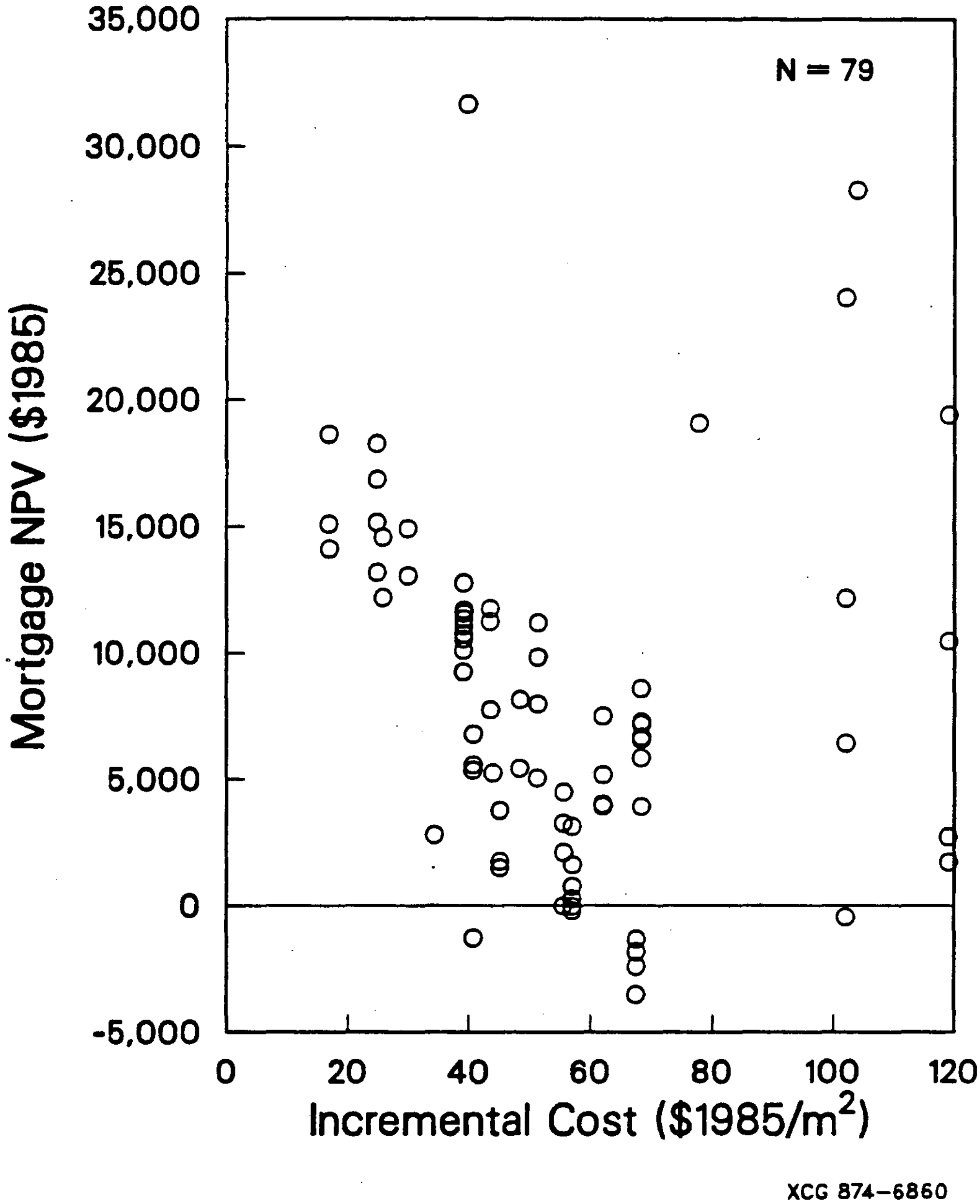

Figure 4. M-NPV as a function of incremental cost.

