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# ABSTRACT

The comparative impacts of substituting a conservation investment program on Long Island in lieu of completing the power plant at Shoreham is quantitatively assessed. In contrasting the two resource planning alternatives, analytic focus is placed on technical achievability, costs and benefits, and relative scarce fuel savings.

Preliminary sections are devoted to issue definition, qualitative identification of the types of tradeoffs involved, and clarification of the framework employed for investigation.

Using a detailed end-use oriented computer model, a yardstick Reference forecast is established. Then, a set of some forty conservation measures affecting the efficiency with which energy is converted at the end-use are described in detail. These measures satisfy the twin criteria of technological availabilty and social cost-effectiveness (the cost to ratepayers of saving a unit of energy must be less than the cost of supplying a unit of energy).

A policy program for promoting and financing conservation investments is assumed to effect a gradual phase-in of the measuresover twenty years as the existing stock of equipment is replaced and retrofitted. No change in end-use amenities, consumer behavior, or economic activities is posited in the Conservation case. The conservation alternative is designed to represent an illustrative real world program, not a maximal or optimal conservation scenario, and thus includes only a subset of energy reducing options.

A second run of the forecast model incorporating the impacts of the Conservation measures at the end-use over time is produced. The stream of measure implementations and associated costs are also computed as well as attendant oil, gas, and electric energy savings. The results are collected in the form of the costs and benefits of the Conservation versus the Shoreham approach. Roughly speaking, the capital costs for the two scenarios are comparable in present worth terms (even assuming full ratepayer responsibility for utility recovery of sunk costs in the Shoreham project). However, the fuel reductions are far greater in the conservation scenario amounting to a net savings of some 53 million barrels of oil to 2000 (and 76.2 billion cubic feet of natural gas). The first order cumulative cost difference to ratepayers shows a net savings of over $3 billion (discounted to 1980).

Relative affects on the electric generating system are comparable with each scenario achieving adequate reliability (peak load reduction in the Conservation program case eventually matches the capacity expansion in the Shoreham completion case). Other factors such as indirect economic and employment stimulation and environmental impact appear to favor the conservation alternative.

On the basis of its relative cost-effectiveness, scarce fuel husbandry, and long term system reliability, the conservation approach is shown to be a feasible and meritorious option. The results suggest that detailed consideration of the conservation investment alternative by policymakers is warranted at this time.

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# 1. OVERVIEW

In this report, two energy investment strategies for Long Island are compared. In the first, the nuclear facility currently under construction at Shoreham is completed. In the second, that project is cancelled and instead a program promoting and financing conservation measures is adopted. In particular, we wish to establish which strategy would be less expensive and which would save more scarce fuel (especially oil).

Recently, it has become widely acknowledged that conservation offers tremendous potential to save energy at a cost generally much less than the cost of delivering additional energy (e.g., Refs. 10-17, 28,32). That realization has lead to a number of attempts at the national, state, and local levels to promote and finance investments in conservation equipment to overcome the various impediments to their market penetration.

At the same time, the electric utility industry has experienced a fundamental alteration since 1974. The long term prognosis for demand growth as well as cost-estimates for new power plants has changed dramatically -- the former is much less, the latter much more. Before 1974, the mandate for a well-managed utility seemed self-evident: try to develop an optimally reliable and efficient electric generation and distribution system to meet a rapidly growing market for electric power. Long range planning was based on massive construction programs to keep power supply comfortably above exponentially increasing customer demand; growth rates were typically at 7% annually and higher still in areas undergoing robust economic development, such as Long Island.

The problem this posed for supply expansion -- doubling the size of the generation system every decade or so -- had, it appeared, a felicitous resolution. Large numbers of nuclear fission power plants were to be constructed producing power which was anticipated to be unprecedentally inexpensive, safe, and, with the parallel development of fast breeder reactor technology, virtually inexhaustible. The question of moderating demand growth through conservation-oriented policy was simply not on the agenda. Indeed, the utility industry contributed significantly to the high growth levels through promotional advertisement and rate structures that rewarded intensive electric energy usage.

Such indefinite extrapolation of the pre-1974 trends seems, retrospectively, to have been a terribly naive vision of the last quarter of the century and a misguided basis for the development of a rational energy strategy. All of the major determining variables of demand growth -- energy price, economic pace, demographic trend, governmental policy, technological development, consumer attitudes and values -- have radically altered. The interruption in post-war patterns was not anticipated by the utility industry (and perhaps could not have been) and then not accepted for many years as the transformation it is now widely acknowledged to have represented.

The dilemmas currently facing Long Island Lighting Company (LILCO) and its customers present a textbook case of these patterns from the recent history of the utility industry. Over the years, the Company has inexorably adjusted its annual long range forecast of future demand in lagged recognition of the complex forces marking the 1970's as a watershed in energy growth dynamics. This historic cascade in LILCO's forecast is illustrated in Figure 1 (along with the forecast sequence developed using ESRG's engineering/end-use model for comparison). Experienced growth in annual energy requirements in LILCO's service area has averaged less than 1% in the 1973-1979 period. By contrast, the Company's 1974 ten year forecast of average annual growth was 6.3% (the Company's most recent forecast is moderated to 1.8%).

The series of revisions of its demand forecast by the Company suggests the extent of the fundamental transformation in the planning framework used as the basis for designing a long term construction program. The corresponding adjustments in that program have been correspondingly dramatic. As of 1974, LILCO's generation expansion schedule included the following elements:

TABLE 1

LILCO 1974 EXPANSION PROGRAM[1]

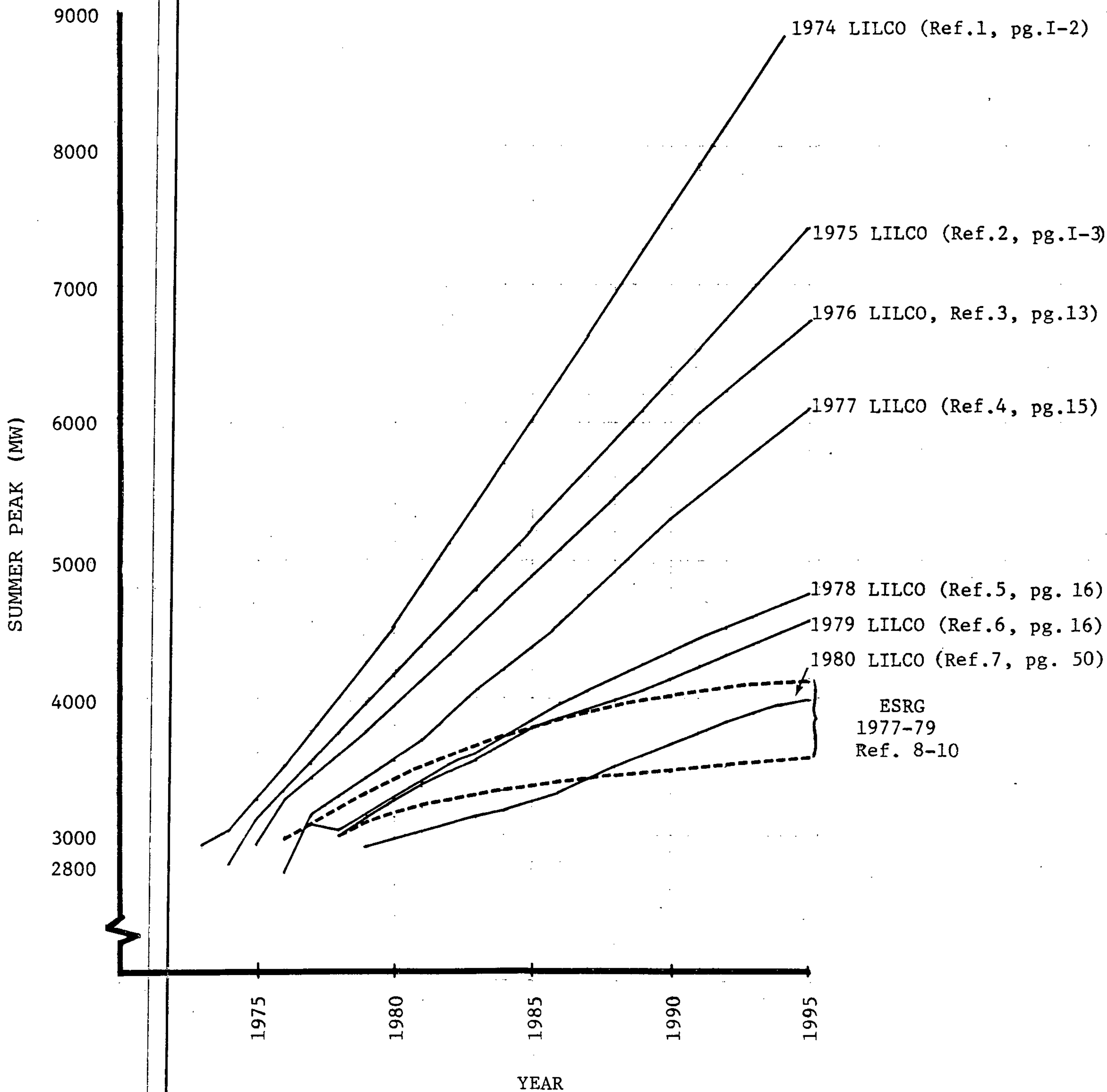
| Facility | Size | In-Service Date |
|---|---|---|
| Shoreham Nuclear | 820 MW | 1978 |
| Jamesport 1 - Nuclear | 1150 | 1981 |
| Jamesport 2 - Nuclear | 1150 | 1983 |
| Additional Required[2] | 2430 | 1983-1994 |

Notes:

1. Source: Ref. 1, Vol. 2, p. 43, 99-101.
2. Based on 18% reserve requirement.

Figure 1

HISTORICAL COMPARISON OF PEAK FORECASTS: LILCO AND ESRG



By contrast, the current plan looks as follows:

TABLE 2

LILCO CURRENT EXPANSION PROGRAM[1]

| Facility | Size | In-Service Date |
|---|---|---|
| Mitchell Gardens - Solid Waste | 32 MW | 1980 |
| Shoreham - Nuclear | 820 | 1983[2] |
| Nine Mile Pt. 2 - Nuclear | 194[3] | 1987 |
| Jamesport Coal | 400 | 1989 |

Notes:

1. Source: Ref. 7, Vol. 1, p. 412, 423, and Ref. 16.
2. Ref. 18, p. 4.
3. LILCO's 18% share.

The one item that appears on both lists is the subject of this inquiry: the Shoreham Nuclear Power Station (hereinafter "Shoreham"). Conceived during the pre-1974 period, it stands as an artifact of the unrealistic forecasts of need, premature commitment to supply expansion, and extreme optimism about nuclear construction costs that characterized that era. The time sequence of Company forecasts of Shoreham on-line dates and costs are summarized below in Table 3. Other analyses indicate that even these last figures may remain overly optimistic (Refs. 12 and 13).

TABLE 3

LILCO ESTIMATES OF SHOREHAM COST AND COMPLETION DATES

| Date of Forecast | Target In-Service Date | Total Cost (millions of dollars) |
|---|---|---|
| December 1973 | Mid 1977 | 350 |
| December 1974 | Mid 1978 | 498 |
| April 1976 | May 1979 | 699 |
| April 1977 | May 1980 | 969 |
| April 1978 | September 1980 | 1,190 |
| May 1978 | September 1980 | 1,240 |
| September 1979 | May 1981 | 1,600 |
| May 1980 | January 1983 | 2,235 |

Source: Ref. 19

The escalating costs of the Shoreham project coupled to the unrealized growth in the demand for electricity, have put severe stress on LILCO's financial health. Access to financial markets and the ability to raise capital at acceptable terms is contingent on the Company maintaining sufficiently high levels of cash flow to minimize investor risk (as measured by various indices such as "interest coverage"). In order to adequately satisfy these tests of financial health and thereby permit the continuation of its heavy construction commitments, the Company has regularly come before the New York State Public Service Commission to request increased rates. For example, the gist of Case #27774, the latest in a sequence of similar rate cases over the past several years, is LILCO's putative need to increase its cash flow to enable the early completion of the Shoreham unit.

Given the prospect of such financial problems -- and attendant rate increases -- continuing into the future and the Company's poor track record in estimating ultimate cost and completion dates, it is natural to explore the viability of alternatives to the Shoreham nuclear facility. The cost effectiveness of other options is complicated by the disposition of the $1400 million already sunk into the Shoreham facility. Indeed, the Company has developed a set of comparative analyses of completing Shoreham according to their current plan versus delaying the in-service date (Ref. 14) and versus conversion to coal or building a new coal unit (Refs. 15 and 16). These studies -- based of course on Company assumptions and methodologies -- find the rapid completion of Shoreham to be most beneficial to the customers. These conclusions on the economics of LILCO's Shoreham completion strategy versus various power plant construction alternatives will not be critically examined here.*

Instead, the focus is on the potential for economic merits of an alternative to Shoreham completion not considered by LILCO in their extant documents: the development and financing

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*It is worth noting that in a 1977 rate case, LILCO argued that a construction delay from the then projected in-service date of 1979 would not be cost-effective. Based on the assumption that a rapid construction schedule would lead to negative impacts on customer rates due to the cash flow problems discussed in the text, other analysis showed that LILCO's conclusion was erroneous (Ref. 17). The passage of time has confirmed the validity of that assumption. Analogous complaints would need to be voiced as part of any thorough review of the more recent Company economic analyses of alternative construction programs.

of an intensive conservation program on Long Island over the next twenty years. The goal is to test the validity of the Company's fundamental assertion that the option of abandoning the Shoreham project would be "against the public interest" from the point of view of economics and oil savings (Ref. 18, p. 12).

As mentioned earlier, a number of utilities have already made substantial reorientations in their development program by stressing conservation financing as a cost-effective substitute for at least part of their capacity expansion requirements. It is recognized that the energy policy and regulatory community need not have electric utilities simply respond to conjectured long range demand growth through power plant construction. Rather, they along with other actors could manage the level of demand growth to a significant degree through conservation investment programs.*

Should construction at Shoreham be terminated? To the Company, on grounds of minimizing costs and oil consumption, the answer must be negative. In this study, however, the question is treated as an open hypothesis requiring careful investigation. It is indeed the point of departure for our analysis.

It will be shown that even at this late date in the Shoreham construction trajectory, there is the practical potential to save more oil at lower cost to the people of Long Island over the next twenty years by redirecting funds from continued construction to a program of investment in conservation.

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*In this report, "conservation" refers to increasing the efficiency of devices providing end-use services, not decreasing the level or quality of those services. Consequently, <u>no</u> decrements in the quality of life (e.g., turned down winter thermostats), or in the level of service (e.g., decreased street lighting) are included.

## 2. THE ISSUE

The issue under investigation can be put crisply. The relative merits of two energy investment scenarios are to be assessed. In one scenario, the Shoreham plant is assumed to be completed. In the other, the Shoreham construction ceases and investment capital flows instead to implementing a set of measures on Long Island designed to improve the efficiency of energy use.

The task of the analytic work in this study is to carefully specify the menu of realistic conservation opportunities, establish reasonable targets for their phase-in over time, develop cost estimates for each implementation, and quantify the impacts on consumption of electricity and other fuels from benchmark (or "business-as-usual") usage levels for the myriad of appropriate end-use categories. Estimates of costs and construction schedule for Shoreham will be drawn from independent analyses.

It is essential here to clarify the character of the conservation scenario to be designed and evaluated in this study. To begin with, there are two types of functions it is not meant to serve. First, it is not offered as a blueprint for program action over the next twenty years. Rather, it represents one choice of plausible target conservation levels in order to test the proposition that a conservation alternative to Shoreham completion is feasible by showing that the technologies are available, the costs acceptable, and the fuel savings superior. While it represents the main contours of any candidate program, there is no claim that the scenario is precisely what would emerge in an actual program.

Second, the scenario does not incorporate the full technological potential for conservation. In other words, a different question from the one addressed here could be asked: what is the long range potential for demand reduction through implementing the full set of conservation measures which are technologically available and cost-effective?* This would cast the conservation net far wider than we intend to here, to include extreme improvements in appliance efficiencies, community energy systems, maximal insulation levels, and so on. In reality, there

*Such a question was indeed asked recently by the California PUC (Decision No. 91107) and then answered in Ref. 11. A conservation measure was considered "cost effective" in this instance if the cost of saving a unit of energy were less than the cost of supplying an additional unit of energy.

of course are other significant constraints, such as the timing and level of the commitment of regulators, utilities, and other institutions in designing, promoting, financing, and administering a program capable of assuring high levels of conservation measure penetration. While the technological potential approach defines the universe of cost-effective actions, the scenario defined here, as will be amply demonstrated below, is oriented toward a modest subset of these.

In summary, we may locate the function of the conservation scenario in the terrain between a detailed programmatic blueprint for conservation and a general technological potential for conservation. Reference to the stages of large scale projects might be suggestive. The possible "project" in this case is the adoption of the conservation program. The analysis here is offered as a "proof-of-concept" or feasibility study designed to indicate whether the next stage -- the development of the actual program elements analogous to the detailed engineering construction plan -- ought to be pursued.

Rather than specifying either the ultimate potential, on the one hand, or the blueprint for action, on the other hand, the conservation scenario represents a set of plausible targets to test the feasibility for a conservation investment program to save more energy at less cost than would the alternative strategy of completing the Shoreham plant.

Once the conservation scenario has been defined and modelled, a number of issues emerge for assessment. The quantitative analysis is aimed at answering two central questions:

- <u>Which scenario displaces more oil</u>?

  Decreasing oil consumption is a priority in national energy policy, especially in heavily oil dependent areas such as Long Island. Both scenarios under consideration would bring a substantial reduction in oil use on Long Island. The Shoreham plant would reduce the need for generating electricity from LILCO's oil-fired power plants. The conservation scenario would, like the Shoreham plant, displace oil-fired generation. It would also reduce oil consumption for space and water heating in buildings.

- Which scenario costs less?

  There are costs and savings associated with each choice -- capital, fuel, operation and maintenance. The stream of costs over the twenty-year time frame of investigation needs to be computed, accumulated in constant dollars and compared.

Assuming a feasible conservation scenario with the potential of displacing more oil than the Shoreham scenario at lower direct social cost, other important areas of concern may be addressed:

- Electric system reliability

  The Shoreham and conservation scenarios affect the long-term electric power supply/demand balance in quite different ways, the former by increasing generating capacity and the latter by decreasing the demand for new capacity. The reduction in peak load demand resulting from the conservation strategy must be comparable to the additional capacity of the Shoreham plant in order that the two scenarios not have significantly different impacts on the degree of reliability of the electric power system.

- Indirect economic impacts

  The Shoreham versus conservation cost comparisons referred to above compute only the direct costs of providing or saving energy. The two strategies have very different indirect effects on on-site employment, demand for local materials (and labor to produce those materials), local spending of wages and increased disposable income resulting from savings in energy costs, and so on. Recent investigations have suggested that significantly higher levels of employment result from the conservation approach (Refs. 21, 23, 24).

- Natural gas demand

  In comparing the two scenarios, direct cost and oil-savings are highlighted. Though the emphasis in today's policy climate is on reducing oil consumption, in the recent past the policy imperative to conserve "scarce fuels" has included natural gas conservation. Furthermore, if the level of switching from oil to natural gas usage is constrained by the latter's availability, a scenario which conserves natural gas will indirectly promote oil savings by increasing the supply of an attractive alternative.

* Risk

In comparing the two scenarios we shall focus on such factors as energy savings and direct costs to ratepayers. In addition, there are risks associated with each scenario which, while not lending themselves to statistical analysis, should be identified for completeness. For the case of the Shoreham scenario, the risks include the possibilities (1) of extreme errors in current cost and completion date estimates, (2) of extraordinary periods of downtime due to plant malfunction, (3) of a nuclear power moratorium at some point during the lifetime of the plant, (4) of unanticipated harm to human health, and (5) of severe radioactive waste disposal problems. For the case of the conservation scenario, the primary uncertainty lies with the capability of the utility and other relevant actors to mount a sufficiently rigorous and coordinated effort for the design, promotion, and financing of an adequate set of programs.

One of the more complex issues to be addressed is the quantification of the cost tradeoffs between the scenarios. There are a number of factors involved in computing the direct cost benefits and penalties between the stream of conservation investment compared to the Shoreham completion strategy.* These are sketched in Table 4 below.

Of these, the most significant costs are in the capital and fuel related categories. The capital related items include the costs of the stream of conservation investments (both equipment and financing charges). These include such items, as we shall see, as improved building shells and more efficient electric using devices. In the next section of this report, the conservation measure implementations constituting the conservation scenario will be specified and their costs and energy savings identified. An additional capital related penalty of the conservation alternative is shown in Table 4. This is the need for the Company to recover the capital and interest charges already expended on the Shoreham project. The magnitude of the penalty is a function of regulatory policy on the amount of the loss to be borne by the ratepayers and on

*Throughout this study, the issue is posed as conservation <u>versus</u> Shoreham. While in principle there could be oil-saving and cost benefits in <u>both</u> completing Shoreham and promoting the high levels of conservation envisaged here, capital raising constraints are assumed to require exclusivity.

TABLE 4

MAJOR DIRECT BENEFITS AND COSTS OF THE CONSERVATION ALTERNATIVE

| | Benefits | Costs |
|---|---|---|
| Capital Related | Avoided Cost of Shoreham | Conservation equipment investment<br>Cost of Shoreham cancellation passed to ratepayers |
| Fuels for Electricity Generation | Displaced oil-fired generation due to conservation<br><br>Avoided cost of Shoreham nuclear fuel | Displaced oil-fired generation from Shoreham |
| Other Fuel | Decreased oil use for heating and hot water in buildings<br>Decreased natural gas for heating and hot water use in buildings | None |
| Operation and Maintenance | Avoided Shoreham O & M | Conservation equipment maintenance<br>Conservation program administration |
| Taxes and Insurance | Avoided Shoreham insurance<br>Conservation investment tax credit<br>Avoided Shoreham property tax | Make-up local property taxes |

the accounting treatment adopted for the recovery of that amount. We shall return to this issue in Sec. 5. The major benefit in the capital-related category is, of course, the avoidance of the costs of the completed Shoreham facility: depreciation, return, and income taxes.

Regarding relative fuel savings, both Shoreham and conservation decrease the need for producing electricity with LILCO's oil-fired generators. In comparing the scenarios,we shall compute the savings from each and credit the most efficacious oil generation displacing scenario appropriately. Additionally, due to the improvement in buildings' shells, decreases in oil and natural gas used on-site for heating and hot water must be credited to the conservation alternative. The scorecard on the various cost and fuel tradeoffs will be presented in Sec. 6,

## 3. THE REFERENCE FORECAST

The aim of this study is to compare the costs and energy benefits of a long-range program of promotion of conservation on Long Island to the costs and benefits of an alternative strategy, completion of the Shoreham generating station. In order to determine the costs and energy savings of the twenty-year conservation program, it is necessary to measure its impacts relative to conservation activity which is likely to occur anyway.

Thus a "business-as-usual" yardstick is needed to identify reasonably likely levels of future energy usage.* This yardstick is our "Reference" forecast. The Reference forecast attempts to capture the effects of existing policies, cost inducements, and other relevant trends upon energy demand during the forecast period.

Systematic long-range forecasts of energy use on Long Island are at present available only for electricity. The Reference forecast that we establish can thus draw upon three analyses, the recent detailed electric load forecasts for the LILCO service area developed by the State Energy Office (SEO), LILCO and ESRG (Refs. 23, 7 and 10). Variations among the three forecast results are not significantly dependent on differing assumptions about the degree or kind of conservation activity. Rather they are due primarily to certain differences in modelling methodology.** In order to establish a Reference forecast whose assumptions were consensual with the SEO and LILCO, effort was made to "zero out" the divergences. The result is a Reference forecast for electric demand growth that falls between the SEO and LILCO forecasts.

The Reference forecast adopted for purposes of this analysis is summarized below. In Table 5, the Reference forecasts of annual peak load, aggregate energy requirements, and sales by major customer sector are displayed.*** In Table 6, the Reference forecast is further disaggregated by selected end-use subcategories.

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*The term "business-as-usual" as employed here is not meant to imply invariance of policy, economic, or demographic variables, or in levels of conservation activity, but to connote the incorporation of currently identifiable trends. The conservation scenario, in contrast, assumes a quantum change in energy policy toward a vigorous promotion of cost-effective demand reducing measures. ✓

**The methodological differences between the ESRG long-range forecast results and the corresponding SEO and LILCO forecasts are discussed in Refs. 27 and 10, respectively.

***Detailed explanation of the mathematical structure and basic data source used in generating these outputs was offered in Ref. 10.

The relationship of the Reference forecast to the most recent long-range forecasts of the State Energy Office and LILCO are shown in Table 7. The mid-range Reference forecast is a suitable basis for our subsequent analysis. Forecasters may disagree on where the absolute level of future demand is likely to be and still accept estimates of the change in demand which would attend the introduction of the conservation measures.

TABLE 5

AGGREGATE REFERENCE FORECAST

| LILCO | ENERGY IN GWH | | | | | PEAK POWER LOAD IN MW | |
|---|---|---|---|---|---|---|---|
| | RESIDENT. | COMMER. | INDUSTR. | OTHER | TOTAL | SUMMER | WINTER |
| 1978 | 5559. | 5020. | 1239. | 1901. | 13719. | 2870. | 2390. |
| 1979 | 5720. | 5140. | 1280. | 1940. | 14080. | 2930. | 2470. |
| 1980 | 5860. | 5270. | 1320. | 1980. | 14430. | 3000. | 2550. |
| 1981 | 6010. | 5390. | 1360. | 2020. | 14780. | 3050. | 2630. |
| 1982 | 6150. | 5520. | 1400. | 2070. | 15130. | 3110. | 2710. |
| 1983 | 6280. | 5640. | 1440. | 2110. | 15470. | 3160. | 2790. |
| 1984 | 6410. | 5770. | 1480. | 2150. | 15800. | 3220. | 2860. |
| 1985 | 6520. | 5900. | 1520. | 2190. | 16130. | 3270. | 2940. |
| 1986 | 6610. | 6000. | 1540. | 2230. | 16370. | 3300. | 2990. |
| 1987 | 6690. | 6100. | 1570. | 2260. | 16610. | 3340. | 3040. |
| 1988 | 6770. | 6190. | 1600. | 2290. | 16850. | 3380. | 3090. |
| 1989 | 6850. | 6290. | 1620. | 2330. | 17090. | 3410. | 3140. |
| 1990 | 6920. | 6390. | 1650. | 2360. | 17330. | 3450. | 3190. |
| 1991 | 7000. | 6490. | 1680. | 2400. | 17560. | 3490. | 3240. |
| 1992 | 7070. | 6590. | 1710. | 2430. | 17800. | 3520. | 3280. |
| 1993 | 7130. | 6690. | 1730. | 2470. | 18030. | 3560. | 3330. |
| 1994 | 7200. | 6790. | 1760. | 2510. | 18260. | 3590. | 3380. |
| 1995 | 7260. | 6900. | 1790. | 2540. | 18490. | 3630. | 3430. |
| 1996 | 7320. | 7000. | 1810. | 2580. | 18720. | 3660. | 3470. |
| 1997 | 7380. | 7100. | 1840. | 2620. | 18940. | 3700. | 3520. |
| 1998 | 7440. | 7210. | 1870. | 2650. | 19170. | 3730. | 3560. |
| 1999 | 7500. | 7310. | 1900. | 2690. | 19400. | 3770. | 3610. |
| 2000 | 7570. | 7420. | 1920. | 2730. | 19640. | 3800. | 3660. |

TABLE 6

DISAGGREGATED REFERENCE FORECAST

RESIDENTIAL SECTOR

| | 1978 | 1983 | 1988 | 1993 | 1998 |
|---|---|---|---|---|---|
| 1: REFRIGERATORS | 1146. | 1283. | 1323. | 1307. | 1242. |
| 2: FREEZERS | 340. | 381. | 402. | 411. | 411. |
| 3: RANGES | 257. | 282. | 301. | 316. | 329. |
| 4: LIGHTING | 798. | 834. | 857. | 864. | 859. |
| 5: TELEVISIONS | 359. | 377. | 387. | 399. | 415. |
| 6: CLOTHES DRYERS | 372. | 429. | 475. | 513. | 547. |
| 7: CLOTHES WASHERS | 68. | 72. | 75. | 78. | 81. |
| 8: DISH WASHERS | 153. | 172. | 186. | 199. | 212. |
| 9: WATER HEATERS | 239. | 293. | 324. | 353. | 385. |
| 10: ROOM A/C | 293. | 292. | 281. | 275. | 273. |
| 11: CENTRAL A/C | 245. | 289. | 327. | 366. | 405. |
| 12: SPACE HEATERS | 266. | 454. | 605. | 722. | 836. |
| 13: HEATINGAUXILIARY | 436. | 429. | 422. | 414. | 407. |
| 14: MISCELLANEOUS | 586. | 693. | 804. | 918. | 1038. |

COMMERCIAL SECTOR

| | 1978 | 1983 | 1988 | 1993 | 1998 |
|---|---|---|---|---|---|
| 1: OFFICES | | | | | |
| 1: HEATING | 32. | 61. | 81. | 98. | 114. |
| 2: COOLING | 307. | 330. | 348. | 362. | 376. |
| 3: LIGHTING | 447. | 474. | 500. | 526. | 552. |
| 4: AUX & POWER | 378. | 471. | 569. | 669. | 776. |
| 2: RETAIL | | | | | |
| 1: HEATING | 15. | 28. | 38. | 46. | 54. |
| 2: COOLING | 302. | 336. | 361. | 379. | 396. |
| 3: LIGHTING | 1124. | 1237. | 1315. | 1368. | 1421. |
| 4: AUX & POWER | 433. | 544. | 657. | 770. | 889. |
| 3: HOSPITALS | | | | | |
| 1: HEATING | 3. | 6. | 7. | 9. | 11. |
| 2: COOLING | 51. | 51. | 51. | 51. | 50. |
| 3: LIGHTING | 137. | 142. | 145. | 146. | 147. |
| 4: AUX & POWER | 81. | 98. | 113. | 129. | 144. |
| 4: SCHOOLS | | | | | |
| 1: HEATING | 13. | 17. | 22. | 30. | 37. |
| 2: COOLING | 86. | 79. | 77. | 78. | 79. |
| 3: LIGHTING | 352. | 316. | 302. | 304. | 307. |
| 4: AUX & POWER | 226. | 234. | 253. | 283. | 313. |
| 5: OTHER | | | | | |
| 1: HEATING | 11. | 22. | 28. | 32. | 36. |
| 2: COOLING | 221. | 237. | 246. | 250. | 254. |
| 3: LIGHTING | 469. | 524. | 553. | 562. | 572. |
| 4: AUX & POWER | 334. | 435. | 525. | 602. | 680. |

INDUSTRIAL SECTOR

| | 1978 | 1983 | 1988 | 1993 | 1998 |
|---|---|---|---|---|---|
| 20: FOOD | 56. | 63. | 68. | 72. | 75. |
| 22: TEXTILES | 31. | 38. | 43. | 47. | 50. |
| 23: APPAREL | 24. | 23. | 23. | 23. | 22. |
| 24: LUMBER | 7. | 8. | 9. | 9. | 10. |
| 25: FURNITURE | 5. | 6. | 6. | 7. | 7. |
| 26: PAPER PRODUCTS | 42. | 41. | 39. | 38. | 37. |
| 27: PRINTING & PUBL. | 73. | 87. | 101. | 115. | 129. |
| 28: CHEMICALS | 61. | 58. | 53. | 46. | 37. |
| 29: PETROLEUM & COAL | 12. | 14. | 15. | 16. | 17. |
| 33: PRIMARY METALS | 43. | 52. | 58. | 63. | 67. |
| 34: FABRICAT. METALS | 68. | 72. | 76. | 80. | 84. |
| 35: MACHINERY | 102. | 120. | 137. | 154. | 172. |
| 36: ELECTRIC EQUIP. | 218. | 238. | 258. | 279. | 299. |
| 37: TRANSPORTATION | 305. | 360. | 406. | 443. | 481. |
| 30: RUBBER & PLASTIC | 59. | 82. | 102. | 122. | 143. |
| 31: LEATHER | 1. | 1. | 1. | 1. | 1. |
| 32: STONE,CLAY,GLASS | 24. | 26. | 28. | 30. | 31. |
| 38: INSTRUMENTS | 95. | 132. | 155. | 169. | 183. |
| 39: MISC. MANUFACT. | 12. | 15. | 17. | 19. | 21. |

TABLE 7

COMPARATIVE FORECAST ELECTRIC ENERGY CONSUMPTION
GROWTH RATES
(% Per Annum, 1978-1994)

| | SEO[1] | REFERENCE | LILCO[2] |
|---|---|---|---|
| Total Energy | 2.1 | 1.8 | 1.7 |
| Residential Sales | 1.6 | 1.6 | 1.9 |
| Commercial Sales | 2.6 | 1.9 | 1.7 |
| Industrial Sales | 3.0 | 2.2 | 1.1 |

[1]Ref. 23 (Appendices, p. 46-48)
[2]Ref. 7

The detailed structure of the model used for the Reference case electricity forecast was also employed to prepare a Reference case forecast of fossil fuel use. The sectors considered were the residential and commercial/institutional sectors. Industrial fossil fuel use on Long Island, at about 2% of total, is dwarfed by usage in other customer sections.

The end-uses considered were space and water heating, and the fuels considered were oil and gas. The forecasted growth rates for these fuels and sectors for the same period as used in Table 7 are given below in Table 8. No independent detailed long-range forecasts for these fuels are available for comparison with these forecasts.

TABLE 8

REFERENCE FORECAST FOSSIL FUEL CONSUMPTION
GROWTH RATE
(% Per Annum, 1978-1994)

| | Oil | Gas |
|---|---|---|
| Total Energy[1] | - 0.3 | - 0.6 |
| Residential Sales | - 0.2 | - 0.6 |
| Commercial/Institutional Sales | - 0.7 | - 0.7 |

[1]For residential/commercial, space heat/water heat usage.

The structure of the residential forecasting model is outlined in Sec. 4..1 below, while that of the commercial model is outlined in Sec. 4.2 and then discussed in greater detail in Appendix C. The disaggregated Reference case forecast of fossil fuel use on Long Island is set out in Table 9. In order to permit fuel comparability, values are expressed in terms of Btu content.

TABLE 9

DISAGGREGATED REFERENCE CASE FORECAST OF OIL AND GAS USE BY SECTOR AND END-USE, 1978-2000
($10^{12}$ Btu)

| YEAR | TOTAL CONSUMPTION | Residential Sector | | | | Commercial Sector | |
|---|---|---|---|---|---|---|---|
| | | Oil | | Gas | | Oil | Gas |
| | | Heating | Hot Water | Heating | Hot Water | | |
| 1978 | 188.3 | 98.3 | 12.1 | 21.4 | 4.2 | 45.6 | 6.7 |
| 1983 | 185.2 | 96.7 | 12.5 | 21.1 | 4.3 | 44.1 | 6.5 |
| 1988 | 181.7 | 95.1 | 12.7 | 20.7 | 4.5 | 42.5 | 6.2 |
| 1993 | 178.1 | 93.3 | 13.0 | 20.3 | 4.5 | 41.0 | 6.0 |
| 1998 | 179.1 | 91.7 | 17.9 | 19.7 | 4.6 | 39.4 | 5.8 |
| 2000 | 175.4 | 88.8 | 18.0 | 19.4 | 4.7 | 38.8 | 5.7 |

## 4. THE CONSERVATION SCENARIO

In this section, we shall specify the package of measures and policies which define the conservation scenario, the timing for the practical phase-in of these measures, and the costs for their achievement. Descriptive summaries of the conservation measures will be presented in the subsections below. In some cases supporting data has been collected in technical appendices referenced in the text and found at the end of the report.

Several guidelines are used in selecting the measures which comprise the conservation scenario. The first guideline to be satisfied is technological availability. Only "off-the-shelf" equipment is considered. Fuel conserving measures which require further technological development (e.g., the heat pump water heater) are not considered.

The second guideline employed in measure selection is cost effectiveness. All measures satisfy the general criterion of social cost-effectiveness in the sense indicated earlier: the cost of saving a unit of energy with the measure is less than the cost of delivering an extra unit of energy.* Thus measures requiring further development before they approach direct cost-attractiveness (e.g., photovoltaic cell conversion of sunlight to electricity) are excluded. Indeed, for almost all of the measures utilized here, there is no contest -- conserving energy is far cheaper than producing it. We shall return to a discussion of conservation costs by measure below. Some additional clarification on the concept of cost effective criterion is presented in Table 10.

The third guideline is the notion of program achievability. The conservation scenario is not meant to exhaust the potential for technically feasible conservation. Indeed, even the objective of promoting maximal levels of cost-effective conservation technology is tempered by the need to phase in elements only as the existing stock of equipment turns over and to develop moderate program targets to allow for incomplete market penetration and possible error margins in the program design.

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*A full social cost/benefit analysis would consider such factors as environmental and health impacts, long-term repercussions on depletable resource usage and employment impacts in addition to direct tradeoffs. Since we know of no non-controversial methodology for quantification of such factors, we shall restrict "social cost" here to total direct expenditures by society for the alternative energy strategies. However, the conservation measures generally have more benign "external" impacts than the energy growth alternative, so that the narrow direct social cost/benefit assessments should be seen as merely suggestive of lower bounds on conservation measure cost attractiveness.

TABLE 10

COST EFFECTIVENESS CRITERION

Let

| | | |
|---|---|---|
| PVIC | = | present value of incremental benefits minus costs of achieving conservation scenario; |
| $I_t$ | = | incremental costs of "saved" energy; |
| $C_t$ | = | incremental costs of implementing conservation resources; |
| i | = | conservation measure; |
| t | = | year; |
| d | = | social discount rate reflecting time value of money. |

Then

$$PVIC = \sum_i \sum_t \frac{\left(I_t^i - C_t^i\right)}{(1 + d)^t}$$

This expression gives the relative savings of the conservation scenario measure over Reference case assumption. "Incremental" signifies the <u>extra</u> costs and savings in making the transition to the conservation <u>case.</u> Costs incurred in both cases "wash," cancelling out in taking the differences in the stream of costs.

Typically, one compares the cost of delivering an extra KWH (or Btu of oil) with the cost of saving a KWH (or Btu). To see this, let

| | | |
|---|---|---|
| P | = | price per unit of energy |
| $\Delta E$ | = | energy saved annually by a given conservation measure. |

Then, assuming an investment $C_0$ is made in year "0" in a conservation measure, we have (ignoring operation and maintenance costs)

$$PVIC = \sum_{t=0}^{T_L} \frac{P_t \times \Delta E}{(1 + d)^t} - C_0$$

where the limits on the first sum run over the lifetime of the measure $T_L$. Finally, we may simplify these relationships by assuming, heuristically, that escalation in marginal energy costs is roughly at the level of the discount rate which, after some simple manipulations, implies:

$$PVIC/(\Delta E \times T_L) = P_0 - C_0/(\Delta E \times T_L)$$

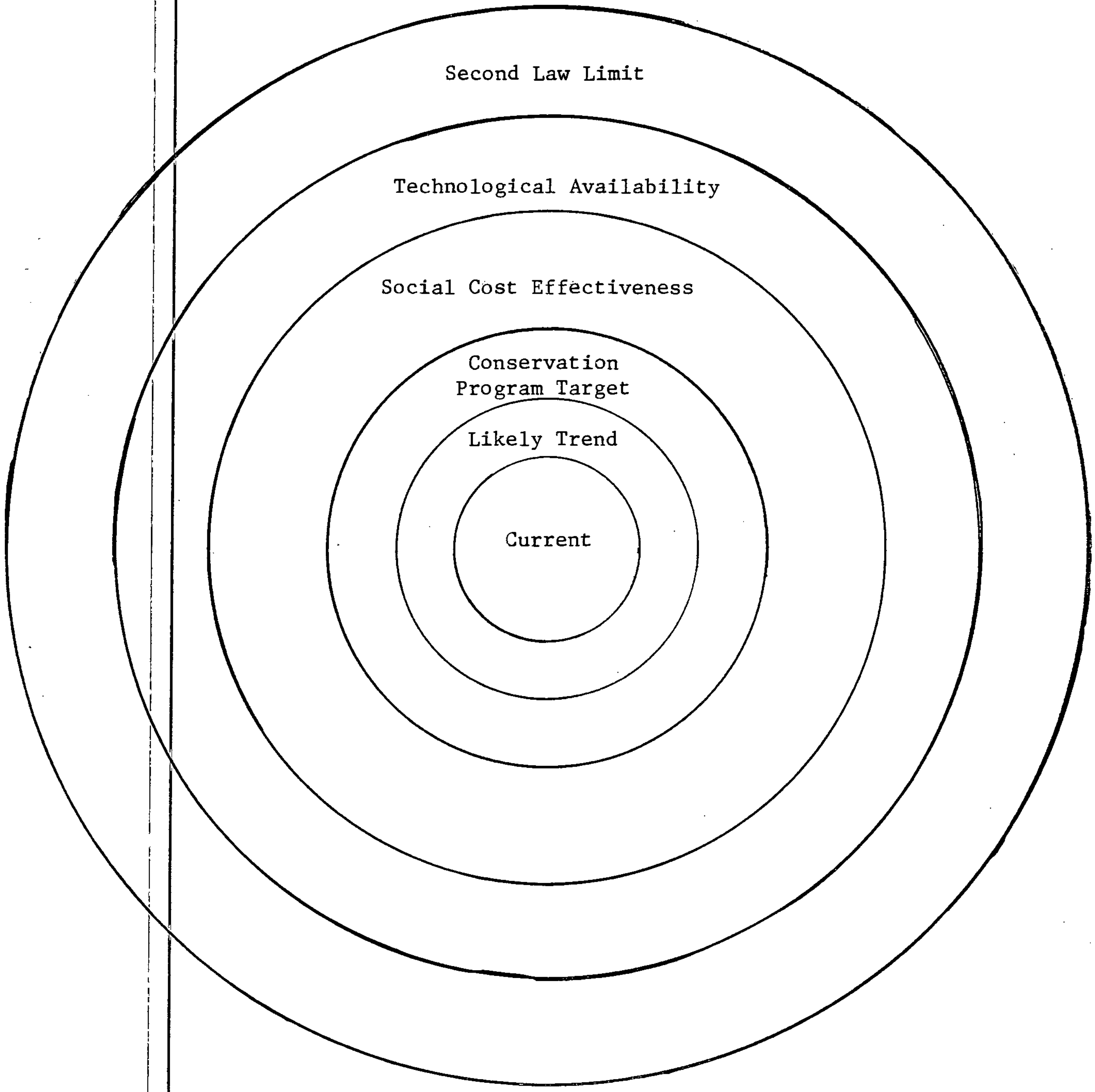
So that $C_0/\Delta E \times T_L \leq P_0$ is a rule of thumb test for conservation cost effectiveness.

Conservation program assessment is an emerging analytic discipline which is undergoing a period of clarification of conceptual formulation. In the literature, the notion of conservation potential is used in several senses. In the hope of better situating the present project, a variety of alternatively defined conservation levels is illustrated as a series of embedded sets in Figure 2. Let the radii of inscribed circles in the figure represent the level of conservaton (not to scale, of course). At the center is the current level of conservation activity. Next the circle broadens to include the "likely trend" of increased conservation, corresponding to the levels incorporated in our Reference forecast. Beyond these is the further expanded circle of heightened activity representing the conservation scenario program targets under investigation in this study. Beyond this level is the set of all conservation activities satisfying the criterion of social cost effectiveness -- the marginal cost of savings is less than or equal to the marginal cost of supplying energy. This level in turn may be encompassed by a larger set of currently available or evolving technologies which would save conventional energy resources. And, ultimately, the universe of conservation options is constrained by inherent physical limitations imposed by the physics of natural processes and expressed by the second law of thermodynamics.

Thus, the conservation scenario described in this study is a moderate one seen against the larger definitions of conservation potential that can reasonably be employed. The scenario is bold only in hypothesizing that institutionally feasible programmatic initiatives that are not at this point likely are in fact taken and their benefits realized.

Figure 2

CONSERVATION LEVEL TYPOLOGY



## 4.1 The Residential Sector

The conservation scenario is based on both a set of conservation measures and a modelling approach to computing their effects over time. Our description of the scenario proceeds on a sector-by-sector basis for the three major energy-consuming sectors, beginning with the residential sector.

The component end-uses of residential energy consumption are treated in fourteen separate submodels. This level of detail allows the incorporation of the central factors affecting overall demand. These factors can be lost in methodologies which forecast aggregate demand alone. The residential end-uses for which submodels have been developed are listed in Table 11.

TABLE 11

RESIDENTIAL END-USE SUBMODELS

| Input | End-Use |
|---|---|
| 1 | Refrigerator |
| 2 | Freezer |
| 3 | Electric Range |
| 4 | Lighting |
| 5 | Television |
| 6 | Clothes Dryer |
| 7 | Clothes Washer |
| 8 | Dishwasher |
| 9 | Water Heater |
| 10 | Air Conditioning - Room |
| 11 | Air Conditioning - Central |
| 12 | Space Heat |
| 13 | Heating Auxiliaries |
| 14 | Miscellaneous |

The residential forecast for each end-use can be viewed as a combined forecast of (1) the number of end-use units, on the one hand, and (2) the average annual energy consumption per unit, on the other. Thus, at the most elementary level, annual consumption for one of the end-uses (i) in one of the forecasts years (t) is given by the equation:

$$E_{t,i} = N_{t,i} \times C_{t,i}$$

where

$E_{t,i}$ = Total annual energy consumption of end-use (i) in year (t)

$N_{t,i}$ = Total number of corresponding units

$C_{t,i}$ = Average annual energy consumption per unit

Then the total energy consumption in the residential sector for year (t) becomes

$$\sum_i E_{t,i}$$

The number of units for a given end-use is itself computed as the product of the number of households and the end-use saturation. Saturation is defined here as the average number of units per household. The number of household units is further divided into single family units (SF) and units in buildings containing multiple dwelling units, denoted simply as "multifamily units" (MF). This breakdown is desirable because appliance ownership and usage patterns may vary significantly by housing type. A shift in the mix of SF and MF in the forecast period thus affects ultimate demand.

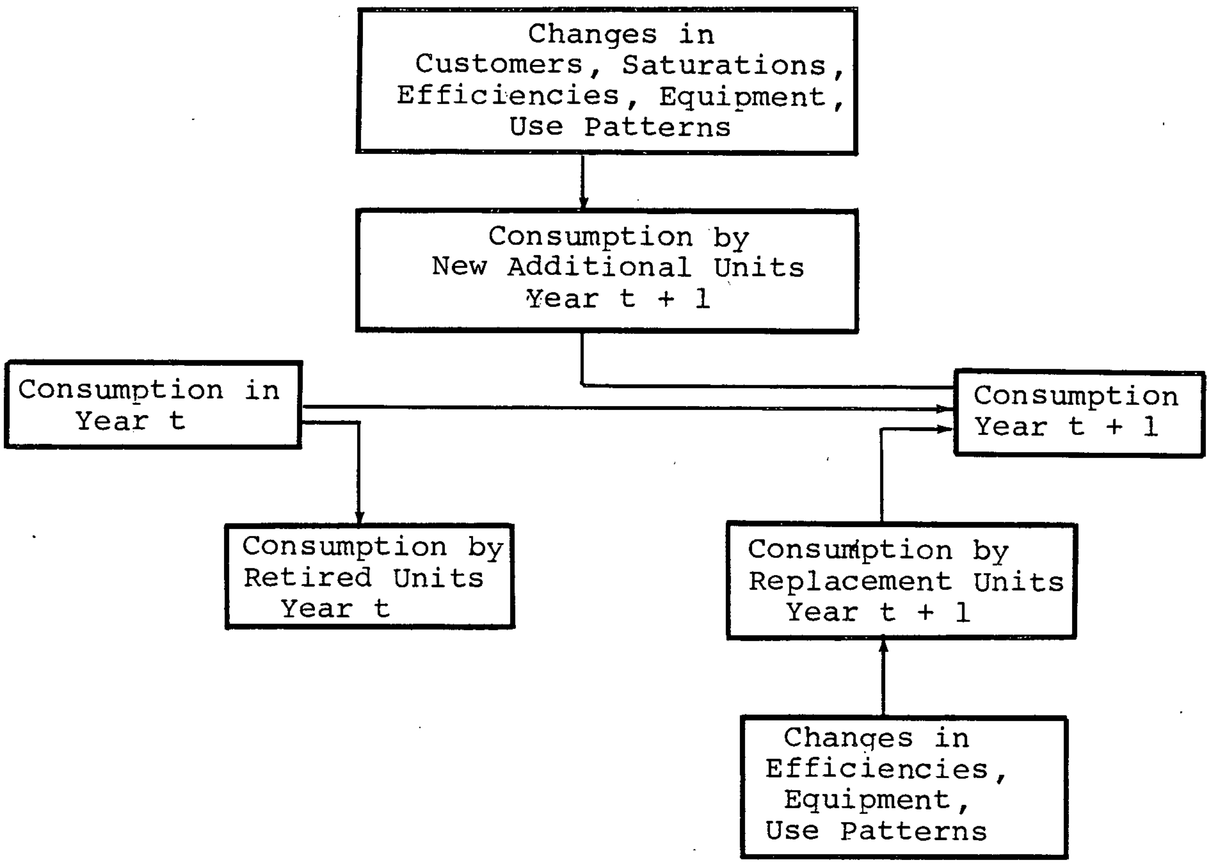
The second term in the equation above, the average annual energy consumption for each end-use, is rather complex. Once the base year energies are established, the time dependence of average energy consumption must be computed. The major factors which can impact average energy use are:

- appliance efficiency increases
- thermal integrity improvements of building shells
- new technology market penetration
- population per household decreases
- energy consumption reductions induced by electricity price increases.

The end-use submodels are designed to permit the quantification of the effects of such trends on energy consumption. The submodel energy forecasts are sensitive to varying input assumptions concerning these trends. As the first three factors listed suggest, the effects of a conservation program such as hypothesized for this study are tracked at the level of specific end-use equipment assumptions.

Figure 3

COMPUTATION OF YEARLY ENERGY INCREMENTS
FOR A GIVEN RESIDENTIAL END-USE



Although the end-uses have particular characteristics which require unique model elements, the overall forecasting strategy displayed schematically in Figure 3 is used throughout. The yearly increment in energy consumption is calculated by (1) subtracting the energy consumption of retiring units, (if any), (2) adding the energy consumption of replacements, and (3) adding the energy consumption of additional new units due to customer and saturation growth. Once the base year breakdown is established, we can use this iteration technique to compute energy consumption for each year of the forecast under a given set of assumptions on changes in saturation, customers, technology mixes, efficiencies and patterns of equipment usage.

The conservation scenario developed for this study applies a number of technically feasible conservation measures in the end-use submodel forecasts. The measures will affect both the level of electricity consumption and the amount of fossil fuel consumed on-site for heating and hot water. The following classes of measures are incorporated in the scenario:

- Improved weatherization levels in residential buildings.
- Restriction on future unassisted electric resistance space heating.
- High efficiency levels for several major appliances (refrigerators and freezers, air conditioners and heat pumps, hot water heaters, electric ranges and clothes dryers).

The scenario attempts to capture the additional conservation that will occur above and beyond that which is incorporated in the Reference scenario. In other words, it quantifies the effects of <u>higher</u> appliance efficiencies than are likely without the adoption of a major conservation strategy program, <u>more</u> weatherization than is likely without such a program, etc. As is evident from the discussion of findings earlier in this report, the aggregate effect of such incremental conservation measures on residential conservation is very substantial.

- <u>Building Shell Quality</u>

An important component of the conservation scenario is improvement of the thermal integrity of residential buildings. Both the federal government and the states have begun the process of promoting improved thermal integrity through legislation. Improvement in residential thermal integrity slows the rate of heat loss in winter and the rate of heat gain in summer. It thus reduces the electricity and fossil fuel requirements of households by reducing the heating and cooling load for a given type of dwelling unit.

Considerable detail is required to adequately capture the variations in usage across building categories and over time as a function of alternative forecast assumptions. Specifically, in the model used here, the two major housing types (single- and multifamily) are broken down further by primary heating system (electric and fossil fuel heated), and then again by vintage (existing and new construction) for a total of eight building type/heating system/vintage combinations for <u>each</u> forecast scenario (Reference and Conservation). Within each of these, the impacts of changing building shell characteristics on heating and air conditioning energy requirements are evaluated separately. All of these energy adjustments -- or thermal integrity factors -- are required inputs in the ESRG end-use model forecasting machinery. A separate building energy flow model has been employed in computing these thermal integrity factors. The algorithms, data, and assumptions used in generating the quantitative estimates of annual heating, ventilating, and air conditioning (HVAC) requirements will be found in Appendix A. There also is presented a detailed tabulation of results. We limit the discussion here to a summary of findings.

X Basically, the Reference forecast incorporates two assumptions. One is that new residential units will be built to the thermal integrity levels that are mandated in the state code (Ref. 51) or to the levels of current new construction (whichever are higher) during the forecast period. The second assumption is that existing fossil fuel-heated homes that remain in the housing stock will be gradually "retrofitted," <u>i.e.</u>, their thermal integrity levels will be improved. We <u>do</u> not assume any improvement through the retrofitting of electrically-heated buildings, for their thermal integrity levels are already well above average. Building thermal integrity upgrade is occurring due to the state energy conservation building code, weatherization programs, fuel price trends, and increased awareness of the value of conservation. The measures consist primarily of higher levels of insulation, double-glazing of windows, and weatherstripping in new houses (compared to previous building practices) and to the retrofitting of existing structures with these features.

The analysis indicates that under business-as-usual conditions, typical new electrically heated dwelling units will consume 10 to 15 percent fewer kwh per year as a result of higher levels of insulation, multiple-glazing, and weatherstripping than dwellings typical of the existing stock of electrically heated homes. Typical new oil heated units will consume over 30 percent less oil (and over 30 percent fewer kwh for the electrically driven fans or pumps associated with their fossil heating systems) than do average existing units.

Business as usual: <u>new</u> elect heat 10-15% savings
fossil " 30% savings
A C room 15% ← due to envelope
central 3% ←

In the Reference forecast, the space heating energy consumption of all new units was reduced in accordance with the above findings. Electricity consumption by new air conditioners was also reduced due to improving thermal integrity -- 15 percent for room air conditioners and about 3 percent for central air conditioning systems. It should be borne in mind that other factors affecting energy use for space conditioning -- such as changes in equipment efficiency -- were treated sequentially in the model used for the analysis in order to avoid "double counting" of energy savings. For example, the potential for savings from improved air conditioner efficiency must be reduced as air conditioning requirements decrease due to improved building shells.

X

Forecasting the long-term rate of retrofitting of existing housing units that remain in the housing stock necessarily requires judgmental estimates. In establishing the Reference forecast benchmark, we assume that, by 1998, on the average, one-half of the existing single-family units will achieve the heating savings associated with the higher thermal integrity of new units. The reductions are phased in gradually for these existing units, from zero in 1978 to the full unit reduction in 1998. We assume that for multifamily units, where lower rates of owner occupancy reduce the conservation incentive, one-quarter of existing units will be so retrofitted by 1998. Air conditioning usage is also reduced appropriately due to the retrofitting of existing units.

Business as usual: ~~ongoing~~

SF retrofit 1/2

MF - 1/4

Once the ongoing conservation through improved building shells is captured in the Reference case, we are in a position to quantify the additional conservation that could be secured through the conservation program. Using current local insulation and weatherization costs, on the one hand, and current electricity and oil prices, on the other, the housing prototypes used in the Reference forecasts were taken to higher conservation thermal integrity levels that are cost-effective for consumers. As shown in Appendix A, the payback periods associated with Reference forecast are quite short.

We found a very substantial potential for additional conservation through further investment in improving thermal integrity. In principle, any payback falling within the lifetime of the conservation measure purchases is acceptable within the framework of this analysis (see Table 10). In practice, caution dictated using much shorter paybacks. Through additional weatherization (specified in Appendix A), consumption of electricity and fuel oil for space heating is reduced by about 30 percent (relative to the Reference case) in new units. Cooling kwh savings, while smaller than heating energy savings both absolutely and relatively, are still significant: over five percent further

addtl (?) 30% savings

savings in both room and central air conditioner kwh use are realized (relative to the Reference case) through investment in improved new-dwelling weatherization alone. In addition there is a potential for further reducing the fuel needed for heating and cooling by incorporating passive solar elements in building design. This potential is treated later in a sub-section on solar energy.