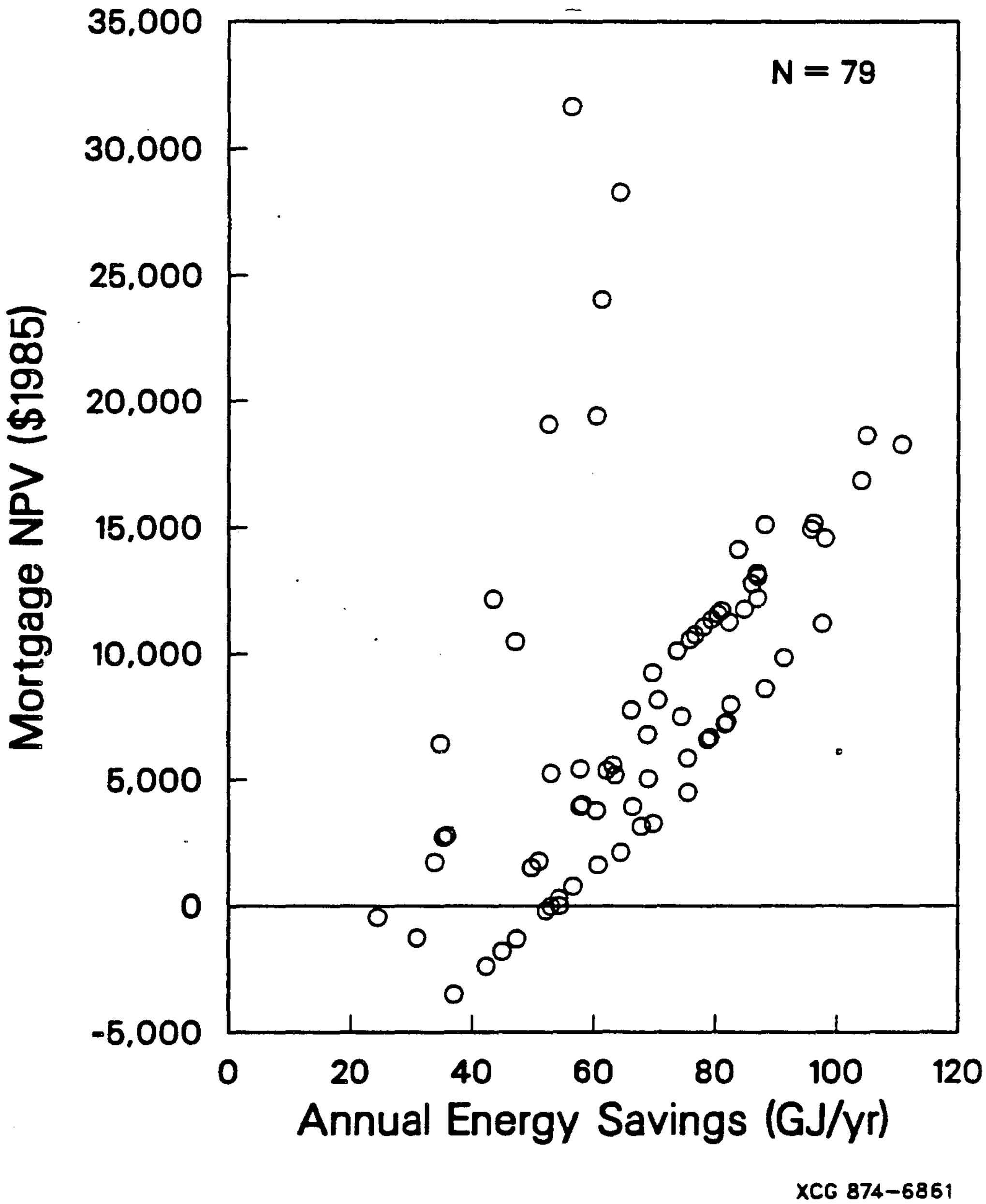

Figure 5. M-NPV as a function of annual energy savings.