A major problem for a conservation strategy is to increase the rate of weatherization retrofits in existing units. In the Reference case, we assume the existence of such programs as the federal low-income weatherization program, tax credits, the new federal solar-conservation bank, and the federal/state Residential Conservation Service and/or the state's Home Insulation and Energy Conservation Act (HIECA), and LILCO's customer information program. It is clear that such programs are moving forward at a slow pace. Most eligible homes have not been weatherized. Very few of the customers of LILCO have taken out conservation loans pursuant to HIECA. As we have indicated, in the Reference case we assume gradual growth of such programs and a gradual increase in weatherization retrofits to cumulative totals of 50% of existing single-family and 25% of existing multifamily units retrofitted after twenty years.

Additional
SF 25%
MF 30%
savings

For the Conservation strategy, we assumed that some degree of retrofitting to higher weatherization levels occurs in 100% of homes remaining in the housing stock. By the end of the forecast period, the oil usage of typical single-family units has been reduced almost 25 percent (beyond the Reference case levels) and of typical multifamily units, 30 percent (with kwh usage for fossil heating auxiliaries being reduced by the same percentages). In addition to the savings described, there is a real potential for reinsulation of existing electrically heated homes, though this is not included in this Conservation scenario.

- Equipment Efficiency

An important component of the residential Conservation scenario is the set of measures to improve the efficiency of operation of home appliances. Conservation criteria of technical feasibility have been used in establishing target levels for efficiency improvements. The improvement must meet one or more of these criteria:

- The improvement is already embodied in appliances on the market.
- The improvement has been demonstrated in tests for the United States Department of Energy (DOE).
- The improvement is under active commercial development for near-term marketing.

Consequently, additional savings beyond those quantified here in the Conservation scenario may be attainable over the twenty year forecast period through additional appliance efficiency improvements. Furthermore, adoption of programs to implement improvements now technically and economically feasible may encourage additional technical progress in residential appliances.

Most of the conservation scenario efficiency levels employed were obtained from an engineering analysis conducted for the U.S. Department of Energy (Ref. 46). In fact, they are the levels proposed by DOE as minimum efficiency standards for new appliances to apply to most manufacturers by 1986. Since these standards are only proposed, since they would not apply to all manufacturers, and since they have encountered significant opposition from the U.S. Small Business Administration, the U.S. Regulatory Analysis Review Group, and manufacturers, it would be unwise to forecast their implementation at the time or in the form proposed by DOE, and they are therefore not incorporated in the Reference forecast. However, the detailed engineering analysis performed for DOE supports pursuit of the proposed 1986 levels as targets for a Long Island conservation program. The use of these levels in our conservation scenario is cautious. The DOE engineering analysis shows that there is a higher, "best technology" level for these appliances, and an analysis performed for the Pacific Gas and Electric Company suggests that the incremental costs of producing appliances at this highest level of efficiency (compared with the D.O.E. 1986 level) might be modest relative to energy saved (see Appendix B). Other studies illustrating potentials for conservation through improvement of electric equipment efficiency are summarized in the recent ESRG report submitted in connection with the state of New York's 1979 Energy Master Plan hearings (Ref. 10, Sec. 3).

The Conservation forecast computes the incremental savings that will be achieved if conservation investment subsidies lead consumers to purchase new equipment that on average is at the efficiency levels proposed by the D.O.E. for 1986 as minimal. (Thus if some consumers purchase equipment that is either more or less efficient than the indicated levels, the effect on aggregate usage is the same as if all purchases were at the average levels.)

It is commonly anticipated that equipment efficiency will improve even in the absence of the Conservation program. Indeed, the Reference forecast assumes that unit usage of electricity and fossil fuel will decrease throughout the 1980's for major classes of new equipment. For the electrical appliances, most of the improvements were computed on the basis of the "Energy Conservation Program for Appliances" developed by a predecessor agency to the D.O.E. (the Federal Energy Administration, or F.E.A.). Final voluntary "energy efficiency improvement targets" for fourteen types of appliances were issued by the F.E.A. during 1978 (Refs. 47, 48). The annual energy use reductions implied by the voluntary targets for electrical appliances were summarized in the recent ESRG report submitted in connection with the 1979 Master Plan hearings (Ref. 10, Vol. I, p. 69) and were programmed into the Reference forecast.

Thus, the Conservation forecast incorporates only the additional energy conservation beyond Reference case levels that will occur should efficiencies be further improved. Beginning in 1982, the Reference level improvements are interrupted and the additional energy savings for new appliances listed in the following table are computed and folded into the forecast output.

Technical details concerning the characteristics of the prototype appliances used in making the savings computations may be found in Appendix B. The question of measures affecting space heating usage requires separate analysis and treatment, which follows.

TABLE 12

INCREMENTAL UNIT ANNUAL ENERGY SAVINGS AND UNIT RETAIL PRICE INCREASES FOR NEW RESIDENTIAL EQUIPMENT AT CONSERVATION EFFICIENCY LEVELS

| Appliance | Unit Energy Savings | Unit Price Increase |
|---|---|---|
| Refrigerator | 34% | $24 |
| Freezer | 49% | $17 |
| Room air conditioner | 16% | $41 |
| Central air conditioner | 26% | $260* |
| Heat pump | 25% | $543* |
| Electric oven | 2% | $2 |
| Electric clothes dryer | 8% | $16 |
| Water heater (electric or fossil) | 5% | $0 |
| Light bulb | 48% | $5 |
| Plumbing fixtures | 36% | $10 |

*The price given is for a unit in a prototypical single-family home. For an air conditioner, the price increase for the smaller unit required for a home in a multifamily structure is taken at 50 percent, i.e., $130. On SF and MF heat pump price increments, see Appendix B.

- Electric Space Heating

Currently, about four percent of households served by LILCO have electrical space heat (ESH). However, the Company expects the penetration of ESH (the fraction of new ESH customers to total new customers in a given year) to be at quite high levels in the future. Indeed, the Reference case incorporates an average penetration of 50 percent for the forecast period; fully 30 percent of residential electric energy growth is accounted for by the end-use. Therefore, conservation alternatives to allowing such unrestrained growth deserves special policy scrutiny.

=50% SH saturation

For purposes of analysis, we may divide the ESH category into subdivisions: direct resistance heating, electrically driven heat pumps, and supplementary electric heat for solar heat systems. We posit here an ESH policy regulation referring only to the first of these alternatives. Specifically, the recommended regulation is to ban additional unassisted resistance heating.

There are two major alternatives for the customers who otherwise would have selected electric resistance heating: heat pump or conventional fossil-fuel heating systems.* Indeed, the conservation model is designed to allocate the new resistance ESH customers proportionately to the relative market penetration ratios of these alternatives in the Reference case, a process beginning in 1982.

The energy consumption tradeoffs in substituting a heat pump or fossil fuel system for direct electric resistance heat are quite favorable. For the case of the heat pump substitution, energy consumption is more than halved. This is traced to the "pumping" property of heat pumps in which delivered indoor heat is composed of both thermal energy transferred from outdoor air (or water) and the electricity delivered to run the pump.

The energy savings resulting from substituting fossil fuel for ESH are also quite favorable. For example, it takes over twice as much primary energy to satisfy a unit of final heating demand from electric heating than from fossil-fired boilers. This is illustrated in Table 13 below.

TABLE 13

PRIMARY ENERGY COMPARISON
(Arbitrary Units)

| | Primary Energy | Conversion Loss | Delivered Heating Energy |
|---|---|---|---|
| Resistance Heating | 3.3 | 2.3 | 1 |
| Fossil Fuel Heating | 1.5 | 0.5 | 1 |

*Active solar applications are assumed to have negligible impacts on Long Island throughout this study.

The energy penalty for resistance heating is traced to the large conversion losses inherent in the thermodynamics of electricity production. The conversion losses in the table are based on a 33 percent plant efficiency (electrical energy out to primary energy in) and another 8 percent electric line loss in delivering the electricity through the transmission and distribution grid. For the fossil fuel system, boiler efficiencies are on the order of 70 percent (the value used in Table 13), but may be more like 80 percent in newer units.

We have shown that the ESH ban dramatically satisfies the criterion of energy conservation and scarce fuels preservation (displaced generation is primarily from oil fired units on Long Island). To see if it also satisfies the criterion of cost effectiveness, we utilize the following estimates (for single-family units):

| | Incremental Capital Cost* | Equipment Life | Incremental Energy Savings |
|---|---|---|---|
| Fossil Fuel System | $1826 - oil<br>1032 - natural gas | 15 | 13,000 KWH |
| Heat Pump | 1726 | 10 | 7,000 KWH |

*Above baseboard resistance costs.

The capital cost penalty for the fossil fuel oil investment is about 1¢/KWH (see Table 10), while oil fuel costs are the equivalent of about 3¢/KWH so that the sum is less than the marginal cost of delivering electricity. These costs are of course much less for the natural gas alternative.* Similarly, for the heat pump we compute the cost of saving electricity at a satisfactory 2.5¢/KWH. In sum, the ESH regulation appears to be oil-reducing, cost-effective, and implementable.

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X *The residential fossil fuel split is taken at its current ratio of 80 percent oil and 20 percent natural gas throughout the period of this study.

- Solar Energy

The conservation program scenario includes the incorporation of minimal passive solar specifications in new construction. No active solar promotion and finance is included. This should not be interpreted as a negative assessment of the possible role of active solar as a worthwhile conservation option, but rather as a recognition that its cost effectiveness is much less certain than the other program elements considered and that numerous programs already support its use.

Passive solar strategies are based on architectural techniques for advantageously coupling building interfaces and the insolation environment. These considerations include building orientation, materials choices, fenestration, and shading design. Active solar, on the other hand, generally includes the solar collector, a working fluid for heat transport, a heat storage device, and supporting pumps and fans.

Estimates of likely construction cost additions and energy savings in incorporating selected passive solar measures in building design appear in the literature (e.g., Refs. 41, 43). Costs typically vary from $450 to $1000 for the achievement of from 12 to 50 percent heating energy savings per household. For purposes of this analysis, a conservation policy target of a 25 percent reduction in heating requirements (at a $730 incremental expenditure) in new single-family units is assumed. This measure easily meets the social cost/benefit criterion. The cost per KWH of saving electricity (or the equivalent in fossil fuel) is less than 1¢ given the assumptions above and a cautious 25 year lifetime assumption for the structural measures involved. The cost of delivering the electricity in the absence of such a measure is (and will be), of course, considerably higher. It should be noted that passive solar design measures also have energy saving implications for summer air conditioning loads. This additional credit has not been incorporated in this study.

## 4.2 Commercial Sector

In symmetry with the residential sector, the conservation program affects energy use in three areas: building characteristics, equipment efficiency and operations, and electric space heat regulation. Other promising but still developing energy saving techniques -- e.g., solar applications, cogeneration -- are not included.

The model for energy consumption for the commercial sector tracks demand for five building types, four end-uses, or twenty combinations each for existing and new buildings. These are displayed in Table 14 along with the commercial category allocated to each building type. The space heating end-use is further segmented into electric and fossil fuel categories.

The modeling strategy for the commercial sector is analogous to that of the residential sector. In the commercial sector, the measure of energy using activity is the magnitude of floorspace while the energy intensity is expressed in terms of average annual energy consumed per square foot for each end-use and building type. The elements of the model are displayed schematically in Figure 4. The commercial sector is considerably more heterogeneous than the residential and must be treated on a more aggregate basis. The specifications of base year floorspace, average consumption per square foot of each end-use ("electrical use coefficients"), and saturations (fraction of floorspace with end-use) gives the base year breakdowns. Folding in the time dependences of floorspace, conservation, and saturations, one arrives at the yearly forecasts.

The commercial forecast model, therefore, divides conceptually into two separate submodels: one for floorspace and the other for electric intensity. The mathematical formulation and relevant data base were presented in complete detail in the New York State Energy Master Plan Proceedings (Ref. 10) and are not recapitulated here. Rather, we limit this discussion to a definition of the conservation scenario elements and their impacts relative to the Reference forecast.

- Equipment Efficiency and Building Standards

  For each of the building types, we wish to identify a package of cost-effective, technologically available conservation measures to indicate the possible impacts of commercial sector conservation policies. A hierarchy of three levels of conservation are identified for each building type and vintage. Associated with each level are mean fractional reductions in energy requirements for each end-use category and the capital costs required to achieve the level.

TABLE 14

COMMERCIAL MODEL END-USES, BUILDING TYPES AND COMMERCIAL CATEGORIES

| Index i | End Use |
|---|---|
| 1 | Space-Heating |
| 2 | Cooling |
| 3 | Lighting |
| 4 | Aux. & Power |

| Index k | Building Type |
|---|---|
| 1 | Office |
| 2 | Retail |
| 3 | Hospitals |
| 4 | Schools |
| 5 | Other |

| Index J | Commercial Category |
|---|---|
| 1 | Finance, Insurance and Real Estate |
| 2 | Federal Government |
| 3 | State & Local Government |
| 4 | Professional Services |
| 5 | Retail and Wholesale |
| 13 | Hospitals and Health Related Establishments |
| 14 | Schools and Educational |
| 6 | Trucking and Warehouse |
| 7 | Other Transportation Serv. |
| 8 | Communications |
| 9 | Lodging & Personal Services |
| 10 | Business & Repair Services |
| 11 | Amusement & Recreation |
| 12 | Railroad |

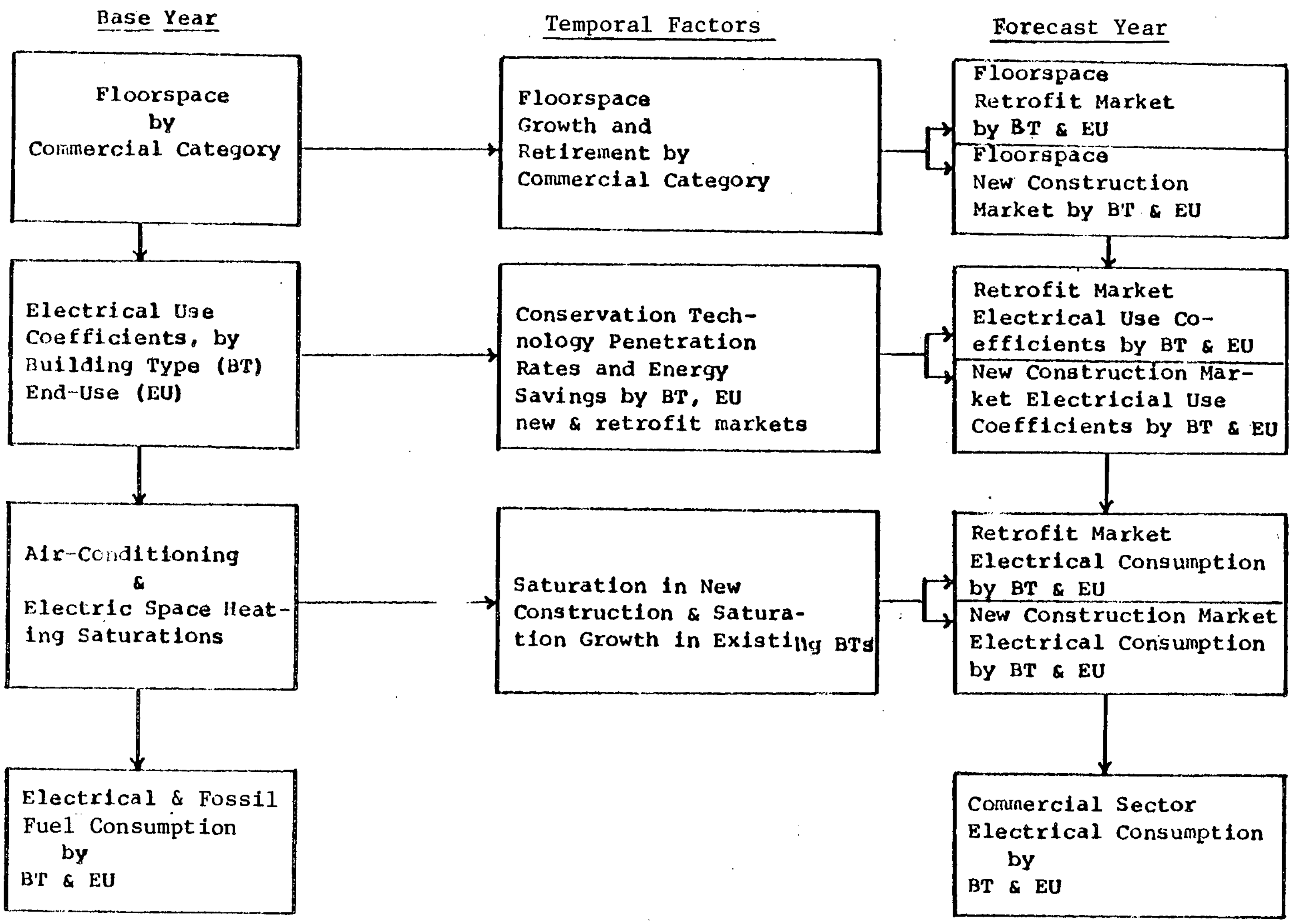


FIGURE 4
COMMERCIAL SECTOR MODEL SCHEMATIC

The elements comprising each of the Conservation levels, costs, and fractional savings have been collected in Appendix C. The particular commercial sector conservation elements contained in the three levels are not meant to be exclusive or exhaustive. Rather the levels are used to establish reasonable cost/saving curves for conservation investments in each building type which could represent a variety of alternative strategies for saving energy in commercial/institutional buildings.

In the Reference forecast, the penetration of conservation technology is based on S-shaped market penetration curves and assumptions concerning payback criteria for investment. While it incorporates significant increases in conservation from current practices, the Reference case is tied to the investor's perception of cost-effectiveness (implying very short paybacks for investments). This level of penetration, however, far from exhausts the potential under the social cost effective standard used as a criterion for Conservation scenario targets. Indeed, the strongest level identified easily satisfies our cost criterion and is the basis for the Conservation scenario. The specification of conservation level targets, the market penetration of conservation investments, and costs and energy savings in the Conservation vs. the Reference case are presented in Appendix C.

- Electric Heat Regulation

As we saw in the residential sector discussion of the previous subsection, the use of resistance heating for space heating (rather than on-site boilers or heat pumps) increases the consumption of scarce fossil fuels by a factor of approximately two. In the commercial sector, as in the residential, the Conservation scenario therefore assumes that no new unassisted resistance heating is used after 1982.

The Reference case assumes an average ESH penetration of 15 percent in new and retrofit commercial/institutional floorspace. In the conservation runs, this floorspace is switched to electric heat pumps. The incremental cost associated with this shift -- above the Reference case cost of resistance heating equipment and air conditioning since the heat pump replaces both -- is about $250 per 1000 square feet (Ref. 45). Based on a 15 year equipment lifetime, this converts to an incremental cost of the ESH restriction of less than 1¢ per saved KWH (see Table 10) or comfortably less than the costs of delivering an additional KWH.

## 4.3 Industrial Sector

Nationwide the industrial sector consumes more than one-third of primary fuels and over forty percent of electrical energy. The situation on Long Island is strikingly different. Here, industry accounts for only ten percent of total electric energy consumption and less than five percent of all energy forms. The potential impact of a conservation program for industry is small compared to the other sectors. Nevertheless, an industrial conservation scenario has been included for completeness. Three broad areas for industrial conservation are building-related usage, manufacturing process requirements, and cogeneration levels.

- Building and Process Use

  There are two major categories of electricity consumption in industrial installations: energy for buildings (lighting and space conditioning) and energy for process (machinery, pumps, materials control, and so on). The former typically amounts to some 20 to 30 percent of electricity consumption, though this breakdown will vary by category of industry. Electrical energy for buildings (especially the office sections of industrial structures) would be subject to the types of building shell equipment, and operational improvements found in the commercial sector (see Sec. 3).

  In addition, there is the potential of increasing the efficiency of energy used in the manufacturing process itself. Recently there have been several major attempts to develop analytic models for analyzing the potential for efficiency improvements among the multitude of processes used in industry (Refs. 29-31). The analysis is hampered by insufficiency of a detailed data base on industrial energy flows, on the necessity to use prototypical representations (generally at the 2-digit Standard Industrial Classification (SIC) level) of heterogeneous industrial subcategories, and incompleteness in available characterizations of the array of process technology options.

  In view of these limitations, a simplified approach is used here. First, we do not consider conservation measures (*e.g.,* improved boiler efficiencies) which would affect the level of on-site oil and natural gas usage, for the fossil fuels consumed directly in Long Island industry are relatively inconsequential.

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*According to the Census Bureau's 1975 *Survey of Manufactures*, direct oil and gas use by industry was some 8 trillion Btu; this was much less than a tenth of the residential-commercial-industrial total.

With regard to electricity, consumption by Long Island manufacturers is heavily concentrated in SIC's in which electricity is used primarily for machine drive (SIC electricity consumption levels are displayed in Table 6). If we can assume that the end-use electricity patterns within Long Island SIC's reflect the generic pattern for each SIC (Ref. 29, vol. 3, page 33), then over 97 percent of electricity consumption in LILCO service area manufacturing is for electric motor drive.

Savings potential and associated costs for motor drive efficiency improvements are given in Ref. 32 (Technical Appendix, p. 23). There it is estimated that one-half of all motor drives can be equipped with variable speed controls which reduce power requirements by a mean value of 30 percent. These estimates are utilized here to characterize the Conservation scenario improvement levels. Specifically, a 14.6 percent improvement ($.97 \times .5 \times .30$) target for industry is phased in from 1983 to 1990. The capital costs for the measure average to 13¢ per saved KWH.*

There is no doubt that the analysis would benefit from development of a detailed inventory of Long Island usages and savings potential. However, the savings target appears to be reasonably moderate, especially in light of the large additional savings for the building usage component that are available at generally attractive costs, and have not been included explicitly in this scenario.

Cogeneration

Cogeneration has tremendous energy conservation potential regionally and nationally (Refs. 33-38). The term cogeneration as defined here refers to the simultaneous production of electricity and useful thermal energy. In essence, cogeneration combines two otherwise nonintegrated energy flows. Steam (or hot gas) is needed to drive the turbines which produce electricity and also needed for industrial processes and space conditioning. Without cogeneration

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*These are based on Ref. 32 values of $\$1.07 \times 10^{-5}$ per saved Btu of primary fuel (1978 \$), a 33 percent power plant conversion efficiency and an eight percent cost escalation rate.

the energy lost in electricity production -- roughly two-thirds of the fuel inputted -- is lost. With cogeneration, this "waste energy" is captured and utilized, thereby reducing boiler fuel requirements.

In New York State, approximately 7 percent of industrial electricity requirements are currently produced in-plant. The corresponding national figure is 10 percent. By contrast, industrial generation alone accounts for 13 percent of total electricity production for West Germany. The potential for cogeneration in the United States is vast, with one recent study concluding that some 68 percent of total electricity requirements could be economically produced (Ref. 33).

Despite this promise, there is no evidence of significant cogeneration currently in place on Long Island. Indeed, the Reference forecast includes no cogeneration throughout the period. The limiting factor to increased cogeneration is not the availability of sufficient demand for steam. Rather, as discussed in a recent ESRG report to the State Energy Office designed to identify policy opportunities for overcoming hurdles to increase cogeneration development, there are several substantial institutional impediments to the cogeneration investment in New York as perceived by plant managers. The removal of these barriers -- the requirement for high rates of return on cogeneration investment, the discomfort with regulatory review, unfavorable rates for back-up electricity -- could greatly increase the penetration of socially cost-effective cogeneration.*

One policy approach to eliminating major obstacles to the development of cogeneration is an active role for the utility in owning, constructing and maintaining cogeneration facilities at industrial (or commercial/institutional) sites. Specifically, with utility involvement the required rate of return

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*Here, the emphasis on social cost-effectiveness is particularly significant. Cost-effectiveness from the point of view of, say, industrial decision-makers might be interpreted as requiring a rate of return on the cogeneration investment of perhaps 40 percent, while from society's perspective the much weaker condition is that the incremental cost be less for cogenerated than for conventional electricity production.

is lowered of the order of 12 percent versus 20 to 40 percent), the expertise and skills are available in-house, familiarity with the regulatory climate already exists, better integration into the existing generating system is possible, and more optimal plant sizes can be built because the supply and demand balance of an isolated industry would be less of a factor.

Detailed estimates based on analysis and survey of industrial and other facilities on Long Island are, of course, beyond the scope of the present conservation scenario feasibility study. Indeed, were the conservation alternative to be pursued, LILCO at an early stage would need to identify potential industrial and other sites in its service area which satisfy the cost-effectiveness criterion* -- an exercise that has not yet been done. Then, various arrangements for utility ownership, financing, and interface would need to be designed for pursuing this potential.

Utility involvement in cogeneration development has been widely recognized as having tremendous potential to increase the likely level of cogeneration potential (Refs. 34-36, 40-41). The Public Utility Regulatory Policies Act (PURPA) would probably have to be amended, as has been recommended by the Institute of Electrical and Electronics Engineers, to permit utility ownership of decentralized cogeneration systems. In the utility ownership mode, economic potential for in-plant generation has been estimated to increase by 75 percent (Ref. 34) and over 100 percent (Ref. 35). Given the current underdevelopment of the data base on cogeneration potential, it is difficult to develop hard estimates on reasonable conservation program goals. In the interest of analytic caution, the Conservation scenario is targeted to achieve extremely modest levels of cogeneration in the forecast period. Specifically, it is assumed that the fraction of industrial demand supplied via cogeneration reaches current New York State industrial fraction cogenerated by the year 2000. This is equivalent to 10 MW of cogeneration capability in-place on Long Island by 1990.** By comparison, the State Energy Office's

*In this instance, the statement of criterion is that the incremental cost of producing electricity and steam above that of producing steam alone be less than the cost of supplying an equivalent quantity of electricity from a conventional power plant.

**In terms of the reduction of central station generation requirements, cogeneration saves 69 GWH; the power equivalent is derived by assuming a generic 80 percent capacity factor.

"Proposed Case" goal is 12 MW for 1990 without the assumption of special utility involvement.

The cost-effectiveness of this investment is favorable from society's point of view. The incremental costs of installation are taken on a generic basis at $700 per KW, cautiously on the high side of the most recent estimates for New York State (Ref. 42, pp. 40 ff.). These capital costs compare favorably with the construction alternative (the Shoreham facility is now estimated to cost over $2500/KW). Incremental fuel costs are almost 2¢/KWH*. Therefore, the combined costs associated with electricity production through cogeneration is on the order of 4¢/KWH.

## 4.4 Voltage Regulation

Electrical utilities in the United States widely observe the national voltage standards of the American National Standard Institute (A.N.S.I.). The A.N.S.I. standards prescribe a service voltage range to be provided around a nominal voltage. For example, the minimum service voltage standard on a 120 volt line is 114 volts and the maximum is 126 volts for the type of service provided most residences.

Since 1974 there have been several studies and experiments designed to explore the potential for saving energy through voltage reduction. A number of these analyses are summarized in a report on voltage regulation issued by the Energy Conservation Branch of the California Public Utility Commission (Ref. 20). The energy conservation potential suggested by pertinent studies and experiments led the California P.U.C. to begin implementing voltage regulations keeping allowable service voltage on the lower half of conventional voltage ranges. Thus, on 120 volt circuits, allowable customer service voltage would be between 120 and 114 volts rather than between 126 and 114 volts. This program is referred to as the conservation voltage regulation (c.v.r.) program. We shall use the abbreviation c.v.r. here to refer to regulations keeping service voltage on the lower half of the acceptable (A.N.S.I.) range and the nominal voltage, as in California.

Studies carried out at the behest of the P.U.C. showed that energy would be saved and that appliance performance would be enhanced through decreased maintenance, longer lifetime, and, in the case of 1/4 to 1/2 horsepower electric motors, greater efficiency and a higher power factor (Refs. 20, 25, and 39).

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* Figured at an incremental heat rate (extra fuel above that required to produce steam alone in the absence of cogeneration) of about 6,000 BTU/KWH and a fuel cost of $4 per MMBTU.

The first phase of the California program is limited to distribution feeder circuits serving primarily residential and commercial customers and requiring no significant capital expenditures. The regulation is being implemented on a utility-by-utility basis. The P.U.C. staff have concluded that even though the program is only in its first phase it is already the single most effective conservation program in the state of California. Apparently the extension of the Phase I regulations alone to all utilities will result in an energy savings of up to 3 percent. The savings are not distributed evenly along the system load curve. Off-peak, they may be 5 percent or more; at daily peak, more like 1-2 percent. At annual system peak, where many circuits may be loaded at or near capacity, the P.U.C. engineers expect very small savings.

Ideally, the specific responses of major commercial and residential end-uses to a voltage reduction would be separately quantified. For most appliances, including thermostatically controlled ones, energy is reduced; for some, it is not. Examples of the latter include air conditioners operating in the hottest weather and certain small resistance loads like toasters (Ref 39). Logically, thermostatically controlled electric water heaters and resistance space heaters would not experience energy reductions, either.

The second phase of the California program involves the implementation of the c.v.r. on circuits where significant capital expenditures may be necessary for reconductoring, installation of shunt capacitors, or installation of substations to form shorter circuits. Where it is cost-effective the regulation is to be implemented. The P.U.C. criterion of cost-effectiveness is the same as that used in this scenario generally, namely, the value of the energy saved on a life cycle basis must equal or exceed the life cycle cost of the measures necessary to achieve the savings. (Ref. 25, page 67). Marginal costs are the measure for the value of energy saved. The precise energy savings portion of full implementation of cost-effective voltage regulation in California will not be known until all circuits have been assessed, but P.U.C. staff anticipate possible total program additional savings of two percent or more.

In neither Phase I nor Phase II does the California c.v.r. program presently contemplate significant voltage changes on distribution feeder circuits serving primarily agricultural or industrial loads. Industrial reduction potential exists, but some customers require no change in voltages, others regulate their high voltages internally, and in any case, more testing of the effects of industrial voltage reduction need to be undertaken.

In addition to California, Connecticut has adopted a new voltage regulation in order to conserve energy (Ref. 53). The state's utilities had operated with a voltage range somewhat more demanding than A.N.S.I.'s, one of +5 to -3 percent of nominal voltage. The regulation changed this to +3 to -5 percent of service voltage. Thus, for a 120 volt circuit, the standard is being changed from a range of 126 to 116.4 volts to one of 123.6 to 114 volts. This two percent voltage reduction regulation will not realize as great an ultimate savings as will the c.v.r. in California. By April of 1980, virtually all of the circuits of Connecticut's largest utility had been converted, as had most of those of the other major utility. Thus the bulk of the conversions have been effected. No definitive report of energy savings from this new program is available but the experience of the California tests and c.v.r. suggest that the energy savings will be at least as great as the two percent voltage reduction being implemented in Connecticut. The Connecticut order permits temporary waivers from conversion of circuits based on technical need (e.g., a very specific voltage need) or economic hardship. Some technical waivers have been granted, but no economic ones have been requested (Ref. 54). Apparently, the voltage regulation in Connecticut is not requiring major utility expenditures.

LILCO now uses voltage reduction as a peak load management method, but this is different from the systematic narrowing of the band of service voltage in order to conserve energy, i.e., it is not c.v.r. LILCO believes implementation of a c.v.r. would require technical improvements in its distribution system whose costs and benefits would need to be studied on a circuit-by-circuit basis (Ref. 55 , Response 22). The extensive experience of California, the recent experience of Connecticut, and the technical promise of energy savings have led us to program a tentative commercial/residential total energy reduction of 2.5 percent commencing in 1982. The peak savings are programmed at a tenth of that reduction. There is insufficient information to include LILCO-specific costs for the c.v.r. expenditures. Whatever they precisely are, energy savings that accumulate year after year for the lifetime of the regulating equipment (capacitors, meters) that may be required are likely to prove strongly attractive.

## 5. THE POTENTIAL FOR CONSERVATION

In Sec. 4, the measures considered as part of the conservation program alternative were introduced. They were justified on grounds of technological availability and social cost-effectiveness. In specifying the Conservation scenario, effort was made to include only reasonable end-use improvement targets and plausible phase-in periods for achievement of the targets.

In the interest of caution and realism, only a subset of available measures satisfying the cost criterion are incorporated in the Conservation scenario. Furthermore, no claim is made that the particular mix of targets selected here would emerge in every detail were a major effort launched at this time to go from the program feasibility assessment offered here to the development of a blueprint for program action. The goal of this study is thus to construct a specific plausible Conservation scenario and to determine whether implementation of that scenario would be competitive with the option of completing Shoreham. The impacts of the Conservation program in four important areas -- electricity savings, oil savings, natural gas savings, and costs -- are summarized in the sections below.

### 5.1 Electric Generation Displacement

The end-use forecasting model builds up aggregate demands in the service area from an enumeration of the physical stock and the engineering characteristics of electricity using equipment.* The model therefore has the capability of tracking the impacts of alternative forecast assumptions with precise attention to stock turnover constraints, interrelated effects of multiple conservation measure implementations, and policy phase-in assumptions. The Conservation scenario forecasts are produced by perturbing the Reference case driving variables with the adjustments of end-use demands and conservation implementation schedules indicated in the previous section.

The Conservation scenario forecasts are presented in aggregate form in Table 15 and by selected end-use classifications in Table 16. To identify Conservation scenario impacts, these results can be compared to the Reference case forecast results of Sec 3. This comparison is presented visually in Figure 5. The annual electricity savings

*The modelling approach was outlined at the beginning of Sec. 4.

TABLE 15

AGGREGATED CONSERVATION CASE

CONSERVATION SCENARIO

| LILCO | ENERGY IN GWH RESIDENT. | COMMER. | INDUSTR. | OTHER | TOTAL | PEAK POWER LOAD IN MW SUMMER | WINTER |
|---|---|---|---|---|---|---|---|
| 1978 | 5559. | 5020. | 1239. | 1901. | 13719. | 2870. | 2390. |
| 1979 | 5720. | 5140. | 1280. | 1940. | 14080. | 2930. | 2470. |
| 1980 | 5860. | 5270. | 1320. | 1980. | 14430. | 3000. | 2550. |
| 1981 | 6010. | 5390. | 1360. | 2020. | 14780. | 3050. | 2630. |
| 1982 | 5730. | 5310. | 1400. | 2040. | 14480. | 3050. | 2630. |
| 1983 | 5620. | 5140. | 1400. | 2010. | 14180. | 2980. | 2590. |
| 1984 | 5500. | 4980. | 1410. | 1990. | 13890. | 2900. | 2540. |
| 1985 | 5520. | 4840. | 1410. | 1990. | 13770. | 2860. | 2520. |
| 1986 | 5530. | 4680. | 1400. | 1970. | 13580. | 2810. | 2490. |
| 1987 | 5540. | 4520. | 1390. | 1960. | 13410. | 2750. | 2460. |
| 1988 | 5540. | 4600. | 1370. | 1980. | 13490. | 2760. | 2470. |
| 1989 | 5550. | 4680. | 1360. | 2000. | 13580. | 2780. | 2480. |
| 1990 | 5550. | 4760. | 1340. | 2010. | 13670. | 2790. | 2490. |
| 1991 | 5560. | 4840. | 1360. | 2030. | 13790. | 2810. | 2510. |
| 1992 | 5560. | 4920. | 1370. | 2050. | 13910. | 2830. | 2520. |
| 1993 | 5560. | 5000. | 1390. | 2070. | 14030. | 2840. | 2530. |
| 1994 | 5570. | 5090. | 1410. | 2090. | 14150. | 2860. | 2550. |
| 1995 | 5570. | 5170. | 1420. | 2110. | 14270. | 2880. | 2560. |
| 1996 | 5560. | 5250. | 1430. | 2140. | 14390. | 2900. | 2580. |
| 1997 | 5560. | 5340. | 1450. | 2160. | 14510. | 2920. | 2590. |
| 1998 | 5560. | 5430. | 1460. | 2180. | 14630. | 2940. | 2600. |
| 1999 | 5560. | 5510. | 1480. | 2200. | 14750. | 2960. | 2620. |
| 2000 | 5570. | 5600. | 1490. | 2220. | 14890. | 2980. | 2630. |

TABLE 16

DISAGGREGATED CONSERVATION CASE

RESIDENTIAL SECTOR

| | 1978 | 1983 | 1988 | 1993 | 1998 |
|---|---|---|---|---|---|
| 1: REFRIGERATORS | 1146. | 1229. | 1157. | 1029. | 847. |
| 2: FREEZERS | 340. | 363. | 344. | 315. | 277. |
| 3: RANGES | 257. | 281. | 298. | 312. | 324. |
| 4: LIGHTING | 798. | 559. | 438. | 454. | 471. |
| 5: TELEVISIONS | 359. | 377. | 387. | 399. | 415. |
| 6: CLOTHES DRYERS | 372. | 423. | 457. | 487. | 514. |
| 7: CLOTHES WASHERS | 68. | 72. | 75. | 78. | 81. |
| 8: DISH WASHERS | 153. | 172. | 186. | 199. | 212. |
| 9: WATER HEATERS | 239. | 269. | 261. | 263. | 282. |
| 10: ROOM A/C | 293. | 280. | 250. | 231. | 220. |
| 11: CENTRAL A/C | 245. | 269. | 271. | 282. | 298. |
| 12: SPACE HEATERS | 266. | 382. | 403. | 425. | 448. |
| 13: HEATINGAUXILIARY | 436. | 423. | 383. | 344. | 305. |
| 14: MISCELLANEOUS | 586. | 693. | 804. | 918. | 1038. |

COMMERCIAL SECTOR

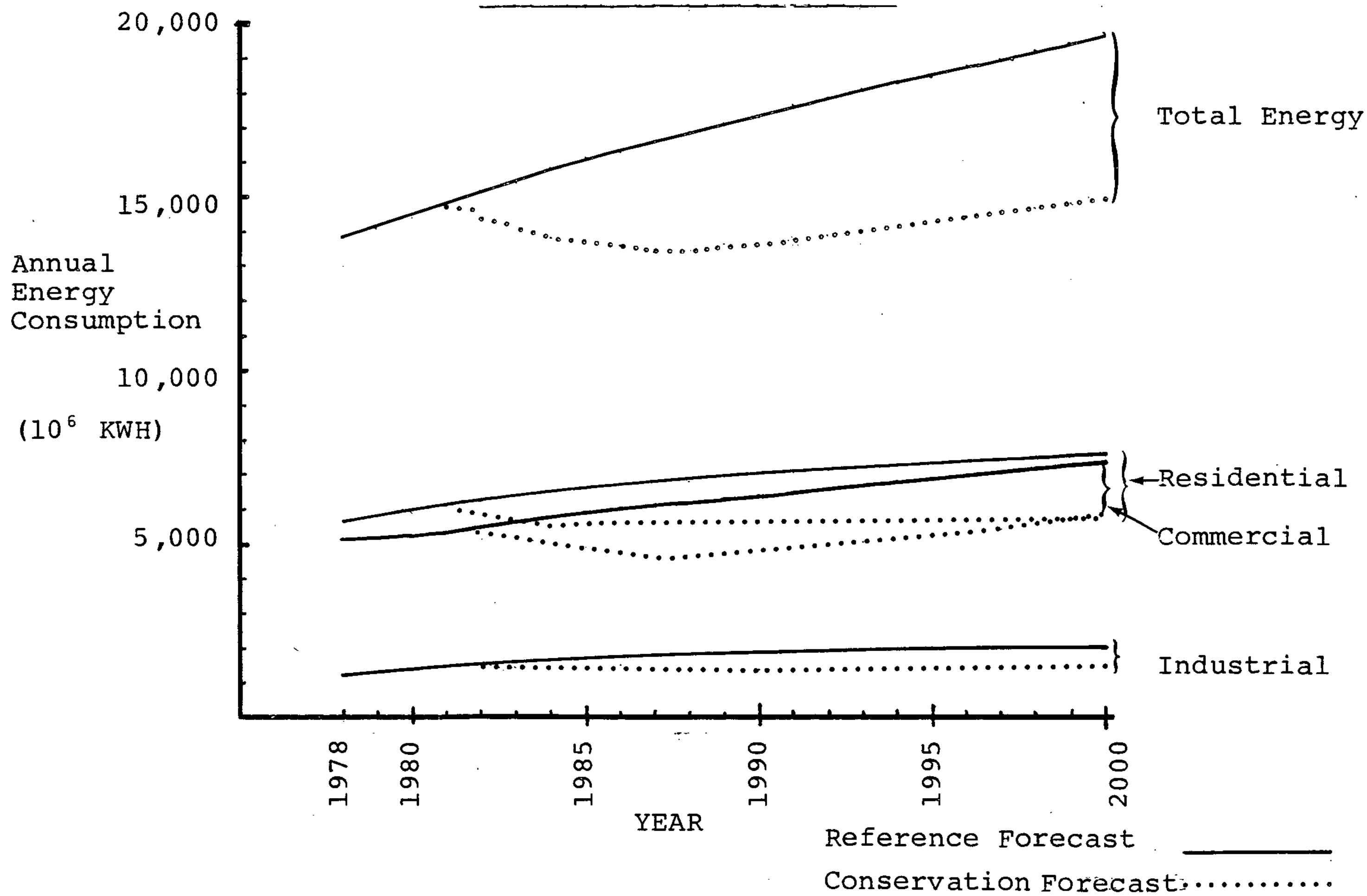
| | 1978 | 1983 | 1988 | 1993 | 1998 |
|---|---|---|---|---|---|
| 1: OFFICES | | | | | |
| 1: HEATING | 32. | 51. | 50. | 51. | 53. |
| 2: COOLING | 307. | 309. | 266. | 277. | 287. |
| 3: LIGHTING | 447. | 439. | 365. | 394. | 423. |
| 4: AUX & POWER | 378. | 445. | 448. | 537. | 633. |
| 2: RETAIL | | | | | |
| 1: HEATING | 15. | 23. | 23. | 23. | 24. |
| 2: COOLING | 302. | 320. | 304. | 316. | 328. |
| 3: LIGHTING | 1124. | 1181. | 1110. | 1156. | 1202. |
| 4: AUX & POWER | 433. | 507. | 485. | 583. | 688. |
| 3: HOSPITALS | | | | | |
| 1: HEATING | 3. | 5. | 5. | 5. | 5. |
| 2: COOLING | 51. | 49. | 39. | 39. | 39. |
| 3: LIGHTING | 137. | 138. | 126. | 128. | 130. |
| 4: AUX & POWER | 81. | 93. | 88. | 102. | 116. |
| 4: SCHOOLS | | | | | |
| 1: HEATING | 13. | 15. | 11. | 12. | 12. |
| 2: COOLING | 86. | 71. | 38. | 41. | 43. |
| 3: LIGHTING | 352. | 292. | 197. | 208. | 219. |
| 4: AUX & POWER | 226. | 212. | 139. | 165. | 192. |
| 5: OTHER | | | | | |
| 1: HEATING | 11. | 18. | 17. | 17. | 17. |
| 2: COOLING | 221. | 224. | 190. | 193. | 196. |
| 3: LIGHTING | 469. | 500. | 446. | 457. | 468. |
| 4: AUX & POWER | 334. | 409. | 392. | 455. | 520. |

INDUSTRIAL SECTOR

| | 1978 | 1983 | 1988 | 1993 | 1998 |
|---|---|---|---|---|---|
| 20: FOOD | 56. | 62. | 59. | 57. | 59. |
| 22: TEXTILES | 31. | 37. | 37. | 37. | 40. |
| 23: APPAREL | 24. | 23. | 20. | 18. | 17. |
| 24: LUMBER | 7. | 8. | 7. | 7. | 8. |
| 25: FURNITURE | 5. | 6. | 6. | 6. | 6. |
| 26: PAPER PRODUCTS | 42. | 40. | 34. | 31. | 29. |
| 27: PRINTING & PUBL. | 73. | 85. | 87. | 92. | 101. |
| 28: CHEMICALS | 61. | 57. | 46. | 37. | 29. |
| 29: PETROLEUM & COAL | 12. | 14. | 13. | 13. | 14. |
| 33: PRIMARY METALS | 43. | 51. | 50. | 50. | 53. |
| 34: FABRICAT. METALS | 68. | 71. | 66. | 65. | 66. |
| 35: MACHINERY | 102. | 117. | 118. | 124. | 135. |
| 36: ELECTRIC EQUIP. | 218. | 232. | 222. | 224. | 234. |
| 37: TRANSPORTATION | 305. | 352. | 349. | 356. | 377. |
| 30: RUBBER & PLASTIC | 59. | 80. | 88. | 98. | 112. |
| 31: LEATHER | 1. | 1. | 1. | 1. | 1. |
| 32: STONE,CLAY,GLASS | 24. | 25. | 24. | 24. | 24. |
| 38: INSTRUMENTS | 95. | 129. | 133. | 135. | 143. |
| 39: MISC. MANUFACT. | 12. | 15. | 15. | 15. | 16. |

Figure 5

ELECTRIC ENERGY FORECAST

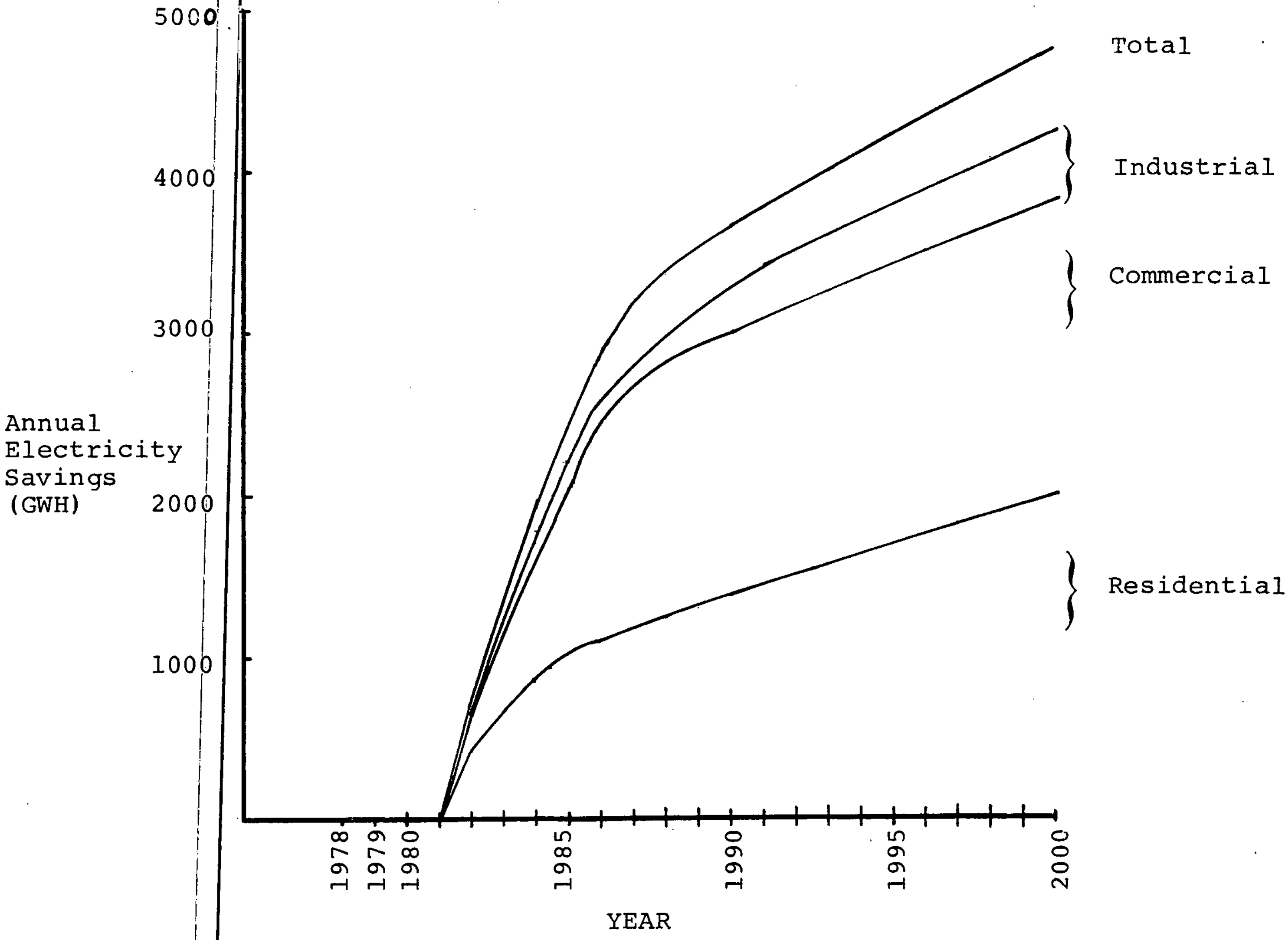



produced by the Conservation program are shown in Figure 6. The Conservation and Reference forecast comparison for annual peak load growth is depicted in Figure 7. Figure 8 charts the growing saving in peak demands in the Conservation case forecast.

The results display the gradual takeoff of conservation impacts as the measures phase in with new equipment and retrofit schedules. The figures also suggest that the savings brought about by the Conservation program will continue to increase into the next century. Consequently, the cutoff of the study time-frame at the year 2000 is likely to bias the findings on long-run cumulative savings against the Conservation scenario. Nonetheless, the cumulative electric energy displaced during the study period is substantial. This is shown in Figure 9.

Figure 6

CONSERVATION PROGRAM ANNUAL SAVINGS






E S R G

Figure 7
PEAK LOAD FORECAST COMPARISONS

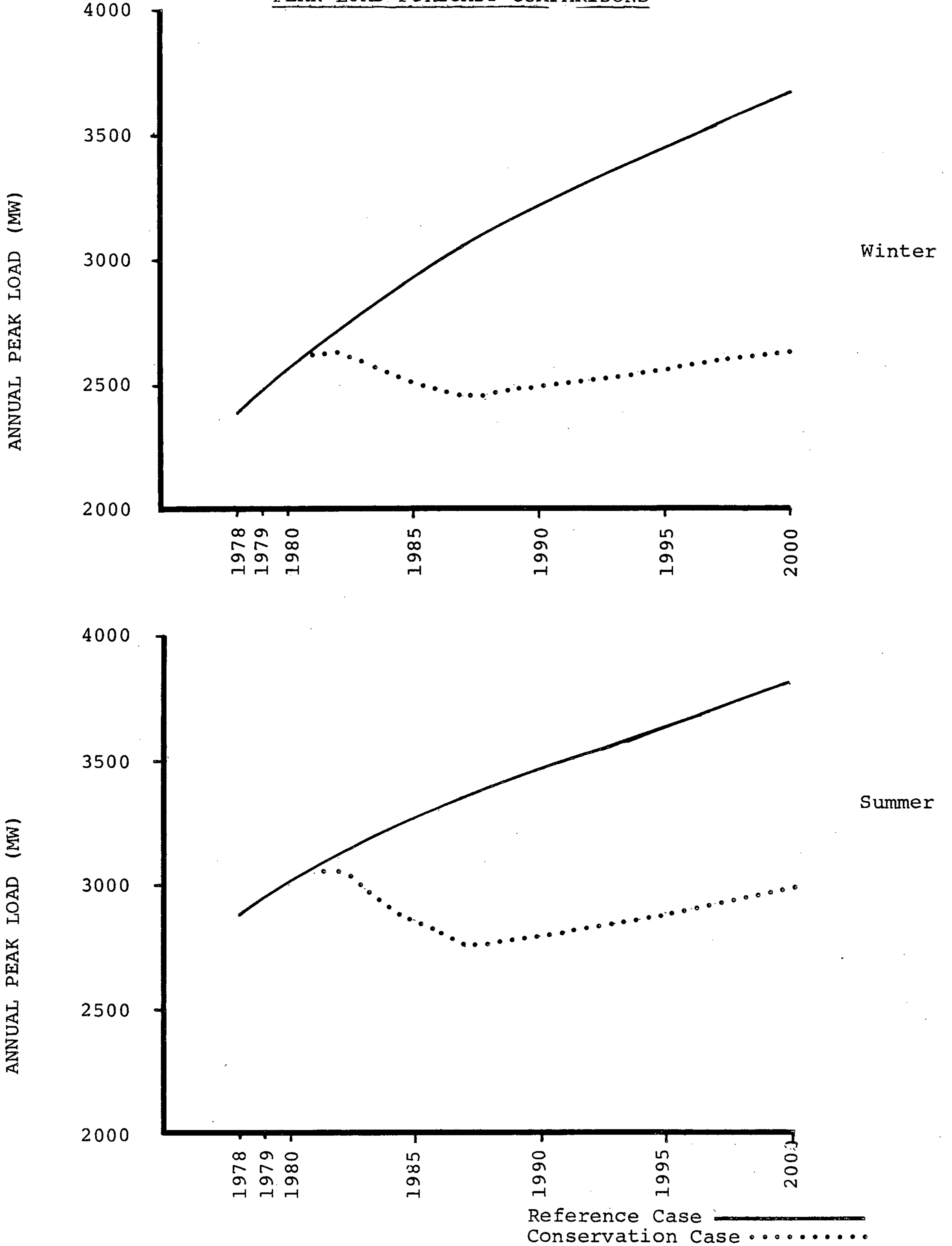
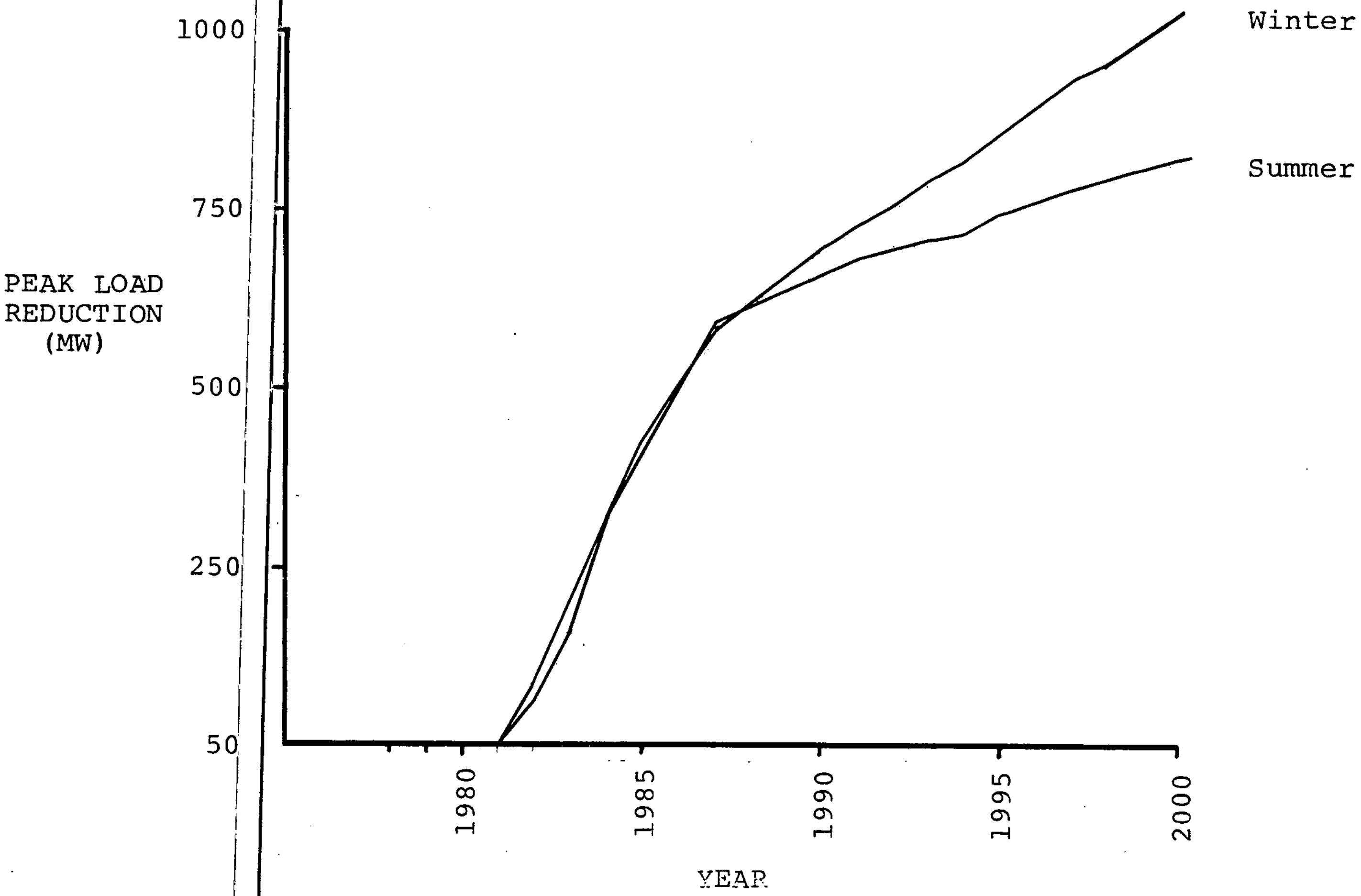