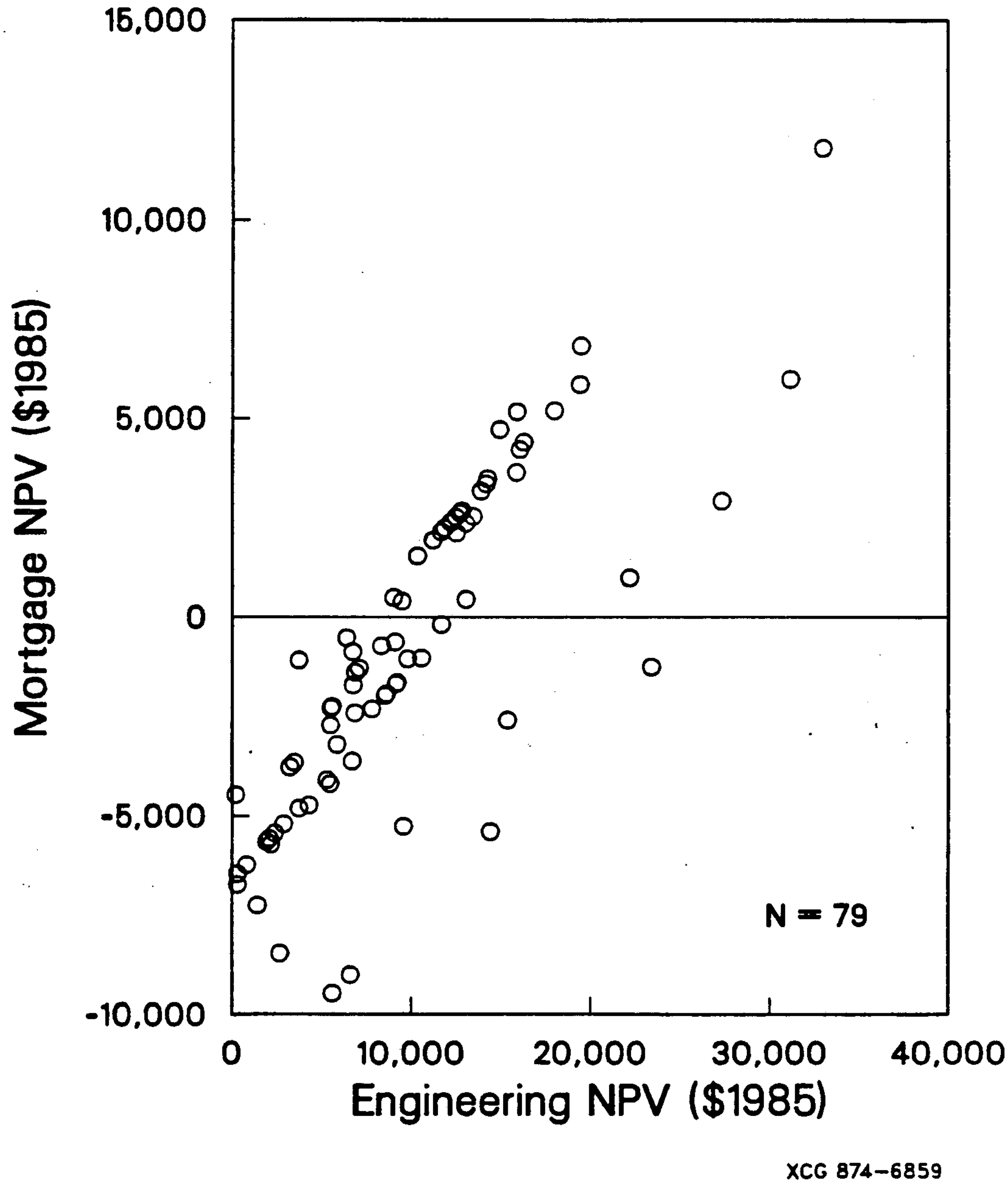

Figure 6. E-NPV versus M-NPV for the 79 homes: 15-year mortgage. Note that electric homes stand out to the right because of the higher energy price.

Table 1. Base case assumptions for mortgage variables and their incremental costs.*					
VARIABLE	RATE	PAYMENT SCHEDULE	FIRST YEAR CASH FLOW	M-NPV	% of M-NPV
Energy savings	8%†	annual price escalation rate	468	17396	57%
Principal	—	annually	-39	-1652	5%
Interest	9.5%	annually	-549	-6151	20%
Tax savings	28%	marginal tax rate	184	1763	6%
Fire ins. + prop. tax	1.71%	annually	-124	-1640	5%
Down payment	20%	one-time	-1546	-1546	5%
Points	2.5%	one-time	-155	-155	0.5%
Title insurance	0.44%	one-time	-34	-34	0.1%
TOTAL			-1726	7981	100%

* Assumes a 30-year loan and a 7% discount rate.

† Real energy price escalation rate is 1%/year.