Figure 8

CONSERVATION PROGRAM PEAK LOAD REDUCTIONS




in units of million kilowatt-hours (GWH) saved and million ($10^6$) barrels.*

## 5.2 Oil Savings

The conservation measures decrease oil consumption from Reference forecast levels in two distinct ways. First, the

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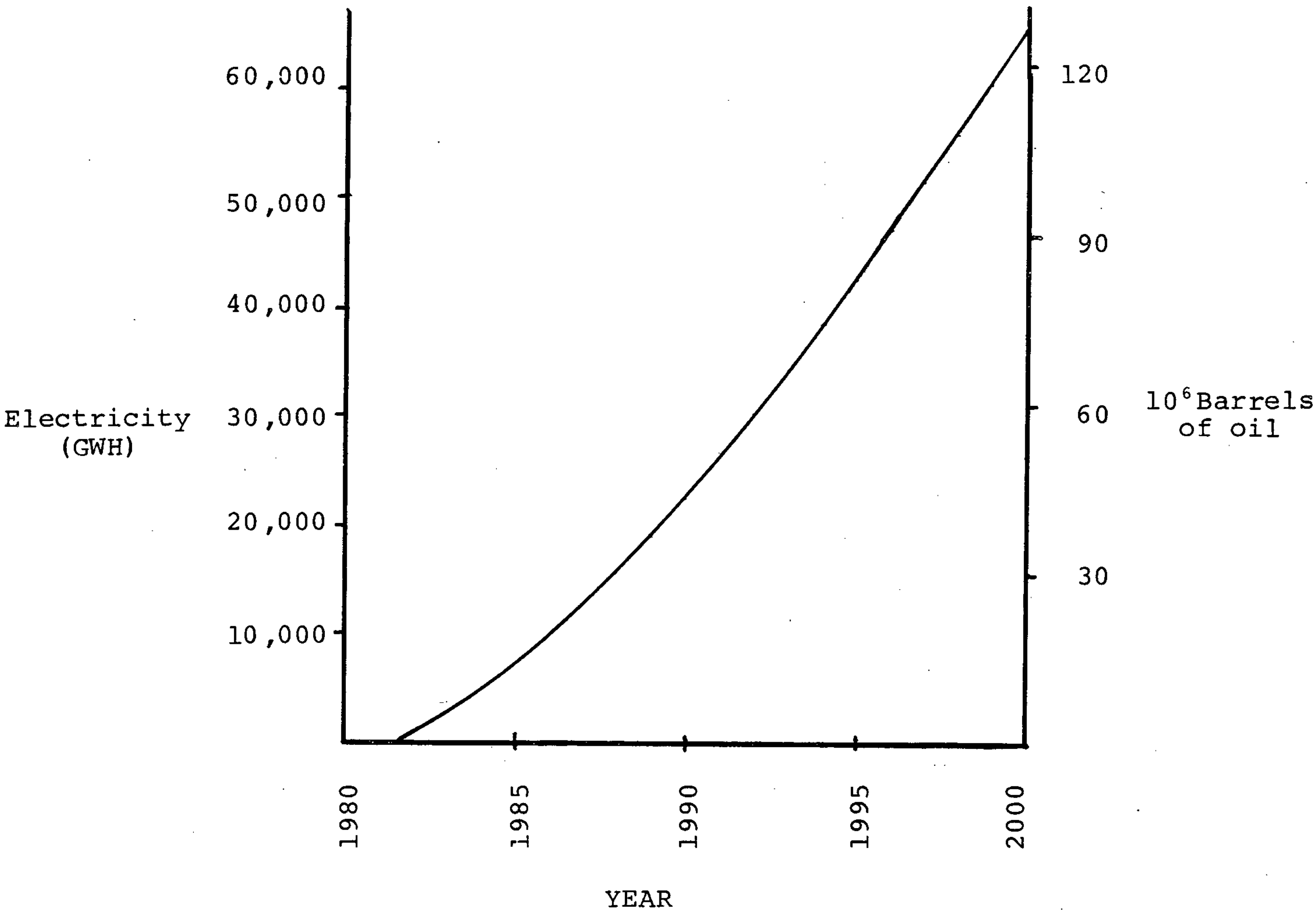
*In converting electric energy savings to primary oil displacement, the conversion efficiency of displaced oil-fired electric plants must be estimated. Expressed as a heat rate, the efficiency assumed for these studies is 12,000 BTU/KWH, and the conversion factor used is $6.227 \times 10^6$ BTU/BBL (Ref. 49). At a 60 percent capacity factor, the Shoreham plant is assumed to displace $8.6 \times 10^6$ BBL/oil in Ref. 14. This implies a heat rate for displaced plants at about the same level used here.

Figure 9

CUMULATIVE ELECTRIC GENERATION DISPLACEMENT




lower electric energy requirements imply that the least efficient generating units will at least in part be idled. In other words, the generating system will be dispatched to meet a decreased demand so that LILCO's oil-fired power plants may be run correspondingly less. The cumulative oil savings from this effect were displayed in Figure 9.

Second, the improved building characteristics and energy management practices incorporated in the Conservation measure targets would lead to decreases in oil requirements for on-site heating and hot water requirements, as discussed in Sec. 4. The computer program evaluates the impacts with respect to the Reference forecasts for on-site oil use reported in Sec. 3. Just as with the electric demand analysis, the on-site oil savings resulting from the relevant conservaton measures are computed by submodels disaggregated by building or housing type, end-use and fuel mix. In addition, the Conservation scenario includes a measure -- the ESH regulation -- that increases oil (and natural gas) usage. Buildings and homes that would have used unassisted electric resistance heating are shifted to on-site fossil fuel usage (or ESH with heat pump assist). The fossil fuel savings reported here are <u>net</u> savings reflecting this penalty.

The oil savings associated with the shift from Reference case conservation levels to the higher levels of the Conservation scenario are displayed in Table 17. Also included in the table are the savings already discussed from electric generation displacement, total annual savings, and the running cumulative total oil savings identified with the Conservation program measures.*

## 5.3 Natural Gas Savings

Since oil is the major fossil fuel used on Long Island and oil use reduction has been given national energy policy priority recently, it has received primary focus here. Nevertheless, natural gas does supply approximately 15 percent of building energy demands and should not be ignored.

Applying the end-use energy demand model to natural gas usage allows the computation of the savings resulting from the reduced requirements in the Conservation scenario relative to the Reference level demands. The Conservation measures affect oil and gas end-use usage comparably, including the penalty for the additional natural gas usage resulting from the shift induced by the conservation program away from resistance heating.** The stream of savings, not surprisingly, is similar to the building oil savings we have just seen, though on a smaller scale. The

*It should be noted that the ESRG model allows for a furnace efficiency improvement conservation measure. However, since substantial improvements in furnace performance seem to be occurring already on Long Island (<u>e.g.</u>, retrofits to retention head burners), no additional efficiency improvements are included in the Conservation scenario and no oil savings credit taken. More detailed scrutiny of the issue could reveal an additional opportunity here for oil savings.

**No measure for the gas range is included in the Conservation scenario.

TABLE 17

ANNUAL CONSERVATION CASE OIL SAVINGS ($10^6$ Barrels)

| YEAR | (1) Residential | (2) Commercial | (3)=(1)+(2) Total On-Site | (4) Generation Displaced | (5)=(3)+(4) Total Oil Savings | (6) Cumulative Oil Savings |
|---|---|---|---|---|---|---|
| 1980 | - | - | - | - | - | - |
| 1981 | - | - | - | - | - | - |
| 1982 | .1 | - | .1 | 1.3 | 1.4 | 1.4 |
| 1983 | .4 | .3 | .7 | 2.4 | 3.1 | 4.5 |
| 1984 | .6 | .6 | 1.2 | 3.7 | 4.9 | 9.4 |
| 1985 | .9 | .9 | 1.8 | 4.6 | 6.4 | 15.8 |
| 1986 | 1.2 | 1.1 | 2.3 | 5.3 | 7.6 | 23.4 |
| 1987 | 1.5 | 1.4 | 2.9 | 6.2 | 9.1 | 32.5 |
| 1988 | 1.8 | 1.3 | 3.1 | 6.5 | 9.6 | 42.1 |
| 1989 | 2.1 | 1.3 | 3.4 | 6.7 | 10.1 | 52.2 |
| 1990 | 2.4 | 1.3 | 3.7 | 7.1 | 10.8 | 63.0 |
| 1991 | 2.6 | 1.2 | 3.8 | 7.3 | 11.1 | 74.1 |
| 1992 | 2.8 | 1.2 | 4.0 | 7.5 | 11.5 | 85.6 |
| 1993 | 3.1 | 1.2 | 4.3 | 7.7 | 12.0 | 97.6 |
| 1994 | 3.3 | 1.2 | 4.5 | 7.9 | 12.4 | 110.0 |
| 1995 | 3.5 | 1.1 | 4.6 | 8.1 | 12.7 | 122.7 |
| 1996 | 3.7 | 1.1 | 4.8 | 8.4 | 13.2 | 135.9 |
| 1997 | 4.0 | 1.1 | 5.1 | 8.5 | 13.6 | 149.5 |
| 1998 | 4.2 | 1.1 | 5.3 | 8.8 | 14.1 | 163.6 |
| 1999 | 4.4 | 1.0 | 5.4 | 8.9 | 14.3 | 177.9 |
| 2000 | 4.6 | 1.0 | 5.6 | 9.2 | 14.8 | 192.7 |

cumulative natural gas savings to the year 2000 for the residential and commercial sectors are 61.0 MMBTU and 17.0 MMBTU, respectively. The total natural gas savings traced to the conservation measures is, therefore, 78.0 MMBTU (or 76.2 million cubic feet).

## 5.4 The Costs

The first analytic task in evaluating the costs of the conservation alternative to LILCO ratepayers is to compute the capital cost increments associated with the implementation of the conservation measures in the scenario. Costs per measure implementation have been discussed in Sec. 4. For the purposes of Conservation scenario capital cost calculations, a computer program was developed and coupled to the forecasting program. Its function is to compute the stream of implementations for each of the some forty conservation measures and, applying the incremental cost per measure to each implementation, to output costs of each measure over time.

We then wish to evaluate the costs of the conservation alternative in a framework that renders them comparable with the costs of completing and operating Shoreham. This framework, using the nomenclature of utility resource planning, consists of the "required revenues" for conservation program achievement. The required revenue method provides a mechanism for comparing the attractiveness of alternative projects. In this approach, the annual flow of money to support a project (depreciation, interest or return on capital investment, operations and maintenance, taxes, fuel costs) are established. To compare expenses at different points in time, these expenditures are generally brought back to present worth dollars by applying a discount rate reflecting the time value of money. For convenience, we annualize capital investments in equal installments over the life of the investment such that the cumulative present worth of the stream of such annualized investments equals the cumulative present worth of the actual time varying costs. This introduces the notion of "fixed charge rate" -- ratio of annualized to initial capital costs -- a concept which is specified mathematically in Table 18.

The costing program has been designed with a high degree of flexibility in specifying discount, inflation and interest rates and capital recovery periods. Output is disaggregated by conservation measure investment for each year (by applying the fixed charge rate (FCR) over the lifetime (L) of the investment) and reported as annual and cumulative required revenues in both current and present worth dollars. The conservation program is predicated on the development of financing programs to overcome the first cost hurdles which deter consumer purchases of cost-effective conservation items. There are a

TABLE 18

## CAPITAL COSTING METHODOLOGY

Let:

| | | |
|---|---|---|
| PWRR | = | Present worth of required revenue |
| C | = | Initial capital cost (inflated to year of investment) |
| L | = | Capital recovery period (life of loan or investment) |
| d | = | Discount rate |
| r | = | Interest rate or pre-tax rate of return |
| t | = | Year (year of investment = 0) |
| FCR | = | Fixed charge rate |

Then:

$$\text{PWRR (in year } t=0) = \sum_{t=0}^{L-1} r \times C \times (1-t/L) \times (1+d)^{-t} \quad \text{(interest on unamortized part)}$$

$$+ \sum_{t=0}^{L-1} (C/L) \times (1+d)^{-t} \quad \text{(straightline recovery of principal)}$$

By definition:

$$\text{PWRR} = \sum_{t=0}^{L-1} \text{FCR} \times C \times (1+d)^{-t}$$

Summing and simplifying:

$$\text{FCR} = r + (1/L) \times \{1 - r(a/(1-a)) - La^{L}/(1-a^{L})\}$$

where $a = 1/(1+d)$

[Note that in the special case of d=r, FCR reduces to the familiar mortgage formula.]

## TABLE 19

## CONSERVATION CAPITAL COSTS BY SECTOR

RESIDENTIAL SECTOR:

| YEAR | CURRENT DOLLARS ANNUAL | CURRENT DOLLARS CUMULATIVE | PRESENT WORTHS ANNUAL | PRESENT WORTHS CUMULATIVE |
|---|---|---|---|---|
| 1980 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1981 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1982 | 10.3 | 10.3 | 8.1 | 8.1 |
| 1983 | 28.1 | 38.4 | 19.8 | 27.9 |
| 1984 | 47.2 | 85.6 | 29.4 | 57.3 |
| 1985 | 61.0 | 146.6 | 33.9 | 91.2 |
| 1986 | 74.8 | 221.4 | 36.9 | 128.1 |
| 1987 | 89.6 | 311.0 | 39.3 | 167.4 |
| 1988 | 105.2 | 416.2 | 41.0 | 208.4 |
| 1989 | 121.9 | 538.2 | 42.2 | 250.6 |
| 1990 | 139.6 | 677.8 | 43.0 | 293.6 |
| 1991 | 158.4 | 836.2 | 43.4 | 337.0 |
| 1992 | 178.8 | 1015.0 | 43.5 | 380.5 |
| 1993 | 203.0 | 1218.0 | 43.9 | 424.4 |
| 1994 | 228.5 | 1446.5 | 43.9 | 468.3 |
| 1995 | 255.3 | 1701.8 | 43.6 | 511.9 |
| 1996 | 283.6 | 1985.4 | 43.1 | 555.0 |
| 1997 | 314.7 | 2300.1 | 42.5 | 597.5 |
| 1998 | 348.0 | 2648.1 | 41.8 | 639.3 |
| 1999 | 383.3 | 3031.4 | 40.9 | 680.2 |
| 2000 | 420.6 | 3452.0 | 39.9 | 720.1 |

COMMERCIAL SECTOR:

| YEAR | CURRENT DOLLARS ANNUAL | CURRENT DOLLARS CUMULATIVE | PRESENT WORTHS ANNUAL | PRESENT WORTHS CUMULATIVE |
|---|---|---|---|---|
| 1980 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1981 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1982 | 2.6 | 2.6 | 2.0 | 2.0 |
| 1983 | 31.1 | 33.7 | 21.8 | 23.9 |
| 1984 | 60.4 | 94.1 | 37.7 | 61.6 |
| 1985 | 90.3 | 184.4 | 50.1 | 111.7 |
| 1986 | 121.0 | 305.4 | 59.7 | 171.4 |
| 1987 | 153.1 | 458.5 | 67.1 | 238.5 |
| 1988 | 152.5 | 611.0 | 59.4 | 297.9 |
| 1989 | 151.8 | 762.8 | 52.6 | 350.5 |
| 1990 | 151.1 | 913.9 | 46.5 | 397.1 |
| 1991 | 150.4 | 1064.3 | 41.2 | 438.2 |
| 1992 | 149.5 | 1213.8 | 36.4 | 474.6 |
| 1993 | 148.6 | 1362.4 | 32.1 | 506.8 |
| 1994 | 147.7 | 1510.1 | 28.4 | 535.2 |
| 1995 | 146.7 | 1656.8 | 25.1 | 560.2 |
| 1996 | 145.6 | 1802.4 | 22.1 | 582.3 |
| 1997 | 144.5 | 1946.9 | 19.5 | 601.8 |
| 1998 | 143.3 | 2090.1 | 17.2 | 619.0 |
| 1999 | 142.0 | 2232.1 | 15.1 | 634.2 |
| 2000 | 140.6 | 2372.7 | 13.3 | 647.5 |

INDUSTRIAL SECTOR:

| YEAR | CURRENT DOLLARS ANNUAL | CURRENT DOLLARS CUMULATIVE | PRESENT WORTHS ANNUAL | PRESENT WORTHS CUMULATIVE |
|---|---|---|---|---|
| 1980 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1981 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1982 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1983 | 0.9 | 0.9 | 0.6 | 0.6 |
| 1984 | 1.9 | 2.8 | 1.2 | 1.8 |
| 1985 | 3.1 | 5.9 | 1.7 | 3.6 |
| 1986 | 4.4 | 10.3 | 2.2 | 5.7 |
| 1987 | 5.8 | 16.1 | 2.6 | 8.3 |
| 1988 | 7.4 | 23.5 | 2.9 | 11.2 |
| 1989 | 9.2 | 32.7 | 3.2 | 14.3 |
| 1990 | 11.2 | 43.9 | 3.4 | 17.8 |
| 1991 | 11.6 | 55.5 | 3.2 | 21.0 |
| 1992 | 12.1 | 67.6 | 2.9 | 23.9 |
| 1993 | 13.6 | 81.2 | 2.9 | 26.8 |
| 1994 | 15.2 | 96.4 | 2.9 | 29.8 |
| 1995 | 17.1 | 113.5 | 2.9 | 32.7 |
| 1996 | 19.1 | 132.7 | 2.9 | 35.6 |
| 1997 | 21.4 | 154.1 | 2.9 | 38.5 |
| 1998 | 23.9 | 178.0 | 2.9 | 41.4 |
| 1999 | 26.7 | 204.6 | 2.8 | 44.2 |
| 2000 | 29.7 | 234.4 | 2.8 | 47.0 |

TOTAL CURRENT DOLLAR EXPENDITURES: 6059.05
TOTAL CUMULATIVE PRESENT WORTH EXPENDITURES: 1414.60

COSTS ARE EXPRESSED IN MILLIONS OF DOLLARS.
DISCOUNT RATE: 12.5% INFLAT.: 8.0% CAPITAL: 12.0%
PRESENT WORTHS ARE DISCOUNTED BACK TO 1980$ USING THE DISCOUNT RATE.

number of promising financing strategies which would have somewhat different impacts on interest rates, capital recovery periods and so on. Since we do not wish to prejudge the precise institutional arrangements, the costs have been computed using generic fixed charge rates.

Measure-specific output is too voluminous for presentation here. Instead, we offer summary running costs by major demand sector in Table 19. Note the financial assumptions: inflation at 8 percent, interest at 12 percent, discount rate at 12.5%*, and capital recovery periods taken as equipment lifetime or twenty years for building improvements. These will be taken as the axiomatic set of financial assumptions for further cost comparison. Based on this, we see from the table that the conservation capital-related investment PWRR is $1414.60 million dollars.

It is also of interest to test for sensitivity against variation in financial assumptions. Selected sets of assumptions are presented with resultant PWRR values in Table 20 for comparison.

Although our primary goal is to determine how the conservation investment strategy competes against the Shoreham completion strategy, a word about conservation cost attractiveness on its own terms is in order. The major terms in the computation are shown in Table 21. Based on the capital cost and fuel savings trade-offs there is a net benefit of over $4 billion dollars over the next twenty years. Other factors not included in this simple cost/benefit exercise are:

- Income tax credits to conservation investments,
- Credit for avoided power plant construction cost,
- Any penalty for the administration and management of the conservation program,
- Indirect economic benefits, (e.g., higher employment) for dollars spent in the local economy rather than exported and
- Credit for continued savings in the post-2000 period.

The first calculation leads to an inescapable conclusion: the conservaton implementation program on its own merits holds the promise of saving Long Island energy users billions of dollars. The more difficult and subtle analytical problem concerns which of two strategies (that both displace large amount of oil) is more advantageous: implementation of the conservation program or completion of the Shoreham plant.

*In conformity with Refs. 14-16.

TABLE 20

PRESENT WORTH OF REQUIRED REVENUE RELATED TO CONSERVATION CAPITAL: SENSITIVITY TO ALTERNATIVE FINANCIAL ASSUMPTIONS*

| Discount Rate* (%) | Interest Rate (%) | Capital Recovery Period | PWRR ($10^6$ 1980 $) |
|---|---|---|---|
| 12.5 | 9.0 | ** | $1216.88 |
| 12.5 | 12.0 | 20 | 1354.53 |
| 12.5 | 12.0 | ** | 1414.60 |
| 12.5 | 12.0 | 15 | 1450.41 |
| 12.5 | 12.0 | 10 | 1521.29 |
| 11.5 | 12.0 | ** | 1547.91 |
| 12.5 | 15.0 | ** | 1612.33 |
| 12.5 | *** | 1 | 1681.64 |

* Inflation rate taken at 8% throughout. Row 3 represents assumptions used in this study.
** Equipment lifetime/20 years for building improvements
*** No financing in this case

TABLE 21

CONSERVATION CASE COST TRADEOFFS TO 2000

| | PWRR ($\times 10^6$) |
|---|---|
| Capital Costs | \$(1,415) |
| Residual Oil (1) | |
| $126 \times 10^6$ BBL × \$20/BBL | \$ 2,520 |
| $67 \times 10^6$ BBL × \$42/BBL | 2,814 |
| Natural Gas | |
| $76 \times 10^9$ c.f. × \$4.75/MCF (2) | 361 |
| Net Savings (3) | \$4,280 million |

Notes

(1) 1980 LILCO Average (Ref. 52, p. 41). Fossil fuel costs are for simplicity assumed to escalate at the discount rate (or 4.5% real). By comparison, the NYS Master Plan (Ref. 23) quotes real growth rates of 4.4% natural gas (Ex. Summary, p.13) and 4.6% for oil (Appendix, p.92).

(2) From 1979 LILCO average costs (Ref. 22) escalated at national rate to 1980 estimate.

(3) Not included: conservation investment tax credit, reliability or power plant capital cost credit for decreased electric demand, conservation program cost penalty.

## 6. THE TRADEOFFS

We now wish to join the issue. Which scenario is preferable, investing in the prototype conservation program as designed above and abandoning the partially completed Shoreham facility or completing the Shoreham facility as currently intended by LILCO? Recall that these are posed as oppositional under the assumption that LILCO's severe capital raising constraints render unrealistic the pursuit of both simultaneously.

In the review of issues in Sec. 2, the important trade-offs were identified. They concern relative fuel savings, comparative capital costs, electric system reliability, and various qualitative issues. Our findings are summarized here.

### 6.1 Oil Consumption

The oil savings resulting from the conservation program were reported in Sec. 5.2. The Shoreham facility would also save oil by substituting nuclear generation for oil-fired generation. The cumulative oil savings comparison between the two investment strategies is displayed graphically in Figure 10.

Our assumptions concerning Shoreham are summarized at the bottom of the figure. Size and capacity factor assumptions are consistent with LILCO assumptions (Refs. 14-16).* The in-service date is of course uncertain at this time. The Company has offered three in-service date scenarios -- early 1983, late 1983, and mid-1984 -- dependent in part on favorable disposition by the Public Service Commission of its request for additional electric rate increases. Other analysis has indicated that delays of six months to a year from Company estimates are to be expected (Ref. 12). The in-service date assumed here (January 1, 1984) appears to be reasonable for purposes of this study.

Figure 10 shows that the likely levels of oil displacement for the two scenario options are indistinguishable to 1988. After that time, the conservation approach begins to dominate. The structure of these curves reflects the different characteristics of the scenario. The impact of the Shoreham plant is immediate while that of the conservation stream builds up slowly

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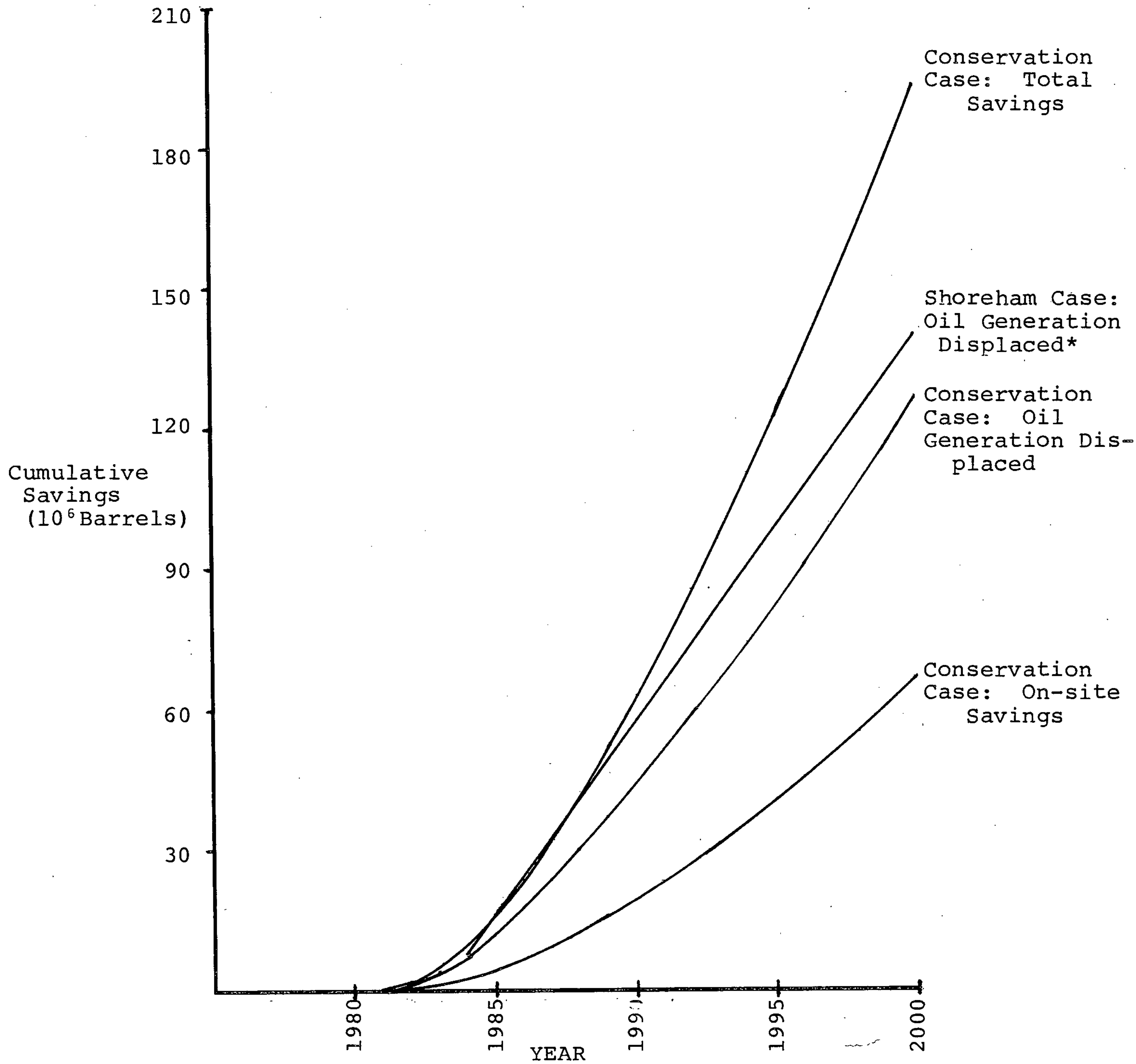
*The Company uses two capacity factor scenarios: 50/60 percent and 60/70 percent, respectively, where the first value applies to the first four years of operation and the second value thereafter. Other statistical research suggests 53% for the Shoreham type of reactor (BWR) with no maturation (Ref. 44).

Figure 10

COMPARATIVE OIL SAVINGS




* Assumptions:

Size: 813 MW
Inservice Date: 1/1/84
Capacity Factor: 60%
Displaced Oil Heat Rate: 12000 BTU
Heat Content: $6.227 \times 10^6$ BTU/Bbl.

with the turnover and retrofit of existing equipment. Indeed, the conservation impacts are still at the take-off phase at the end of the study time frame. By the year 2000, the cumulative difference is about 53 million barrels of oil.

## 6.2 Cost

The major categories for the scenario cost comparisons have been identified in Sec. 2 (See Table 4). Table 24 presents the benefits and costs for capital and fuel-related factors. The conservation side costs have already been discussed in Sec. 5.4. The treatment of Shoreham costs is summarized in notations to Table 22. Shoreham completion costs remain an area of uncertainty (see Table 3). The Company's current prognosis is $2.4 and $2.7 billion for 1983 and mid-1984 in-service dates, respectively (Ref. 18, p.4). Our choice of $2.5 billion for the January 1, 1984 in-service date should be viewed as an illustrative estimate. As Table 24 reveals, conclusions are not sensitive to second order variations in this assumption. Furthermore, although the costs of cancellation in the conservation scenario are charged fully to ratepayers in the cost comparison, the financial disposition of the abandonment would have to be deliberated through the proper PSC forum.* Insofar as responsibility for the investment in an abandoned plant would be charged to stockholders (or split between stockholders and ratepayers in some fashion), the cancellation costs charged to the conservation alternative would need to be suitably adjusted.

The table indicates a benefit of over $3 billion for the Conservation alternative. Roughly speaking, the capital related costs are comparable (with full ratepayer responsibility for the cancellation), while the conservation approach saves considerably more fuel.

A number of costs and benefits have not been included in the table. Other significant conservation benefits include the avoided costs of Shoreham operations and maintenance (about $30 million/year), decommissioning, property taxes, and insurance. On the conservation cost side are the incurred costs of conservation equipment maintenance, the lost local property tax income from Shoreham, and (perhaps most significantly) the costs associated with developing and administering the conservation program itself. (This last issue is addressed in Ref. 13.)

The detailed refinements of the various other impacts seem unnecessary at this point. The conservation alternative has large economic advantages; the net benefits are measured in billions of dollars to Long Island ratepayers.

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*No specific policy recommendation is proposed in this study.

TABLE 22

PWRR OF CONSERVATION BENEFITS AND COSTS TO 2000 AS ALTERNATIVE TO COMPLETION OF SHOREHAM ($10^6$ $ 1980)*

| | BENEFITS | COST |
|---|---|---|
| Capital Related (1) | | |
| Avoided Cost of Shoreham | $2100 | - |
| Conservation Equipment Investment (2) | - | $1400 |
| Cost of Shoreham Cancellation (3) | | 700 |
| Fuels Related | | |
| Electric Generation - Oil (4) | - | 300 |
| - Nuclear Fuel (5) | 300 | |
| Direct Oil | 2800 | - |
| Direct Gas | 400 | - |
| | $5600 | $2400 |
| Net Benefit ≅ 3.2 billion | | |

* Costs rounded to nearest $100 million

(1) Based on $2.5 billion capital cost, 1984 ISD and 17% fixed charge rate.

(2) See Sec. 5.4

(3) Based on $1500 million cancellation charge (Ref. 15), amortized over 20 years net of income tax write-off of non-AFUDC part (75%), and full pre-tax recovery from ratepayers.

(4) Cost represents difference between oil fired generation displaced by Shoreham and conservation ($14\times10^6$ BBL) priced at $20/BBL (see Sec. 5.4).

(5) Based on $35 million in 1984 escalated at general rate of inflation.

## 6.3 System Reliability

The system reliability features of the two scenarios are comparable. In the Conservation case, the reserve margin (capacity in excess of annual peak load) remains above 25 percent throughout the study period with existing equipment. This is comfortably in excess of the reliability target of 18 percent reserve. Indeed, by 2000, the conservation measure has reduced system peak by 820 MW or slightly more than the power which Shoreham is designed to supply.

## 6.4 Other Factors

A number of other differing impacts of the two options were introduced in Sec. 2, and we return to them here. The indirect impacts of the conservation investments on the local economy seem far superior to the power plant construction alternative (Refs.10, Vol. III; 21; 24). The environmental externalities also seem *a priori* favorable: the lower levels of fuel combustion should pass through to improved air quality conditions, while whatever deleterious human health implications of nuclear production may emerge are avoided. At the same time, the possibility of nuclear accident or policy induced extraordinary down time is not a factor.

## 6.5 Conclusion

Implementation of a conservation program such as we have outlined here requires a coordinated and serious redirection of energy development strategy on Long Island. We have shown that on grounds of technology availability, scarce fuel savings, cost attractiveness, and long term system reliability a conservation alternative to completing Shoreham is not only feasible, but is far superior. The question for policymakers remains: will the conservation alternative be foreclosed or vigorously pursued at this time? On the basis of this investigation, the latter course is indicated.

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# APPENDIX A

## THERMAL INTEGRITY IMPROVEMENTS

## RESIDENTIAL HEATING AND COOLING MODEL

# APPENDIX A

## THERMAL INTEGRITY IMPROVEMENTS
## RESIDENTIAL HEATING AND COOLING MODEL

A simple model is used to calculate annual electricity and fuel consumption for prototypical residential structures with different thermal integrity levels. In addition to calculating the amount of fuel used as thermal integrity levels are increased, the model is able to compute (1) the incremental dollar costs of increasing thermal integrity from one level to the next, (2) the incremental annual dollar fuel savings, and (3) simple payback (years to recovery of incremental investment through the stream of resultant annual energy savings). The overall structure of the model is depicted in the following flow chart (Figure A.1).

At the present time the model computes the fuel consumption consequences of thermal integrity characteristics for three prototypical structures adapted from a study by Daifuku (Ref. A.1). Two of the prototypes are employed for this study. These are a single-family unit of 1600 square feet and multifamily structures containing 10 units of some 1000 square feet each (and some public space). In addition, units can be treated separately as a function of primary space heating source (electricity, oil, gas, or other).

Input data used in the model includes the physical characteristics of these prototypes, design heating and cooling loads, region-specific climatic data, the efficiency of fuel use by heating and cooling systems, fuel prices, and the costs of energy-conserving thermal integrity improvement measures in the prototypes.

The annual heating demand of the building is calculated by the following equation:

$$H_D = \frac{H_L \times DD \times 24 \times C_D}{\Delta T}$$

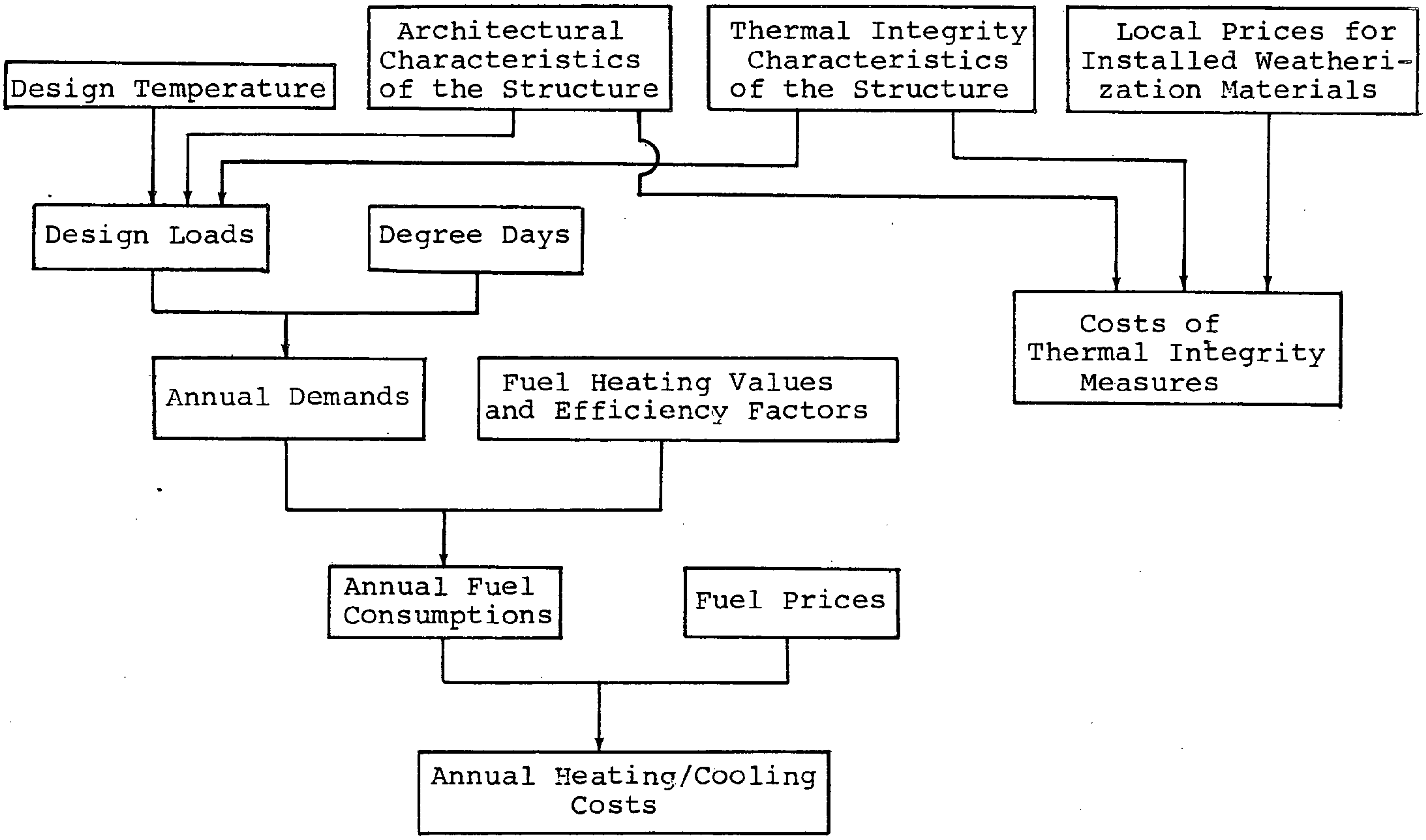
where:

| | | |
|---|---|---|
| $H_D$ | = | Annual Heating Demand (Btu) |
| $H_L$ | = | Design Heating Load (Btu/hour) |
| DD | = | Heating Degree Days* |
| 24 | = | Hours in the day |
| $C_D$ | = | Correction factor for heating effects vs. degree days (from Ref. A.2) |
| $\Delta T$ | = | Winter design temperature difference (°F) for space heating |

*Heating degree days constitute the summation of the number of degrees by which the mean outdoor temperature is less than 65° F for every day in the year.

Figure A.1

STRUCTURE OF RESIDENTIAL HEATING AND COOLING MODEL



The annual fuel use for space heating is calculated by the following equation:

$$\text{Fuel use} = \frac{H_D}{N \times HV}$$

where $H_D$ = Annual heating demand

$N$ = Heating system correction factor for rated full load efficiency, part load performance, oversizing, and energy conservation devices (from Ref. A.2)

$HV$ = Heat value of the fuel

The design heating load, upon which both of the above equations depend, must itself be initially computed as the sum of (1) the heat loss due to infiltration of outdoor air and (2) the heat transmitted through the building envelope. The relevant equations follow:

1. Infiltration Heat Loss (Btu/hr) = $I \times V \times .018 \times \Delta T$

where: $I$ = infiltration rate (air changes per hour)
$V$ = volume of building (cubic feet)
$.018$ = density × specific heat of air (Btu/cubic foot °F)
$\Delta T$ = temperature difference (°F)*

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*The $\Delta T$ (used for the ceiling, walls, windows, doors, and infiltration calculations) is the difference between the living space temperature and the outdoor design temperature and the basement temperature. The basement is assumed to be unheated except by heat lost from the furnace and ducts in the case of fossil fuel systems. The basement temperature is calculated by this equation:

$$T_B = \frac{T_A U_B + (1+F) T_L U_F + F [T_L - T_A) U_L - G]}{U_B + (1+F) U_F}$$

where:

$T_B$ = basement temperature

$T_A$ = outdoor design temperature

$T_L$ = living space temperature

$U_B$ = Btu/hr. °F lost from the basement (including infiltration)

$U_L$ = Btu/hr. °F lost from the living space (including infiltration)

$U_F$ = Btu/hr. °F transferred through the floor

$F$ = % heat delivered to basement/% heat delivered to living space

$G$ = Internal heat gains

2. Transmission Heat Loss (Btu/hr) = U × A × ΔT

where: U = coefficient of transmission (Btu/hr-$ft^2$-°F)

A = area ($ft^2$)

ΔT = temperature difference (°F)

The procedure for calculating the fuel use for summer cooling assumes the use of central air conditioning. The total design cooling load is the sum of five separate sources of heat gain: heat transmitted through opaque materials, heat gain through windows, heat gain due to infiltration, internal heat gains, and latent heat gains.

The cooling load calculation for opaque materials includes the ceiling, walls, and doors. The U-value of the component is multiplied by its area and the appropriate design equivalent temperature difference from ASHRAE (Ref. A.2, Ch. 25, Table 35). The U-value used for the ceiling includes the effects of the ceiling, the attic space, and the roof. Values for the "effective resistance" of attics are listed in Ref. A.2 (Table 6, Ch. 22).

The heat gain through the windows is a combination of transmitted heat and solar radiation. The orientations and shading levels of the windows are taken from Ref. A.1. For each direction and level of shading the glass area is multiplied by the appropriate heat gain factor from Ref. A.2 (Table 36, Ch. 25). The infiltration/ventilation load for summer is calculated by the same equation used for the calculation of the winter infiltration load. The part of the cooling load due to occupancy is estimated using available data for residential electric use for appliances. The cooling load due to latent (humidity) gains is estimated to be 25 percent of the sensible cooling load.

Using the calculated design cooling load, the annual cooling demand of the building is calculated by the following equations;

$$\text{Cooling demand} = \frac{C_L \times DD \times 24}{\Delta T}$$

where: $C_L$ = design cooling load (Btu/hr.)

DD = cooling degree days (°F-days)*

24 = hours per day

ΔT = summer design temperature differences (°F)

The number of kilowatthours used annually for cooling is calculated by the following equation:

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*Cooling degree-days are the summation of the number of degrees Farenheit that the mean outdoor temperature is more than 65° F for each day of the year.

$$KWH = \frac{C_D}{3413 \times COP}$$

where:

$C_D$ = Annual cooling demand (Btu)

3413 = Btu per kilowatt hour

COP = Air conditioners' coefficient of performance

A summary of the architectural characteristics of the prototypical units is given in Table A.1. The subsequent table (Table A.2) lists other input data (climatic and thermal). Some additional input data may be found in the discussion of thermal integrity levels which follows Tables A.1 and A.2.

TABLE A.1

ARCHITECTURAL CHARACTERISTICS OF RESIDENTIAL PROTOTYPES

| Area ($ft^2$) | SF Structure | MF Structure |
|---|---|---|
| Total floor | 1,610 | 10,260 |
| Single floor | 805 | 5,130 |
| Ceiling | 805 | 5,130 |
| Wall | 1,806 | 5,790 |
| Windows | 242 | 1,080 |
| Doors | 40 | 50 |
| Basement above grade | 158 | 416 |
| Basement windows | 16 | 103 |
| Basement below grade | 580 | 1,730 |
| Volume ($ft^3$) | | |
| Living space | 14,490 | 102,600 |
| Basement | 5,233 | 33,345 |

TABLE A.2

CLIMATIC AND THERMAL INPUT DATA FOR RESIDENTIAL PROTOTYPES

| Parameter and Measurement Unit | SF Structure | MF Structure |
|---|---|---|
| Internal gains (Btu/hour) | 2,590.0 | 11,300.0 |
| Winds factor (Btu/hour/$ft^2$) | 27.5 | 20.5 |
| HDD (Heating Degree Days) | 5,415.0 | 5,415.0 |
| CF for heating effect VS. HDD | .75 | .75 |
| Winter design temperature (°F) | 12.0 | 12.0 |
| Winter living space temperature (°F) | 70.0 | 70.0 |
| Cooling degree days | 740.0 | 740.0 |
| Air conditioner C.O.P. | 2.75 | 2.75 |
| Effective attic resistance (R) | 3.1 | 3.1 |
| Design equivalent temperature difference: | | |
| Vertical | 18.6 | 18.6 |
| Horizontal | 39.0 | 39.0 |
| Summer design temperature (°F) | 90.0 | 90.0 |
| Fuel heating values: | | |
| Oil (Btu/gallon) | 144,000.0 | 144,000.0 |
| Electricity (Btu/kwh) | 3,413.0 | 3,413.0 |

## THERMAL INTEGRITY LEVELS, COSTS, AND BENEFITS

Given any particular configuration of weatherization characteristics (insulation, fenestration, weatherstripping, constituting a "thermal integrity level") the model computes fuel use for heating and cooling the prototypes as described above. In addition, once fuel prices and installed weatherization component prices are inputted, it computes annual fuel bills and the total capital costs of providing the given thermal integrity level.

A prototype with better weatherization characteristics (a higher thermal integrity level) can then be compared with a baseline prototype dwelling. The model computes the annual energy costs for the improved prototype, the incremental costs of the additional thermal integrity, and the dollar amount of annual energy saved due to the thermal integrity improvements. Simple payback for the movement from the baseline to the improved level of thermal integrity is then computed. "Payback" refers to the period (in years) required to recover the capital costs of the improved weatherization through the stream of annual energy savings.*

Any number of thermal integrity levels may be developed and payback calculated relative to each previous level. In this study, we have developed three levels for various of our prototypes. In all cases, the baseline level (Level I) represents estimated average Long Island thermal integrities in the base year.** Level II represents a "business-as-usual" or Reference case thermal integrity level. For new homes, this means construction to current building code or local building practice thermal integrity levels (whichever are higher). For existing

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*At this point in the development of the model, no adjustments to this simple payback are made, a practice which may be quite realistic if we assume that fuel prices will increase at roughly the discount rate. These paybacks are, at any rate, only rules of thumb for selecting conservation measures. The component costs (including maintenance, if any, which is not included in this model), properly discounted, are added up in the cost analysis model for the conservation scenarios as a whole.

**Base year insulation levels were estimated by consulting the state insulation survey (Ref. A.3), the Long Island jobs study (Ref. A.4, Appendix B), and making inquiries of local contractors. Given the range of uncertainty as to the precise level that obtains, the same Level I weatherization characteristics were used to describe MF and SF units. (There is, of course, a significant difference between electrically heated and fossil heated homes at Level I.)

homes, a Level II is designed that represents a weatherization retrofit that will place the structure at the same performance level as required of new structures by the state code.

Level III was designed to represent thermal integrity improvements (relative to Level II) that are consistent with the criteria for this Conservation scenario. Levels II and III and the accompanying energy and cost analyses were not developed for existing electrically heated residential buildings. These buildings represent a very small fraction of the base year housing stock. Moreover, they are relatively well insulated (Ref. A.7, Response 5). However, Levels II and III were developed for all other housing types used in this study (SF and MF, electrically heated and fossil heated).

For the cost analysis, we used $1.00 per gallon as the fuel oil price, 6¢/kwh as the winter electricity price, and 8¢/kwh for electricity during the summer. For new buildings, the price of installed weatherization measures were obtained from the "Means Cost" catalogue (Ref. A.5). This catalogue contains regional adjustment factors for prices. For the SF prototype, the catalogue prices were inflated by 15 percent, since the catalogue prices are designed for medium scale (or larger) construction projects. The catalogue cannot be used for those costs that are distinctive to the retrofitting process (primarily putting insulation in the walls of existing structures); to obtain such costs inquiries were made of Long Island contractors. Weatherization characteristics and costs for the three thermal integrity levels are given in Table A.3. Essential detail regarding the entries in the table is contained in the notes thereto.

In Table A.4, we summarize the heating and cooling demand, fuel use, and fuel costs at the three thermal integrity levels. The data are the annual results computed by our model for the SF and MF prototypes.

In Table A.5, we summarize the savings and paybacks associated with the movement from Level I to Level II or Level III. The magnitude of the incremental savings is striking, as are the reasonable payback periods. For new retrofitted oil heated homes, a higher weatherization level than that now recommended by the utility is clearly justified. For an incremental energy savings of 20 percent (Level III compared to the Reference level, assuming central air conditioning as well as electric space heating) the simple payback period is but 5.6 years (without cooling it would be 6.1 years). Note that this is the very highest payback of the six conservation level prototypes (SF and MF; electric (new), oil (new), and oil (retrofitted)). Clearly, constructing a conservation scenario around the conservation levels

TABLE A.3

THERMAL INTEGRITY LEVELS AND PRICES FOR RESIDENTIAL PROTOTYPES*

| Building Type and Level | Variable | Building Characteristic: Ceiling | Wall | Window | Door | Floor | Basement: Above | Basement: Window | Basement: Below | Infiltration (A.C./hour) |
|---|---|---|---|---|---|---|---|---|---|---|
| New Electrically Heated Home | | | | | | | | | | |
| Level I (existing) | Thermal value | 19 | 11 | 2 | 2.5 | 7 | 2 | .9 | 5 | .92 |
| | Price | .39 | .28 | 3.43 | – | .18 | – | – | – | – |
| Level II (Reference) | Thermal value | 30 | 11 | 2 | 3 | 11 | 5 | 2 | 5 | .75 |
| | Price | .49 | .28 | 3.43 | – | .28 | .33 | 3.43 | – | – |
| Level III (Conservation) | Thermal value | 38 | 19 | 3 | 4 | 19 | 8 | 2 | 11 | .5 |
| | Price | .72 | .39 | 4.44 | – | .39 | .67 | 3.43 | .67 | – |
| New Oil Heated Home | | | | | | | | | | |
| Level I (Existing) | Thermal value | 8 | 5 | 1.7 | 2 | 0 | 2 | .9 | 5 | 1.03 |
| | Price | .20 | .13 | 3.09 | – | – | – | – | – | – |
| Level II (Reference) | Thermal value | 30 | 11 | 2 | 3 | 11 | 2 | 2 | 5 | .75 |
| | Price | .49 | .28 | 3.43 | – | .28 | – | 3.43 | – | – |
| Level III (Conservation) | Thermal value | 38 | 19 | 3 | 4 | 19 | 5 | 2 | 5 | .50 |
| | Price | .72 | .39 | 4.49 | – | .39 | .33 | 3.43 | – | – |
| Retrofitted Oil Heated Homes | | | | | | | | | | |
| Level II (Reference) | Thermal value | 8 | 5 | 1.7 | 2 | 0 | 2 | .9 | 5 | 1.03 |
| | Price | .20 | .22 | 3.09 | – | – | – | – | – | – |
| Level III (Conservation) | Thermal value | 19 | 8 | 2 | 3 | 11 | 2 | .9 | 5 | .83 |
| | Price | .39 | .35 | 3.43 | – | .28 | – | – | – | – |

*Notes. For ceiling, wall, and floor values only, R-values represent only the insulation.

Infiltration is measured in air changes per hour (AC/hour). The infiltration rates given in the table are for winter. For summer ventilation rate used was 1 AC/hr.

The prices listed are for multifamily construction for the detached single-family prototype, prices greater by 15 percent were used. Prices are in $1980/ft.$^2$. Window prices represent reduction in losses due to transmission and infiltration.

TABLE A.4

TOTAL WEATHERIZATION COSTS AND FUEL USE FOR RESIDENTIAL PROTOTYPES AT THREE THERMAL INTEGRITY LEVELS*

| Building Type and Thermal Integrity Level | | Annual Heating Energy Requirements MMBTU | Gallons | $ 1980 | Annual Cooling Energy Requirements MMBTU | KWH | $ 1980 |
|---|---|---|---|---|---|---|---|
| OIL HEATED: | | | | | | | |
| Level I | SF | 72.1 | 835 | 835 | 35.6 | 3,776 | 302 |
| (Existing) | MF | 371.1 | 4,295 | 4,295 | 156.5 | 16,604 | 1,328 |
| Level II | SF | 55.8 | 646 | 646 | 31.9 | 3,388 | 271 |
| (Retrofit) | MF | 284.6 | 3,295 | 3,295 | 139.3 | 14,781 | 1,182 |
| Level II | SF | 50.1 | 579 | 579 | 30.4 | 3,221 | 258 |
| (New) | MF | 254.5 | 2,945 | 2,945 | 132.1 | 14,017 | 1,121 |
| Level III | SF | 41.5 | 480 | 480 | 30.0 | 3,180 | 254 |
| (Retrofit) | MF | 206.6 | 2,391 | 2,391 | 130.2 | 13,819 | 1,105 |
| Level III | SF | 35.4 | 410 | 410 | 28.7 | 3,050 | 244 |
| (New) | MF | 177.4 | 2,053 | 2,053 | 126.3 | 13,400 | 1,072 |
| ELECTRICALLY HEATED: | | MMBTU | KWH | $ 1980 | MMBTU | KWH | $ 1980 |
| Level I | SF | 56.4 | 16,531 | 992 | 31.1 | 3,302 | 264 |
| (Existing) | MF | 293.7 | 86,126 | 5,168 | 136.5 | 14,485 | 1,159 |
| Level II | SF | 50.4 | 14,783 | 887 | 30.4 | 3,221 | 258 |
| (New) | MF | 255.0 | 74,782 | 4,487 | 132.1 | 14,017 | 1,121 |
| Level III | SF | 35.6 | 10,435 | 626 | 28.7 | 3,050 | 244 |
| (New) | MF | 177.7 | 52,118 | 3,127 | 126.3 | 13,400 | 1,072 |

* MF structure has 10 dwelling units, each accounting on the average for 1/10 of building consumption. Cooling calculations assume central air conditioning.

TABLE A.5

ANNUAL SAVINGS ASSOCIATED WITH IMPROVED THERMAL INTEGRITY LEVELS AND PAYBACK PERIODS FOR INCREMENTAL WEATHERIZATION INVESTMENTS

| Building Type and Levels Compared | | Incremental Weatherization Investment ($ 1980) | Winter Savings | | | | Summer Savings | | | | Total Savings | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gallons | $ 1980 | Percent | Payback (Years) | KWH | $ 1980 | Percent | Payback (Years) | $ 1980 | Percent | Payback (Years) |
| Oil Retrofit, Level II vs Level I | ·SF | 808 | 189 | 189 | 22.6 | 4.28 | 387 | 31 | 10.26 | 26.07 | 220 | 19.33 | 3.68 |
| | ·MF | 3566 | 1001 | 1001 | 23.3 | 3.56 | 1823 | 146 | 11.0 | 24.45 | 1147 | 20.39 | 3.11 |
| New Oil, Level II vs Level I | ·SF | 1006 | 256 | 256 | 30.6 | 3.94 | 555 | 44 | 14.7 | 22.67 | 300 | 26.38 | 3.36 |
| | ·MF | 4555 | 1350 | 1350 | 31.4 | 3.37 | 2587 | 207 | 15.6 | 22.01 | 1557 | 27.7 | 2.93 |
| Oil Retrofit, Level III vs Level II | ·SF | 1019 | 166 | 166 | 25.8 | 6.12 | 208 | 17 | 6.2 | 61.10 | 183 | 20.0 | 5.56 |
| | ·MF | 4433 | 903 | 903 | 27.4 | 4.91 | 962 | 77 | 6.5 | 57.58 | 980 | 21.9 | 4.52 |
| Oil Retrofit, Level III vs Level I | ·SF | 1827 | 355 | 355 | 42.5 | 5.14 | 596 | 48 | 15.8 | 38.33 | 403 | 35.4 | 4.53 |
| | ·MF | 7999 | 1904 | 1904 | 44.3 | 4.20 | 2785 | 223 | 16.8 | 35.90 | 2127 | 37.8 | 3.76 |
| New Oil, Level III vs Level II | ·SF | 881 | 170 | 170 | 29.3 | 5.19 | 171 | 14 | 5.3 | 64.28 | 184 | 21.9 | 4.80 |
| | ·MF | 3583 | 892 | 892 | 30.3 | 4.02 | 616 | 49 | 4.4 | 72.64 | 941 | 23.2 | 2.81 |
| New Oil, Level III vs Level I | ·SF | 1887 | 425 | 425 | 51.0 | 4.44 | 726 | 58 | 19.2 | 32.49 | 484 | 42.5 | 3.90 |
| | ·MF | 8138 | 2242 | 2242 | 52.2 | 3.63 | 3203 | 256 | 19.3 | 31.75 | 2498 | 44.4 | 3.26 |
| | | | KWH | $ 1980 | Percent | Payback | KWH | $ 1980 | Percent | Payback | $ 1980 | Percent | Payback |
| New Electric, Level II vs Level I | ·SF | 311 | 1748 | 105 | 10.6 | 2.96 | 81 | 7 | 2.5 | 47.75 | 111 | 8.9 | 2.79 |
| | ·MF | 1529 | 11344 | 681 | 13.2 | 2.25 | 468 | 37 | 3.2 | 40.79 | 718 | 11.4 | 2.13 |
| New Electric, Level III vs Level II | ·SF | 1326 | 4348 | 261 | 29.4 | 5.08 | 171 | 14 | 5.3 | 96.72 | 275 | 24.0 | 4.83 |
| | ·MF | 4736 | 22664 | 1360 | 30.3 | 3.48 | 616 | 49 | 4.4 | 96.03 | 1409 | 25.1 | 3.36 |
| New Electric, Level III vs Level I | ·SF | 1636 | 6096 | 366 | 36.9 | 4.47 | 253 | 20 | 7.7 | 80.95 | 386 | 30.7 | 4.24 |
| | ·MF | 6264 | 34009 | 2041 | 39.5 | 3.07 | 1085 | 87 | 7.5 | 72.17 | 2127 | 33.6 | 2.94 |

described in Table A.4 is cautious, it is well within the rule-of-thumb cost benefit criterion and does not represent exhaustion of the economically attractive (let alone technically feasible) conservation potential.