Table 2. Mortgage versus engineering mean net present value for 79 homes.		
	MORTGAGE NPV	ENGINEERING NPV
Mean	7981	9810
Std. Dev.	6868	6732
Minimum value	-3489	193
Maximum value	31649	32936

Table 3. Sensitivity analysis of the mortgage-NPV.		
MORTGAGE PARAMETER	M-NPV ($1985)	PERCENT OF E-NPV
Engineering NPV	9810	100%
Base case M-NPV*	7981	81%
Loan term		
15 years	-925	—
20 years	1852	19%
25 years	4824	49%
35 years	10915	111%
Points		
1%	8050	82%
Interest rate		
12%	6781	69%
Down Payment		
5%	7979	81%
Marginal tax rate		
15%	7163	73%
FHA financing		
i = 7%	8640	88%
DP = 5%		
Points = 2%		
Real discount rate=3%	3403	35%

* All sensitivities are calculated with respect to the base case. Base-case assumptions: term=30 years, points=2.5%, interest rate=9.5%, down payment=20%, marginal tax rate=28%, home held for entire term of loan (no resale), real discount rate=7%, real energy price escalation rate=1%.

APPENDIX-A: Building characteristics and cost effectiveness.

ID#	FLOOR AREA (M^2)	HEAT LOSS COEFFIC. (W/°C)	ENERGY SAVINGS (GJ/Y)**	INCREM COST ($85)	ENERGY PRICE ($/GJ)	INCREASED MORTGAGE PAYMENT	MTG. NPV	ENGIN. NPV	FIRST-YEAR CASH FLOW
212	120	67.0	66.0	5206	6.15	423	7771	8988	-1102
215	120	67.0	84.7	5206	6.15	423	11769	13013	-978
217	120	60.0	82.3	5206	6.15	423	11256	12490	-994
220	111	66.6	57.7	6877	6.15	559	3961	5535	-1652
222	111	66.6	74.3	6877	6.15	559	7510	9099	-1542
223	111	72.5	58.0	6877	6.15	559	4025	5596	-1650
227	111	72.5	63.4	6877	6.15	559	5180	6764	-1614
228	163	121.5	60.6	9288	6.15	756	1644	3738	-2346
229	163	121.5	54.3	9288	6.15	756	297	2387	-2388
230	163	121.5	52.1	9288	6.15	756	-173	1926	-2403
231	163	121.5	67.7	9288	6.15	756	3162	5275	-2299
232	163	121.5	56.6	9288	6.15	756	789	2878	-2373
233	163	121.5	54.3	9288	6.15	756	297	2387	-2388
234	163	121.5	52.9	9288	6.15	756	-2	2079	-2398
235	163	121.5	56.6	9288	6.15	756	789	2878	-2373
236	178	77.4	96.1	4427	6.15	360	15155	16249	-672
237	178	77.4	110.7	4427	6.15	360	18277	19383	-575
238	178	77.4	104.1	4427	6.15	360	16865	17970	-619
239	178	77.4	86.9	4427	6.15	360	13188	14252	-733
240	155	124.0	91.3	7943	6.15	646	9846	11689	-1744
241	155	124.0	97.6	7943	6.15	646	11193	13041	-1703
242	155	124.0	82.6	7943	6.15	646	7986	9815	-1802
243	155	124.0	68.9	7943	6.15	646	5057	6865	-1893
252	166	102.4	60.3	7471	6.15	608	3793	5494	-1811
253	166	102.4	49.7	7471	6.15	608	1527	3220	-1881
254	166	102.4	50.9	7471	6.15	608	1783	3466	-1873
255	166	102.4	49.7	7471	6.15	608	1527	3220	-1881
257	172	104.9	64.3	9539	6.15	776	2130	4286	-2396
263	172	104.9	75.4	9539	6.15	776	4503	6683	-2322
266	172	104.9	69.7	9539	6.15	776	3284	5454	-2360
267	172	104.9	54.4	9539	6.15	776	13	2166	-2462
272	116	66.2	35.9	3988	6.15	324	2818	3723	-942
276	183	71.1	83.7	3102	6.15	252	14118	14901	-362
277	183	71.1	104.9	3102	6.15	252	18650	19448	-221
278	183	71.1	88.3	3102	6.15	252	15101	15885	-332
279	113	71.1	52.9	4958	6.15	403	5272	6409	-1116
281	135	71.1	34.8	13768	19.18	1120	6436	9572	-3354
282	135	71.1	43.4	13768	19.18	1120	12170	15340	-3176
283	135	71.1	61.2	13768	19.18	1120	24039	27279	-2807
284	135	71.1	24.5	13768	19.18	1120	-432	2664	-3567

* 1 GJ=10^9J=0.948 MBtu.