Some of the data on heating energy reductions in Table A.5 is used directly in the Conservation scenario forecast. Consider, for example, a new electrically heated home. For a new SF or MF unit, the Reference case winter percent savings (11 percent) are used directly to reduce unit kwh usage for heating. Then, in the Conservation case, the Level III to Level I percentage reduction (37 percent) is substituted for the Reference case unit reduction. The effective conservation reduction is the difference between Level II and Level III, or 29 percent. The same procedure is used for new oil-heated homes. Not only is fuel usage directly reduced in an analagous fashion, but the usage of the electric heating auxiliaries of the fossil heating system are reduced in direct proportion to the oil reduction. The basis for the working assumption of direct proportionality between the electrical and fossil energy use is a formula for auxiliaries in Ref. A.6 (Ch. 43).

For oil retrofits, the heating calculation involves two steps. In the Reference case the retrofit assumptions are that 50 percent of SF units and 25 percent of MF units attain the prototype reduction attained from going from Level I to Level II. The reductions thus attained, on average, are:

- SF: $22.6 \times .50 = 11.3$ percent
- MF: $23.3 \times .25 = 5.8$ percent

The resulting reductions are phased in linearly from zero to the full reduction (11 or 6 percent) at the end of the forecast period. They are applied to both oil fuel unit usage and the associated kwh annual usage. Then, in the Conservation case, higher retrofit assumptions are applied to greater thermal integrity improvements. In the Conservation case, we assume that due to conservation program implementation all existing oil heated homes are retrofit by the end of the forecast period (we assume no shift from oil to gas, because supply constraints and deregulation may erode its temporary advantage over the long run), 50 percent to Level II and the rest to Level III, for a weighted average reduction (relative to Level I) of 33 percent. Again, this is phased in linearly over twenty years and applied both to the fuel oil usage and the associated kwh usage.

The cooling load model gives the impact of thermal integrity improvements upon central air conditioning usage for the six housing type/heating fuel combinations discussed above. The reductions in usage by new central air conditioners in the Reference and Conservation cases were taken from the Table A.5 entries for new electric units (Level II versus Level I and Level III versus Level I, respectively). The percentage reductions relative to existing units are 2.5 and 7.6 (SF) and 3.2 and 7.5 (MF) for the Reference and Conservation cases, respectively. The heuristic assumption is that new central air conditioners will be located in new electrically heated homes. This is extremely cautious, as base year saturations of central air conditioning are considerably greater than base year electric heat saturations. In reality, some new central air conditioning will be in fossil-heated homes, new or retrofitted to higher thermal integrity levels.

The higher thermal integrity levels associated with a new oil-heated home were used to estimate reductions in new room air conditioner usage. The percentage reductions (taken from Table A.5) are 14.7 (SF) and 15.6 (MF) in the Reference case, and 19.2 (SF) and 19.3 (MF) in the Conservation case. (As indicated in the text, savings due to new equipment efficiencies are treated separately.)

In terms of savings, the effects of thermal integrity improvements on heating fuel use are much more important than their effects on cooling savings. Within the cooling area, the thermal integrity improvements for new units (summarized in the preceding paragraph) are much more important than linearly phased in improvements for existing air conditioners. Nevertheless we estimated modest Conservation scenario reductions in unit usage for existing cooling systems; the incremental conservation gain ranged from some 2 1/2 percent for central air conditioning in SF units to 11 percent for existing room units in MF dwellings.

The thermal integrity improvements in new and retrofit gas-fuel SF and MF dwellings were taken from the analysis for oil-fueled dwellings above. All parameters except heating system efficiency and fuel price are the same for gas and oil, and the short paybacks for oil mean that even if gas were to retain its present price advantage, a situation that in the long run is quite unlikely, our conservation (Level III) improvements are justified within the framework of the social cost criterion.

## APPENDIX A

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APPENDIX B

RESIDENTIAL EQUIPMENT EFFICIENCY IMPROVEMENTS

## APPENDIX B

## RESIDENTIAL EQUIPMENT EFFICIENCY IMPROVEMENTS

The following table presents a summary of the equipment prototypes used in computing the incremental energy savings and unit price increases between Reference and Conservation efficiency levels. For appliances covered in the D.O.E. engineering analysis, referred to in the text of Sec. 4, energy savings were computed on the basis of a change from the efficiency rating targeted for 1980 in the old F.E.A. appliance program to the efficiency rating proposed as a 1986 minimum standard by the D.O.E. in June of 1980 (Ref. B.1). These appliances are: refrigerator, freezer, air conditioner, electric oven and clothes dryer. The savings achieved by the prototypical appliances used in the D.O.E. analysis were assumed likely to characterize average savings for the given type of appliance, as the prototypes are close to the average capacity of new appliances being sold currently. (The D.O.E. engineering analysis demonstrates that significant savings are achievable for the array of diverse subtypes of appliances, e.g., manual defrost refrigerators, refrigerators with automatic defrost and bottom freezers, etc., with different volumes.)

The D.O.E. analysis gives costs at several efficiency levels, making it possible to develop the incremental price increase from the 1980 F.E.A. target efficiency to the 1986 D.O.E. proposed minimum efficiency through interpolation. The costs for the improved central air conditioner are based on a split system of 30,000 Btu/hour cooling capacity. For a dwelling unit in a multifamily structure, a much smaller system is likely to be required. Therefore, our Conservation scenario cost program uses 50 percent of the SF increment, or $130, in computing the incremental costs per MF unit.

Before analyzing the improvements that are not based primarily on the D.O.E. analysis (i.e., those for heat pumps, water heaters, plumbing fixtures, and lighting), it would be useful to reproduce, in Table B.2, some data on energy consumption and retail price across a range of appliance efficiency levels. These data were developed by Arthur D. Little, Inc. (ADL), the consultants for the D.O.E. engineering analysis referred to in Sec. 4.1. The table is reproduced without its footnotes from the ADL report (which constitutes the Pacific Gas and Electric Company assessment of conservation potential referenced in Sec. 4.1).

The measures of efficiency for refrigerators, freezers, air conditioners, electric ovens, and clothes dryers in Table B.2 are defined for those appliances in Table B.1. For these (and

TABLE B.1

INCREMENTAL UNIT ANNUAL ENERGY SAVINGS AND UNIT RETAIL COSTS FOR NEW RESIDENTIAL EQUIPMENT AT CONSERVATION EFFICIENCY LEVELS

| Appliance | Class and/or Capacity | Efficiency | Energy Savings | Price Increment |
|---|---|---|---|---|
| Refrigerator | Automatic defrost, 17 cubic feet | 8 $ft^3$/Kwh per day | 34% | $24 |
| Freezer | Manual defrost, 15 cubic ft. chest | 18.7 $ft^3$/Kwh per day | 49% | $17 |
| Air conditioner | Room unit, 8,500 Btu/hour | 9.5 Btu/ watt-hour | 16% | $41 |
| Air conditioner (SF) | Central system, 30,000 Btu/hour | 10.8 Btu/ watt-hour | 26% | $268 |
| Heat pump (SF) | 38,900 Btu/hour at 47° F | Coefficient of Performance=3 | 25% | $543 |
| Electric oven | Non-microwave, 3.9 cubic feet | 13.7% useful cooking output per energy input | 2% | $2 |
| Clothes dryer | Electric, 6.5 cubic feet | 3 pounds/ kwh | 8% | $16 |
| Water heater | Electric or fossil, 50 gallons | - | 5% | $0 |
| Plumbing fixtures | Two faucets and one showerhead combined | - | 36% | $10 |
| Light bulb | Incandescent, 100 watt | 30 lumens per watt | 48% | $5 |

TABLE B.2

CONSERVATION OPTIONS RELATED TO RESIDENTIAL OPTIONS

| Product Type | Class | Capacity | Efficiency | Yearly Energy Consumption | Average Retail Price (1980) |
|---|---|---|---|---|---|
| Refrigerator | Top-Mount Automatic Defrost | 18 Cubic Feet | 4.5 | 1666 kWh | $ 530 |
| | | | 5.0 | 1484 | $ 533 |
| | | | 5.5 | 1352 | $ 540 |
| | | | 6.4 | 1165 | $ 548 |
| | | | 7.3 | 1021 | $ 555 |
| | | | 8.2 | 909 | $ 558 |
| | | | 10.4 | 716 | $ 580 |
| Freezer | Chest Freezer | 15 Cubic Feet | 11.8 | 749 kWh | $ 350 |
| | | | 14.6 | 604 | $ 355 |
| | | | 16.1 | 550 | $ 357 |
| | | | 18.7 | 471 | $ 361 |
| | | | 22.5 | 393 | $ 375 |
| Water Heater | Gas | 40 Gallon | 47.5% | 366 therms | $ 171 |
| | | | 58.7 | 296 | $ 176 |
| | | | 61.2 | 284 | $ 188 |
| | | | 63 | 276 | $ 197 |
| | | | 86 | 202 | $ 312 |
| | Electric | 52 Gallon | 77 | 6621 kWh | $ 143 |
| | | | 85 | 5998 | $ 145 |
| | | | 89 | 5728 | $ 153 |
| | | | 92 | 5572 | $ 158 |
| | | | 93 | 5482 | $ 162 |
| | | | 140 | 3641 | $ 350 |
| Furnace/Boiler | Gas Forced Air Indoor | 100,000 BTU/HR | 65% | 1217 therms | $ 356 |
| | | | 68 | 1155 | $ 405 |
| | | | 72 | 1099 | $ 408 |
| | | | 76 | 1034 | $ 456 |
| | | | 81 | 970 | $ 521 |
| | | | 94 | 836 | $ 750 |
| Central A/C | Split System | 30,000 BTU/HR | 7.0 | 4286 kWh | $1125 |
| | | | 8.5 | 3529 | $1181 |
| | | | 9.2 | 3261 | $1236 |
| | | | 10.4 | 2882 | $1313 |
| | | | 11.1 | 2710 | $1453 |
| | | | 14.0 | 2143 | $1553 |
| Room A/C | 6,000 - 20,000 BTU/HR | 8,500 BTU/HR | 6.5 | 981 kWh | $ 330 |
| | | | 7.3 | 871 | $ 337 |
| | | | 8.6 | 737 | $ 372 |
| | | | 9.1 | 701 | $ 370 |
| | | | 9.5 | 670 | $ 389 |
| | | | 12.1 | 527 | $ 421 |
| Clothes Dryers | Gas | 6.5 Cubic Feet Drum Capacity | 2.38 | 481 therms | $ 225 |
| | | | 2.58 | 385 | $ 230 |
| | | | 2.67 | 372 | $ 240 |
| | | | 2.72 | 365 | $ 248 |
| | Electric | 6.5 Cubic Feet Drum Capacity | 2.65 | 1099 kWh | $ 183 |
| | | | 2.87 | 1015 | $ 189 |
| | | | 2.98 | 977 | $ 199 |
| | | | 3.03 | 961 | $ 207 |
| Ranges/Ovens | Electric Oven Standard | 3.9 Cubic Feet Oven Cavity | 11.3 | 417 kWh | $ 200 |
| | | | 12.0 | 392 | $ 201 |
| | | | 13.6 | 346 | $ 212 |
| | | | 14.1 | 334 | $ 216 |
| | | | 14.2 | 332 | $ 222 |
| | Gas Oven Standard | 3.9 Cubic Feet Oven Cavity | 3.6 | 45 therms | $ 200 |
| | | | 4.0 | 40 | $ 211 |
| | | | 5.4 | 30 | $ 234 |
| | | | 6.4 | 25 | $ 247 |
| | | | 6.5 | 25 | $ 256 |

the other) products described in Table B.2, several efficiency levels are listed in order of increasing efficiency. The proposed 1986 standards for the consumer products of the indicated class and capacity are at or near the penultimate efficiency listed. The final level represents the best technology likely to be available by 1985 or soon thereafter. The retail prices for the "best technology" levels, unlike the other prices listed, are based on limited rather than mass-production assembly. While they therefore do not incorporate any capital costs of manufacturer retooling, as do the other retail prices, they nevertheless suggest the possibility that higher levels of efficiency than those targeted here are in fact cost-effective.

ESRG did not employ the A.D.L./D.O.E. analysis in targeting higher efficiency levels for water heaters, heat pumps, plumbing fixtures, and lighting. For heat pumps, we examined independent studies (Refs. B.2, B.3). They show that heat pumps with relatively high efficiencies are becoming commercially available. Improved compressor efficiencies, larger heat exchangers, lower valance point, and new defrost control are some of the changes involved. They can increase coefficients of performance (COPs) by 15 to 25 percent over conventional systems. Related COPs are available at over 3.0, compared to a nominal value of 2.4 used in the Reference forecast. Replacing a heat pump that has a COP of 2.4 at standard testing conditions with one having a COP of 3 would reduce annual energy by 25 percent, or some 1500 kwh per year in a single-family home.

The installed costs of an electric heat pump under commercial development (high efficiency I)) relative to a standard heat pump were obtained from a study by Gordian Associates (Ref. B.3, p.228) for a New Hampshire location, and scaled up to 1980 dollars, yielding an incremental cost for a prototypical SF home of $543. No New York location was used in Ref. B.3, but the incremental installed costs for the "high efficiency I" system in Philadelphia were estimated to be considerably less than for the New England location, so using an incremental price figure of $543 seems cautious. ESRG developed the estimate for a multifamily unit by adapting the Gordian analysis to a heat pump design large enough to serve our prototypical MF dwelling building.

For water heaters, we did not target an increase in the efficiency of the water heater _per se_ beyond the 1980 F.E.A. target levels (_e.g._, 94 percent efficiency for an electric heater with a 52 gallon tank). Rather, we posited a reduction in the factory setting of the thermostat from 140° F to 130° F. The F.E.A. test temperature and assumed setting in the 1980 targets program was 145° F. In an energy and cost analysis of hot water heaters, Hoskins and Hirst found that a 10° F reduction in the setting yielded a 5 percent savings (Ref. B.4). It is thus cautious to take 5 percent as the annual savings implied by this essentially costless measure, implying a reduction of some 7 gallons of fuel oil (for an oil-fired heater) or some 170 kwh (for an electric heater) over a year.

Lighting is treated somewhat differently from the other appliances in the Conservation scenario. Due to the rapid turnover in electric lamps, especially in the incandescent market, energy efficiency improvements can rapidly begin to substantially reduce electricity demanded for lighting.

More energy-efficient lamps, especially incandescents or those intended to replace incandescents, tend to cost from three to ten times as much as conventional bulbs. They are, and/or are expected to be, cost-effective over their lifetimes with respect to replaced bulbs. Assume that measures are developed to promote efficiency in lighting. A vigorous promotion of low-energy electric lamps, by state programs, and/or through mandated utility information dissemination, could produce rapid penetration of new low-energy lamps.

Energy savings are targeted to be at levels consistent with the more efficient bulb being developed by the Duro-Test Corporation under contract with the Massachusetts Institute of Technology (Ref. B.5). This bulb is being developed now for marketing within a year (Ref. B.6). It will replace a conventional 100 watt bulb and consume approximately 50 percent of the energy (i.e., it will be rated at 40 to 60 watts). The net incremental cost of the bulb (over the three shorter-lifetime conventional bulbs it would replace) is anticipated to be $5.00. The cost of saving the electrical energy comes out to about 2¢ per kwh over bulb lifetime. The Conservation scenario assumes a vigorous promotion campaign beginning in 1982 and building toward a target of a fifty percent reduction with respect to base year levels due to efficient bulb penetration. Compared to the Base Case, which builds toward a total lighting energy reduction per household of 5 percent with respect to base year levels by the end of the forecast period, projected savings in the Conservation scenario are substantial. In using the fifty percent figure, we assume that, while some consumers do not purchase energy-efficient lamps, like the Duro-Test prototype, the promotion policy would tend to stimulate the interest of others in higher-priced but longer-life and even more highly energy-conserving lamps, such as the General Electric "Electronic Halarc" or "Circlite" lamps.

Plumbing fixture standards for new fixtures are assumed implemented in the Conservation scenario. They apply to faucets and showerheads. The standards utilized here are those now in effect in California. According to the California Energy Commission (CEC), substantial hot water demand reductions will be achieved (Ref. B.7). Forty-four percent of hot water for showers will be saved and twenty-nine percent of faucet hot water. Daily use will be reduced from 26.8 to 17.1 gallons per day, or thirty-six percent overall.

Cost increments are minimal, at about $10 more for a set of three fixtures. The model uses resultant hot water savings to reduce electricity for heating hot water. Approximately ten percent of plumbing fixtures are replaced each year. Standards are assumed to be effective in 1982 with new fixtures phased in over the subsequent ten years.

Due to insufficient analysis being available to date, additional efficiency improvements for remaining appliances (clothes washer, dishwasher, TV, etc.) are not incorporated in this scenario. Socially cost-effective options may exist, but we have not endeavored to quantify them.

## APPENDIX B

## REFERENCES


B.1 Department of Energy, "Energy Conservation Program for Consumer Products," Proposed rule. Federal Register, vol. 45, no. 127, June 30, 1980, pp. 43976-44087.

B.2 J.E. Christian, Unitary Air-to-Air Heat Pumps, ANL/CES/TE 77-10, Argonne National Laboratory; July, 1977.

B.3 Heat Pump Technology, Gordian Associates, Inc. (for the DOE), National Technical Information Service #HCP/M2121-01; June, 1978.

B.4 Robert A. Hoskins and Eric Hirst, Energy and Cost Analysis of Residential Water Heaters. Oak Ridge, Tennessee: Oak Ridge National Laboratory, Report ORNL/CON-10; June, 1977.

B.5 "Light Dawns -- And A Better Bulb Emerges," Science Digest; March, 1978.

B.6 Communication from Paul Wasdyke, Sales Engineering Manager, Duro-Test Corporation, North Bergen, New Jersey.

B.7 California Appliance Efficiency Program, Revised Staff Report Relating to Space Heaters, Storage Type Water Heaters, and Plumbing Fixtures. Sacramento: California Energy Commission, Report 100-6; November, 1977.

# APPENDIX C

## COMMERCIAL SECTOR CONSERVATION MODEL

## APPENDIX C

## COMMERCIAL SECTOR CONSERVATION MODEL

The general structure of the model was summarized in Figure 3 of the text. This appendix is "restricted" to a discussion of the treatment of conservation in the two scenarios. The interested reader will find a complete explication of the commercial model in Ref. 10.

As mentioned in Sec. 4.2, the basic structure employed in simulating energy use for each building type/vintage combination is to decompose consumption into floorspace square footage times use per square foot. It is the latter factor (which we call "intensity") which concerns us, for measures of economic activity (such as active floorspace) are assumed to be the same for the Reference and Conservation scenarios.

As shown in the lower two rows of boxes of Figure 3, the evaluation of intensities involves two phases: first, a specification of initial values of demand coefficients (defined as average annual consumption of a given BT/EU/ service territory combination); second, an estimation of conservation penetration. We shall discuss these two phases sequentially.

Average energy demands by end-use and building types have been adapted from the "theoretical building loads" developed for the Department of Energy by Arthur D. Little, Inc. (Ref. C.1). The study combined engineering design parameters and survey research to arrive at estimates of average building requirements for each of the EU/BT combinations treated in the commercial model. The adaptation of the relevant regional building loads to demands by service territory requires the adjustment of weather sensitive loads to the prevailing climatic conditions. Adjustments for Long Island are based on heating and cooling degree day values of 5415 and 740, respectively. The intensity estimates are shown in Table C.1.

The computation of forecast year intensities is described in Table C.2. Electric intensities are, by definition, the product of the saturation (fraction of floorspace with end-use) and the electrical use coefficients (average annual kwh/ft$^2$ of floorspace with end-use). Note that the intensities are specified by 4 end-uses and 10 building types. In practice, however,

TABLE C.1

COMMERCIAL ENERGY INTENSITIES

| | Heating Electric (KWH/SQ FT) | Heating Fossil (KBTU/SQ FT) | Cooling (KWH/SQ FT) | Lighting KWH/SQ FT) | Aux.&Power (KWH/SQ FT) |
|---|---|---|---|---|---|
| Existing | | | | | |
| Offices | 9.01 | 150. | 5.94 | 7.00 | 5.30 |
| Retail | 4.06 | 82. | 6.72 | 18.20 | 6.40 |
| Hospital | 9.60 | 131. | 7.62 | 17.60 | 9.40 |
| Schools | 8.12 | 160. | 5.04 | 7.60 | 4.40 |
| Other | 4.65 | 80. | 6.72 | 10.00 | 6.40 |
| New | | | | | |
| Offices | 12.77 | 96. | 4.13 | 7.00 | 4.40 |
| Retail | 6.34 | 52. | 4.52 | 18.20 | 5.90 |
| Hospital | 15.64 | 84. | 3.49 | 17.60 | 8.80 |
| Schools | 11.58 | 103. | 3.49 | 7.60 | 3.50 |
| Other | 6.93 | 52. | 2.58 | 10.00 | 5.90 |

TABLE C.2
ELECTRIC ENERGY INTENSITIES

Indices

| | |
|---|---|
| t | Year (1975 = 1) |
| i | Commercial end-use (i = 1 to 4) |
| k | Building type (k = 1 to 5) |
| n | Existing or new buildings (n = 1 to 2) |
| m | Conservation levels (m = 1 to 3) |

Variables

| | |
|---|---|
| INTEN | Electrical intensity (average annual $KWH/FT^2$) |
| EUC | Electrical use coefficient (= INTEN with all saturations = 1) |
| SAT | Saturation (fraction floorspace with end-use) |
| PEN | Market fraction ("penetration") |
| PIMP | Fractional energy savings (i,k,n) at given conservation level (Table 4.5) |
| PENSUM | Fractional energy decrease |
| HPFRAC | Fraction new electrically heated buildings |
| COP | Heat pump coefficient of performance |
| AUPFAC | Fractional increase of terminal year auxiliary and power intensity over base year |

Equations

From definitions:

$$EUC_{t,i,k,n} = (1 - PENSUM_{t,i,k,n}) \times EUC_{1,i,k,n}$$

where

$$PENSUM_{t,i,k,n} = \sum_m PIMP_{t,k,n,m} \times PEN_{t,i,k,n,m}$$

and

$$INTEN_{t,i,k,n} = SAT_{t,i,k,n} \times EUC_{t,i,k,n}$$

except for Auxiliaries and Power, where growth is incorporated:

$$INTEN_{t,4,k,n} = \left(1 + AUPFAC \times \frac{YEAR-BASEYEAR}{25}\right) \times INTEN$$

and for new electric space heating building where heat pumps are phased-in:

$$INTEN_{t,1,k,2} = (HPFRAC_t/COP + (1-HPFRAC_t)) \times SAT_{t,1,k,2} \times EUC_{t,1,k,2}$$

where HPFRAC is given the following linear parameterization:

$$HPFRAC_t = \begin{cases} \left(\frac{t-1}{10}\right) \times HPFRAC_{11} & \text{for } t \leq 11 \\ HPFRAC_{11} & t > 11 \end{cases}$$

many of the inputs are trivial. (E.g., saturations are defined as 1 for i = 3 and 4). Analogous relationships apply for fossil fuel demands for heating and hot water.

The time dependence of the electric use coefficient ("EUC") is obtained by incrementing the 1975 values by changes in end-use demands due to conservation practices initiated in the post-1975 era. Three levels of efficiency improvements are considered*: (1) improvements which provide quick payback and require minimal engineering expertise (e.g., insulation, reduced lighting requirements, and other "housekeeping"); (2) level 1 improvements plus off-the-shelf technologies that require building and equipment modifications (e.g., night setback, HVA/C system controls); and (3) levels 1 & 2, plus capital intensive modifications requiring considerable engineering support (e.g., building automated systems, waste heat reclamation). These three groupings are labelled "m" in Table C.2.

The energy savings that the technology and modifications associated with each conservation level would achieve are provided in Ref. C.2 for each United States region. These savings are to be applied against the base line loads discussed above. The matrix of percentage efficiency improvements is given in Table C.3 by level, building type and end-use. They are also broken down by new buildings and 1975 stock ("retrofit").

The overall savings are functions both of the energy requirement reductions related to the conservation level and the penetration of these levels. Here, level "penetration" is defined as the fraction of floorspace in the given year and BT/EU combinations at the given level. The average savings are then given by the sum over levels of the product of level penetration ("$PEN_{t,i,k,m}$") and percent improvement ("$PIMP_{t,i,k,m}$").

The time dependence of the electrical use coefficient can then be written as the initial value multiplied by a decreased demand factor. The penetration of the conservation level technology groupings is dependent on a number of factors: initial costs, consumer preference, capital availability, payback time and electricity costs. The penetration levels are calculated by using an economic model which applies the estimated payback period to S-shaped acceptance curves. The levels of penetration which result are functions of inputted economic assumptions. Consequently, the forecast scenarios can incorporate sensitivity to a range of assumptions on, e.g., future fuel costs.

The methodology for incorporating future adjustments to electrical intensities is described in Table C.2. Penetration of the conservation levels in the Reference case is based on

*More detailed level descriptions are given in Table C.9 at the end of this appendix.

TABLE C.3
FRACTION OF LOAD SAVED*

| Building Type | End-Use | Conservation Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Retrofit Market | | | New Market | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| Office | Heating | .11 | .15 | .23 | .25 | .35 | .40 |
| | Cooling | .13 | .17 | .34 | .20 | .35 | .47 |
| | Lighting | .25 | .50 | .50 | .15 | .25 | .25 |
| | Aux.&Power | .17 | .28 | .38 | .10 | .16 | .20 |
| Retail | Heating | .08 | .23 | .25 | .30 | .42 | .50 |
| | Cooling | .12 | .20 | .20 | .25 | .37 | .46 |
| | Lighting | .13 | .25 | .25 | .15 | .24 | .30 |
| | Aux.&Power | .18 | .36 | .45 | .10 | .16 | .20 |
| Hospital | Heating | .07 | .15 | .16 | .20 | .32 | .40 |
| | Cooling | .07 | .24 | .28 | .15 | .25 | .33 |
| | Lighting | .08 | .12 | .17 | .10 | .15 | .15 |
| | Aux.&Power | .19 | .25 | .30 | .10 | .15 | .15 |
| Schools | Heating | .14 | .21 | .29 | .30 | .42 | .50 |
| | Cooling | .16 | .26 | .56 | .25 | .35 | .41 |
| | Lighting | .12 | .30 | .42 | .15 | .20 | .20 |
| | Aux.&Power | .26 | .33 | .53 | .20 | .25 | .30 |
| Miscellaneous | Heating | .09 | .15 | .26 | .30 | .42 | .50 |
| | Cooling | .05 | .12 | .24 | .25 | .35 | .40 |
| | Lighting | .09 | .15 | .24 | .15 | .15 | .20 |
| | Aux.&Power | .14 | .23 | .32 | .15 | .20 | .20 |

*Northeast Region, Ref. B.2.

the application of a payback analysis to S-shaped market acceptance curves. These are logistic curves which are defined in terms of 50 percent acceptance levels (i.e., for a given payback period appropriate for a typical mix of owners of a given type of building, that conservation option would be economically acceptable to 50 percent of the building owners). If the payback period is shorter, the acceptance is proportionally greater; if longer, the acceptance is less. The following table shows the 50 percent acceptance values used for the acceptance curves.