APPENDIX-A (cont'd): Building characteristics and cost effectiveness.

ID#	FLOOR AREA (M^2)	HEAT LOSS COEFFIC. (W/°C)	ENERGY SAVINGS (GJ/Y)	INCREM COST ($85)	ENERGY PRICE ($/GJ)	INCREASED MORTGAGE PAYMENT	MTG. NPV	ENGIN. NPV	FIRST-YEAR CASH FLOW
285	144	129.4	60.4	17130	19.18	1393	19411	23380	-3819
286	144	129.4	35.4	17130	19.18	1393	2741	6613	-4337
287	144	129.4	33.9	17130	19.18	1393	1741	5607	-4368
288	144	129.4	47.0	17130	19.18	1393	10476	14393	-4096
289	152	55.9	95.7	4549	6.15	370	14921	16035	-711
290	152	55.9	87.0	4549	6.15	370	13061	14161	-768
291	203	69.1	98.0	5241	6.15	426	14570	15835	-900
292	203	69.1	86.9	5241	6.15	426	12197	13438	-974
293	169		52.6	13134	19.18	1068	19077	22145	-2798
297	117		57.7	5666	6.15	461	5436	6746	-1294
307	117		70.4	5666	6.15	461	8151	9480	-1209
310	123	100.0	79.1	8401	6.15	683	6680	8619	-1961
311	123	100.0	81.6	8401	6.15	683	7215	9142	-1944
312	123	100.0	66.3	8401	6.15	683	3943	5854	-2046
313	123	100.0	81.9	8401	6.15	683	7279	9203	-1942
314	123	100.0	75.3	8401	6.15	683	5868	7790	-1986
315	123	100.0	88.1	8401	6.15	683	8604	10555	-1901
316	123	100.0	78.7	8401	6.15	683	6595	8527	-1964
318	123	56.4	56.4	4892	19.18	398	31649	32936	-280
319	115	54.4	64.2	11937	19.18	971	28270	31122	-2203
321	118		81.0	4617	6.15	376	11695	12803	-828
322	118	55.4	75.7	4617	6.15	376	10562	11666	-864
323	118	52.4	80.4	4617	6.15	376	11567	12680	-832
324	118	48.0	76.6	4617	6.15	376	10754	11850	-858
325	118	48.0	78.1	4617	6.15	376	11075	12188	-848
326	118	55.4	81.0	4617	6.15	376	11695	12803	-828
327	118	55.4	69.6	4617	6.15	376	9258	10345	-904
328	118	48.0	81.0	4617	6.15	376	11695	12803	-828
329	118	55.4	73.6	4617	6.15	376	10113	11205	-878
330	118	55.4	79.4	4617	6.15	376	11353	12465	-839
331	118	48.0	86.0	4617	6.15	376	12764	13878	-795
333	139	73.5	45.0	9377	6.15	763	-1799	301	-2476
334	139	73.5	37.1	9377	6.15	763	-3489	1389	-2529
335	139	73.5	47.3	9377	6.15	763	-1308	792	-2461
336	139	73.5	42.3	9377	6.15	763	-2377	283	-2494
343	159	121.5	62.0	6474	6.15	527	5371	6860	-1504
344	159	121.5	63.0	6474	6.15	527	5585	7075	-1498
345	159	121.5	31.0	6474	6.15	527	-1257	193	-1710
346	159	121.5	68.7	6474	6.15	527	6804	8304	-1460
MEAN	144	87.9	67.6	7730	7.96	629	7981	9810	-1747
STDEV	25	26.7	18.9	3388	4.51	276	6868	6732	942
MIN	111	48.0	24.5	3102	6.15	252	-3489	193	-4368
MAX	203	129.4	110.7	17130	19.18	1393	31649	32936	-221

LAWRENCE BERKELEY LABORATORY
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