TABLE C.4

YEARS PAYBACK FOR 50 PERCENT ACCEPTANCE

| Building Type | Office | Retail | Hospital | School | Other |
|---|---|---|---|---|---|
| Retrofit | 3.7 | 2.6 | 3.5 | 4.0 | 2.6 |
| New | 3.7 | 2.8 | 4.0 | 4.0 | 2.8 |

Source: Ref. C.1

The costs and savings are based on the electrical intensities and savings (discussed previously), the conservation costs (Refs. C.2 and C.3) and the future price assumptions for electricity and fossil fuels. The prices used are shown in the following table.

TABLE C.5

FUTURE ENERGY PRICE ASSUMPTIONS (COMMERCIAL SECTOR)

| | 1985 | 2000 |
|---|---|---|
| Fossil Fuel (1979 $/MMBtu) | $7.65 | $11.92 |
| Electricity (1979 ¢/KWH) | 7.92¢ | 12.33¢ |

The derived penetrations are taken as upper limit conservation estimates, the lower limit is taken at zero conservation, while the Reference case is at the mid-range between those given in Table C.6.

Note that separate penetration matrices are developed for the electric space heat end-use and non-ESH end-uses (including fossil heat). These are fractions of floorspace at these conservation levels; the remainder, when the sum is less than one, have no conservation above base year.

TABLE C.6

REFERENCE CASE PENETRATION FRACTIONS

| Year | Building Type | Electric Space Heat | | | | | | Other End-Uses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing | | | New | | | Existing | | | New | | |
| | Level | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1985 | Office | .05 | .10 | .23 | .04 | .13 | .30 | .05 | .09 | .25 | .05 | .16 | .26 |
| | Retail | 0 | .17 | .15 | .03 | .12 | .31 | 0 | .16 | .17 | .03 | .13 | .30 |
| | Hospitals | .14 | .04 | .01 | .11 | .22 | .12 | .15 | .05 | .01 | .15 | .22 | .05 |
| | Schools | .15 | .05 | .07 | .10 | .24 | .12 | .14 | .07 | .10 | .11 | .25 | .10 |
| | Other | .01 | 0 | 0 | .23 | .23 | .01 | .01 | 0 | 0 | .24 | .09 | 0 |
| 2000 | Office | .03 | .06 | .35 | .02 | .07 | .40 | .02 | .04 | .38 | .02 | .08 | .37 |
| | Retail | 0 | .11 | .30 | .02 | .06 | .40 | 0 | .09 | .33 | .02 | .07 | .39 |
| | Hospitals | .15 | .11 | .08 | .06 | .15 | .27 | .14 | .12 | .10 | .08 | .20 | .19 |
| | Schools | .10 | .06 | .22 | .05 | .15 | .27 | .08 | .06 | .28 | .06 | .17 | .25 |
| | Other | .04 | .01 | .01 | .15 | .24 | .04 | .05 | .02 | .01 | .16 | .22 | .02 |

The costs per saved KWH of the conservation levels is presented in Table C.7.

TABLE C.7

COST PER SAVED KWH (1979 Cents/KWH)*

| | RETRO (N=1) | | | NEW (N=2) | | |
|---|---|---|---|---|---|---|
| Year: 1985 | 1 | 2 | 3 | 1 | 2 | 3 |
| Office | 0.84 | 1.10 | 1.43 | 0.31 | 0.52 | 1.06 |
| Retail | 1.00 | 0.85 | 1.42 | 0.32 | 0.46 | 0.91 |
| Hospital | 1.73 | 2.61 | 3.75 | 0.60 | 1.24 | 2.42 |
| School | 1.13 | 1.81 | 2.26 | 0.35 | 0.79 | 1.67 |
| Other | 2.93 | 3.76 | 4.50 | 0.70 | 1.43 | 3.13 |
| Year: 2000 | | | | | | |
| Office | 0.68 | 0.92 | 1.16 | 0.32 | 0.54 | 1.09 |
| Retail | 0.89 | 0.74 | 1.23 | 0.32 | 0.47 | 0.93 |
| Hospital | 1.51 | 2.23 | 3.25 | 0.61 | 1.26 | 2.46 |
| School | 0.87 | 1.41 | 1.79 | 0.37 | 0.82 | 1.73 |
| Other | 2.46 | 3.17 | 3.77 | 0.71 | 1.46 | 3.20 |

* At nominal equipment lifetimes of 15 years.

Comparison with Table C.7 will reveal that conservation penetrations determined by individual customer market acceptance analysis fail to exhaust the socially cost-effective potential. Indeed, Table C.7 indicates that the highest conservation level satisfies the criterion of saving energy at less cost than it would take to supply the equivalent quantity. Consequently, the Conservation scenario incorporates the most intensive conservation level. The conservation program is assumed to begin affecting the building stock after 1982 with all new construction after that date satisfying the targeted savings and improvements in the existing 1975 stock phased-in over a five-year period. Capital costs are charged at the incremental expense of going from Reference to Conservation case conservation levels where the level costs are presented below in Table C.8.

TABLE C.8

COMMERCIAL SECTOR CONSERVATION COSTS IN 1979 $\$/10^3FT^2$

| Building Type | Existing Buildings (N=1) | | | New Buildings (N=2) | | |
|---|---|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 1 | Level 2 | Level 3 |
| 1. Offices | 800 | 1650 | 2900 | 400 | 1000 | 2325 |
| 2. Retail | 800 | 1450 | 2600 | 400 | 875 | 2100 |
| 3. Hospitals | 1400 | 3800 | 6500 | 700 | 2275 | 5200 |
| 4. Schools | 1150 | 2950 | 5500 | 575 | 1775 | 4400 |
| 5. Other | 1500 | 3300 | 6500 | 750 | 2000 | 5200 |

Source: Refs. C.1, C.2, and C.3

TABLE C.9

CONSERVATION LEVEL DESCRIPTIONS

**Full Description of Representative Technologies**

Three packages of conservation measures were defined for each building type in each region. The technologies included in each of the packages, Levels I, II and III are shown below. In general, Level II includes all the measures in Level I and Level III includes all the measures in Levels I and II.

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| New Office | NE/NC/S/W |

| TECHNOLOGY COMBINATION |
|---|
| Level I |

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking around doors and windows
- Provide air-lock entrances and vestibules
- Provide sealing mechanisms at vehicle loading docks
- Provide external sun shading devices on south, east, west facades for cooling season (overhang creens)
- Provide additional ceiling and wall insulation

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (task illumination, two-step photocell switching devices for daylighting, high efficiency luminaires and ballasts, translucent interior partition systems)
- Provide deadband thermostat setting, 10°F range, between 60°F and 70°F

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork in situations where heat or cool loss is to outdoors or unconditioned space
- Reduce outside air intake (automatic damper and economizer cycle)
- Provide automated fan cycle timing devices
- Recycle contaminated indoor air (electronic filtering devices)
- Provide high-efficiency electric motors, pumps and drives
- Provide automated night setback thermostat

D. OPERATION AND MAINTENANCE PROVISIONS

- Assure proper control of movable internal sun-shading devices on south, east and west facades (drapes, blinds, screens)
- Provide morning warmup cycle for all building systems
- Design for limited use zoning for off-peak building use

TABLE C.9
(Continued)

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| New Office | NE/NC |

**TECHNOLOGY COMBINATION**

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I plus:
- Provide additional ceiling and wall insulation (batt and fill materials)
- Provide increased thermal mass in perimeter walls (masonry and fill materials)
- Provide additional glazing panes on all orientations
- Reduce north-facing facade glazing area (to 10% of wall area)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Provide photocell diming devices staged from periphery
- Provided controlled natural ventilation through selected operable sash systems

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Provide automated startup/shutdown control system, including electrical demand limiting and economizer cycles
- Provide air heat reclamation system from lights and equipment, with exhaust feature and DHW heat exchanger, increased hot water storage capacity
- Provide increased system zoning and HVA/C controls

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Design for increased occupant control of shading and ventilating devices

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| New Office | NE/NC/S/W |

**TECHNOLOGY COMBINATION**

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide additional ceiling and wall insulation on exterior of shell (polymers, batt and fill materials)
- Provide additional thermal mass in perimeter walls and roof (masonry and fill materials) and in interior floors near south-facing perimeter
- Increase glazing materials in south facades (to 80% of wall area) and reduce on other elevations (to 15% of wall area)
- Provide landscaping to promote evaporative cooling in summer, to divert winter winds and increase capacitance of shell at lower stories (planting, ponding, earth-berming)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Increase allowable temperature and humitity differentials through seasonal and diurnal cycles
- Increase activity zoning based on lighting and space conditioning requirements

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide additional waste heat reclamation (waste water, equipment and lights) and increased hot and cold water storage capacity
- Provide integrated energy management systems for operations optimization and control settings
- Provide operable and movable insulating panels for glazed areas
- Provide automated venting and bypass systems
- Provide combustion air preheat systems

## BUILDING TYPE

Existing Office

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking at all windows and doors
- Provide interior shading devices on south facades

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (delamping, installation of high-efficiency luminaires and ballasts upon replacement)
- Increase range of allowable seasonal and diurnal indoor temperature and humidity fluctuations
- Alter functional use zones (relocation of work stations, equipment, storage areas, etc.) according to availability of natural light and existing equipment zones

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork where loss is to outdoors or to unconditioned space

D. OPERATION AND MAINTENANCE PROVISIONS

- Shut down all equipment during periods of extended vacancy
- Generally inspect, clean and repair combustion and distribution equipment
- Reduce domestic hot water domestic supply temperature
- Develop proper occupant control of shading and ventilating devices
- Use artificial illumination only when necessary

TABLE C.9
(Continued)

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing Office | NE/NC/S/W |

## TECHNOLOGY COMBINATION

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I, plus:
- Apply selective films to southernmost facade
- Provide additional insulation for ceiling at top floor

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Reduce outside air intake
- Increase use of task illumination, conversion of incandescent luminaires to fluorescent
- Provide direct venting for sources of internal heat gain

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Increase use of automated combustion controls
- Modify double duct and terminal reheat systems

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Provide for night setback and/or shutdown

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing Office | NE/NC |

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide air lock entrances and/or vestibules
- Provide additional pane of glazing, all facades
- Provide movable interior insulating devices for all glazed areas

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Provide photocell switching devices for artificial illumination
- Increase use of task illumination and replace selected overhead luminaires with high-efficiency lamps

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide combustion air preheat systems

TABLE C.9
(Continued)

## BUILDING TYPE

New Schools

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking around doors and windows
- Provide air-lock entrances and vestibules
- Provide sealing mechanisms at vehicle loading docks
- Provide external sun shading devices on south, east, west facades for cooling season (overhangs, sunscreens)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (task illumination, high-efficiency luminaires and ballasts)
- Provide deadband thermostat setting, 10°F range

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork in situations where heat or cool loss is to outdoors or unconditioned space
- Reduce outside air intake (automatic damper and economizer cycle)
- Provide automated fan cycle timing devices
- Provide high-efficiency electric motors, pumps and drives
- Provide automated night setback thermostat

D. OPERATION AND MAINTENANCE PROVISIONS

- Assure proper control of movable internal sun-shading devices on south, east and west facades (drapes, blinds, screens)
- Provide morning warmup cycle for all building systems
- Design for limited use zoning for off-peak building use

## BUILDING TYPE

New Schools

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I plus:
- Provide additional ceiling and wall insulation
- Provide additional thermal mass in perimeter walls
- Provide additional glazing panes on all orientations
- Reduce north-facing facade glazing area (to 5% of wall area)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Provide photocell dimming devices staged from periphery
- Provided controlled natural ventilation through selected operable sash systems
- Provide discharge of exhaust air to unheated spaces

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Provide automated startup/shutdown control system, including electrical demand limiting and economizer cycles
- Provide air heat reclamation system from lights and equipment, with exhaust feature and DHW heat exchanger, increased hot water storage capacity
- Provide increased system zoning and VAV controls
- Provide outdoor exhaust for toilet and kitchen areas only during periods of use
- Provide heat reclamation for kitchen areas

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Design for increased occupant control of shading and ventilating devices

## BUILDING TYPE

New Schools

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide additional ceiling and wall insulation on exterior of shell (polymers, batt and fill materials)
- Provide additional thermal mass in perimeter walls and roof (masonry and fill materials) and in interior floors near south-facing perimeter
- Increase glazing materials in south facades (to 80% of wall area) and reduce on other elevations (to 15% of wall area)
- Provide landscaping to promote evaporative cooling in summer, to divert winter winds and increase capacitance of shell at lower stories (planting, ponding, earth-berming)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Increase allowable temperature and humidity differentials through seasonal and diurnal cycles
- Increase activity zoning based on lighting and space conditioning requirements

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide additional waste heat reclamation (waste water, equipment and lights) and increased hot and cold water storage capacity
- Provide integrated energy management systems for operations optimization and control settings
- Provide operable and movable insulating panels for glazed areas
- Provide automated venting and bypass systems
- Provide combustion air preheat systems

BUILDING TYPE

Existing Schools

GEOGRAPHIC REGION

NE/NC/S/W

TECHNOLOGY COMBINATION

Level I

DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking at all windows and doors
- Provide interior shading devices on south facades

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (delamping, installation of high-efficiency luminaires and ballasts upon replacement)
- Increase range of allowable seasonal and diurnal indoor temperature and humidity fluctuations
- Alter functional use zones (relocation of work stations, equipment, storage areas, etc.) according to availability of natural light and existing equipment zones

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork where loss is to outdoors or to unconditioned space

D. OPERATION AND MAINTENANCE PROVISIONS

- Shut down all equipment during periods of extended vacancy
- Generally inspect, clean and repair combustion and distribution equipment
- Reduce domestic hot water domestic supply temperature
- Develop proper occupant control of shading and ventilating devices
- Use artificial illumination only when necessary

BUILDING TYPE

Existing Schools

GEOGRAPHIC REGION

NE/NC/S/W

TECHNOLOGY COMBINATION

Level II

DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I, plus:
- Apply selective films to southernmost facade
- Provide additional insulation for ceiling at top floor

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Reduce outside air intake
- Increase use of task illumination, conversion of incandescent luminaires to fluorescent
- Provide direct venting for sources of internal heat gain

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Increase use of automated combustion controls
- Modify double duct and terminal reheat systems

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Provide for night setback and/or shutdown

## BUILDING TYPE

Existing Schools

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide air lock entrances and/or vestibules
- Provide additional pane of glazing, all facades
- Provide movable interior insulating devices for all glazed areas

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Provide photocell switching devices for artificial illumination
- Increase use of task illumination and replace selected overhead luminaires with high-efficiency lamps

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide combustion air preheat systems

## BUILDING TYPE

New Hospitals

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking around doors and windows
- Provide air-lock entrances and vestibules
- Provide sealing mechanisms at vehicle loading docks
- Provide external sun shading devices on south, east, west facades for cooling season (overhangs, sunscreens)
- Provide additional ceiling and wall insulation

TABLE C.9
(Continued)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (task illumination, two-step photocell switching devices for daylighting, hi( efficiency luminaires and ballasts, translucent interior partition systems)
- Provide deadband thermostat setting, 10°F range, between 60°F and 70°F

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork in situations where heat or cool loss is to outdoors or unconditioned space
- Reduce outside air intake (automatic damper and economizer cycle)
- Provide automated fan cycle timing devices
- Recycle contaminated indoor air (electronic filtering devices)
- Provide high-efficiency electric motors, pumps and drives
- Provide automated night setback thermostat

D. OPERATION AND MAINTENANCE PROVISIONS

- Assure proper control of movable internal sun-shading devices on south, east and west facades (drapes, blinds, screens)
- Provide morning warmup cycle for all building systems
- Design for limited use zoning for off-peak building use

## BUILDING TYPE

New Hospitals

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I plus:
- Provide additional ceiling and wall insulation (batt and fill materials)
- Provide increased thermal mass in perimeter walls (masonry and fill materials)
- Provide additional glazing panes on all orientations
- Reduce north-facing facade glazing area (to 10% of wall area)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Provide photocell diming devices staged from periphery
- Provided controlled natural ventilation through selected operable sash systems

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Provide automated startup/shutdown control system, including electrical demand limiting and economizer cycles
- Provide air heat reclamation system from lights and equipment, with exhaust feature and DHW heat exchanger, increased hot water storage capacity
- Provide increased system zoning and VAV controls

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Design for increased occupant control of shading and ventilating devices

TABLE C.9
(Continued)

## BUILDING TYPE

New Hospitals

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide additional ceiling and wall insulation on exterior of shell (polymers, batt and fill materials)
- Provide additional thermal mass in perimeter walls and roof (masonry and fill materials) and in interior floors near south-facing perimeter
- Increase glazing materials in south facades (to 80% of wall area) and reduce on other elevations (to 15% of wall area)
- Provide landscaping to promote evaporative cooling in summer, to divert winter winds and increase capacitance of shell at lower stories (planting, ponding, earth-berming)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Increase allowable temperature and humitity differentials through seasonal and diurnal cycles
- Increase activity zoning based on lighting and space conditioning requirements

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide additional waste heat reclamation (waste water, equipment and lights) and increased hot and cold water storage capacity
- Provide integrated energy management systems for operations optimization and control settings
- Provide operable and movable insulating panels for glazed areas
- Provide automated venting and bypass systems
- Provide combustion air preheat systems

## BUILDING TYPE

Existing Hospitals

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking at all windows and doors
- Provide interior shading devices on south facades

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (delamping, installation of high-efficiency luminaires and ballasts upon replacement)
- Increase range of allowable seasonal and diurnal indoor temperature and humidity fluctuations
- Alter functional use zones (relocation of work stations, equipment, storage areas, etc.) according to availability of natural light and existing equipment zones

TABLE C.9
(Continued)

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork where loss is to outdoors or to unconditioned space

D. OPERATION AND MAINTENANCE PROVISIONS

- Shut down all equipment during periods of extended vacancy
- Generally inspect, clean and repair combustion and distribution equipment
- Reduce domestic hot water domestic supply temperature
- Develop proper occupant control of shading and ventilating devices
- Use artificial illumination only when necessary

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing Hospitals | NE/NC/S/W |

TECHNOLOGY COMBINATION

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I, plus:
- Apply selective films to southernmost facade
- Provide additional insulation for ceiling at top floor

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Reduce outside air intake
- Increase use of task illumination, conversion of incandescent luminaires to fluorescent
- Provide direct venting for sources of internal heat gain

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Increase use of automated combustion controls
- Modify double duct and terminal reheat systems

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Provide for night setback and/or shutdown

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing Hospitals | NE/NC |

TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide air lock entrances and/or vestibules
- Provide additional pane of glazing, all facades
- Provide movable interior insulating devices for all glazed areas

TABLE C.9
(Continued)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Provide photocell switching devices for artificial illumination
- Increase use of task illumination and replace selected overhead luminaires with high-efficiency lamps

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide combustion air preheat systems

## BUILDING TYPE

New Retail

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking around doors and windows
- Provide air-lock entrances and vestibules
- Provide sealing mechanisms at vehicle loading docks
- Provide external sun shading devices on south facade
- Provide additional wall insulation (fill material)
- Provide additional roof insulation (rigid material)

B INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (provide direct display illumination)
- Provide natural general illumination through use of roof monitors and venting skylights
- Provide deadband thermostat setting, 10°F range

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork in situations where heat or cool loss is to outdoors or unconditioned space
- Reduce outside air intake
- Provide automated fan cycle timing devices
- Recycle contaminated indoor air
- Provide high-efficiency electric motors, pumps and drives
- Provide heat recovery device for refrigerating equipment to preheat domestic hot water

D OPERATION AND MAINTENANCE PROVISIONS

- Assure proper operation of southern shading device
- Provide morning warmup cycle for all building systems
- Design for off-peak building use

TABLE C.9
(Continued)

## BUILDING TYPE

New Retail

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I plus:
- Provide additional pane of glazing on south facade
- Provide increased thermal mass in floor slab
- Design for placement of circulation along south-facing edge of plan
- Design for placement of storage along north-facing edge of plan

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Provide photocell dimming devices
- Provided controlled natural ventilation through selective operable sash systems

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Provide automated startup/shutdown control system
- Provide evaporative pre-cooling of outside air
- Provide air heat reclamation system from lights and equipment, with exhaust feature and DHW heat exchanger, increased hot water storage capacity
- Provide increased system zoning and HVA/C controls

## BUILDING TYPE

New Retail

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide additional ceiling and wall insulation on exterior of shell (polymers, batt and fill materials)
- Provide additional thermal mass in perimeter walls and roof (masonry and fill materials) and in interior floors near south-facing perimeter
- Increase glazing materials in south facades (to 80% of wall area)
- Provide landscaping to promote evaporative cooling in summer, to divert winter winds and increase capacitance of shell at lower stories (planting, ponding, earth-berming)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Increase allowable temperature and humidity differentials through seasonal and diurnal cycles
- Increase activity zoning based on lighting and space conditioning requirements

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide additional waste heat reclamation (waste water, equipment and lights) and increased hot and cold water storage capacity
- Provide integrated energy management systems for operations optimization and control settings
- Provide operable and movable insulating panels for glazed areas
- Provide automated venting and bypass systems
- Provide combustion air preheat systems

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing Retail | NE/NC/S/W |

| TECHNOLOGY COMBINATION |
|---|
| Level I |

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking at all windows and doors
- Provide interior shading devices on south facades

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (delamping, installation of high-efficiency luminaires and ballasts upon replacement)
- Increase range of allowable seasonal and diurnal indoor temperature and humidity fluctuations
- Alter functional use zones (relocation of work stations, equipment, storage areas, etc.) according to availability of natural light and existing equipment zones

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork where loss is to outdoors or to unconditioned space

D. OPERATION AND MAINTENANCE PROVISIONS

- Shut down all equipment during periods of extended vacancy
- Generally inspect, clean and repair combustion and distribution equipment
- Reduce domestic hot water domestic supply temperature
- Develop proper occupant control of shading and ventilating devices
- Use artificial illumination only when necessary

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing Retail | NE/NC/S/W |

| TECHNOLOGY COMBINATION |
|---|
| Level II |

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I, plus:
- Apply selective films to southernmost facade
- Provide additional insulation for ceiling at top floor

TABLE C.9
(Continued)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Reduce outside air intake
- Increase use of task illumination, conversion of incandescent luminaires to fluorescent
- Provide direct venting for sources of internal heat gain

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Increase use of automated combustion controls
- Modify double duct and terminal reheat systems

D OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Provide for night setback and/or shutdown

## BUILDING TYPE

Existing Retail

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide air lock entrances and/or vestibules
- Provide additional pane of glazing, all facades
- Provide movable interior insulating devices for all glazed areas

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Provide photocell switching devices for artificial illumination
- Increase use of task illumination and replace selected overhead luminaires with high-efficiency lamps

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide combustion air preheat systems

TABLE C.9
(Continued)

## BUILDING TYPE

New "Other"

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking around doors and windows
- Provide air-lock entrances and vestibules
- Provide sealing mechanisms at vehicle loading docks
- Provide external sun shading devices on south, east, west facades for cooling season (overhangs, sunscreens)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (task illumination, two-step photocell switching devices for daylighting, high efficiency luminaires and ballasts, translucent interior partition systems)
- Provide deadband thermostat setting, 10°F range, between 60°F and 70°F

C. HVA/C SYSTEMS AND CONTROLS

- Insulate piping and ductwork in situations where heat or cool loss is to outdoors or unconditioned space
- Reduce outside air intake (automatic damper and economizer cycle)
- Provide automated fan cycle timing devices
- Recycle contaminated indoor air (electronic filtering devices)
- Provide high-efficiency electric motors, pumps and drives
- Provide automated night setback thermostat

D. OPERATION AND MAINTENANCE PROVISIONS

- Assure proper control of movable internal sun-shading devices on south, east and west facades (drapes, blinds, screens)
- Provide morning warmup cycle for all building systems
- Design for limited use zoning for off-peak building use

## BUILDING TYPE

New "Other"

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I plus:
- Provide additional ceiling and wall insulation (batt and fill materials)
- Provide increased thermal mass in perimeter walls (masonry and fill materials)
- Provide additional glazing panes on all orientations
- Reduce north-facing facade glazing area (to 10% of wall area)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Provide photocell diming devices staged from periphery
- Provided controlled natural ventilation through selected operable sash systems

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Provide automated startup/shutdown control system, including electrical demand limiting and economizer cycles
- Provide air heat reclamation system from lights and equipment, with exhaust feature and DHW heat exchanger, increased hot water storage capacity
- Provide increased system zoning and HVA/C controls

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Design for increased occupant control of shading and ventilating devices

## BUILDING TYPE

New "Other"

## GEOGRAPHIC REGION

NE/NC/S/W

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide additional ceiling and wall insulation on exterior of shell (polymers, batt and fill materials)
- Provide additional thermal mass in perimeter walls and roof (masonry and fill materials) and in interior floors near south-facing perimeter
- Increase glazing materials in south facades (to 80% of wall area) and reduce on other elevations (to 15% of wall area)
- Provide landscaping to promote evaporative cooling in summer, to divert winter winds and increase capacitance of shell at lower stories (planting, ponding, earth-berming)

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Increase allowable temperature and humidity differentials through seasonal and diurnal cycles
- Increase activity zoning based on lighting and space conditioning requirements

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide additional waste heat reclamation (waste water, equipment and lights) and increased hot and cold water storage capacity
- Provide integrated energy management systems for operations optimization and control settings
- Provide operable and movable insulating panels for glazed areas
- Provide automated venting and bypass systems
- Provide combustion air preheat systems

TABLE C.9
(Continued)

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing "Other" | NE/NC/S/W |

**TECHNOLOGY COMBINATION**

Level I

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- Improve sealing and caulking at all windows and doors
- Provide interior shading devices on south facades

B. INTERNAL LOADS AND COMFORT CONDITIONS

- Reduce levels of interior artificial lighting (delamping, installation of high-efficiency luminaires and ballasts upon replacement)
- Increase range of allowable seasonal and diurnal indoor temperature and humidity fluctuations
- Alter functional use zones (relocation of work stations, equipment, storage areas, etc.) according to availability of natural light and existing equipment zones

C. HVAC SYSTEMS AND CONTROLS

- Insulate piping and ductwork where loss is to outdoors or to unconditioned space

D OPERATION AND MAINTENANCE PROVISIONS

- Shut down all equipment during periods of extended vacancy
- Generally inspect, clean and repair combustion and distribution equipment
- Reduce domestic hot water domestic supply temperature
- Develop proper occupant control of shading and ventilating devices
- Use artificial illumination only when necessary

| BUILDING TYPE | GEOGRAPHIC REGION |
|---|---|
| Existing "Other" | NE/NC/S/W |

**TECHNOLOGY COMBINATION**

Level II

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Level I, plus:
- Apply selective films to southernmost facade
- Provide additional insulation for ceiling at top floor

B INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Level I, plus:
- Reduce outside air intake
- Increase use of task illumination, conversion of incandescent luminaires to fluorescent
- Provide direct venting for sources of internal heat gain

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Level I, plus:
- Increase use of automated combustion controls
- Modify double duct and terminal reheat systems

D. OPERATION AND MAINTENANCE PROVISIONS

- All items included in Level I, plus:
- Provide for night setback and/or shutdown

## BUILDING TYPE

Existing "Other"

## GEOGRAPHIC REGION

NE/NC

## TECHNOLOGY COMBINATION

Level III

## DESIGN FEATURES, DEVICES, MEASURES AND/OR EQUIPMENT

A. EXTERNAL FEATURES AND STRUCTURAL PROPERTIES

- All items included in Levels I and II, plus:
- Provide air lock entrances and/or vestibules
- Provide additional pane of glazing, all facades
- Provide movable interior insulating devices for all glazed areas

B. INTERNAL LOADS AND COMFORT CONDITIONS

- All items included in Levels I and II, plus:
- Provide photocell switching devices for artificial illumination
- Increase use of task illumination and replace selected overhead luminaires with high-efficiency lamps

C. HVA/C SYSTEMS AND CONTROLS

- All items included in Levels I and II, plus:
- Provide combustion air preheat systems

APPENDIX C

## REFERENCES


C.1 Glesk, M., et al., Residential/Commercial Market for Energy Technologies, a report to U.S. Department of Energy by Arthur D. Little, Inc.

C.2 Carhart, S. et al., The Brookhaven Building Energy Conservation Optimization Model, Brookhaven National Laboratory, Formal Report, January 1978.

C.3 U.S. Department of Energy, Energy Performance Standards for New Buildings: Economic Analysis (DOE/CS-0129, Technical Support Document 9568.00), January 1980, Table 4-20, page 4-47.