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UNITED STATES OF AMERICA

June 30, 1983

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD
Glenn O. Bright
Dr. James H. Carpenter
James L. Kelley, Chairman

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| In the Matter of<br><br>CAROLINA POWER AND LIGHT CO. et al.<br>(Shearon Harris Nuclear Power Plant, Units 1 and 2) | Dockets 50-400 OL<br>50-401 OL<br><br>ASLBP No. 82-468-01 OL |

AFFIDAVIT IN SUPPORT OF 2.758 PETITION
by Wells Eddleman

## I. INTRODUCTION

This affidavit summarizes the economic and environmental superiority of an alternative to operation of the Harris nuclear power plant. That alternative is described in greater detail in the 3 accompanying affidavits of Dr. G. George Reeves.[1]

Section II explains what Dr. Reeves' affidavits show, and tabulates the economic effects of the alternative in constant 1982 dollars. CP&L's claimed Harris fuel savings are compared with these results, again on a constant 1982-dollar basis.[2] Fuel savings are the only possible benefit of running Harris since its capacity will not be needed under the alternative. Drs. John Blackburn and E. Roy Weintraub provided economic advice used herein. They will provide affidavits later.

[1]Reeves affidavits #1 (July 14, 1982, re capacity savings), #2 (February 11, 1983, $ benefits of capacity savings), and #3 (June 28, 1983, $ benefits of additional kWh savings beyond affidavits #2) are included with this petition and affidavit, and incorporated herein by reference. Dr. Reeves reviewed and approved the summaries and numbers from his affidavits herein.

[2]All calculations and derivations of numbers are in the Appendix hereto, to simplify the narrative, except for those in the two Tables.

Four separate scenarios in Section II show the economic advantages of the alternative compared to operating the Harris plant. That advantage is over $2.5 billion 1982 dollars for the scenario that assumes a 70% lifetime capacity factor for both units, that CP&L's production cost savings estimates (Environmental Report Amendment 5)[3] are correct, that there is no price elasticity effect on demand (from rate-basing $4.5 billion of Harris plant) beyond what CP&L estimated in its forecasts,[4] and that the full cost of both Harris units is sunk.[5]

Section III explains how the load-shifting, solar, and energy-saving components of the alternative to Harris are unusually benign even for "soft technologieS". They have minimal environmental impacts. Nuclear energy has generally greater environmental impacts than do typical "soft technologies" alternatives. Thus, the alternative to Harris is environmentally superior.

Emissions from modern CP&L coal-fired power plants (which might be avoided were Harris available to generate electricity) are compared to the emissions for the nuclear fuel cycle in NRC's Table S-3.[6] Nuclear energy has no great advantage here, and the lesser overall effects of the alternative, which reduces the need for electrical generation overall, prevail. Not operating the Harris plant also guarantees against a catastrophic reactor accident in the Research Triangle area, a vital part of North Carolina which includes the state government and the sites of 4 major universities, several large hospitals, and many people.

Section IV sums up the open-and-shut case for not operating the Harris plant.

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[3]References are given in the Appendix, numbered according to the footnote that refers to each. The same numbering system is used for calculations and derivations of numbers.

[4,6]See Appendix. [5]See scenario 2 of Section II, why HP costs not sunk.

## II. ECONOMIC COMPARISONS

### A. DESCRIPTION OF THE ALTERNATIVE

The alternative to the Harris plant presented here is a combination of load-shifting (to save capacity), energy-storage, solar energy and energy saving measures.[1]

Dr Reeves' first affidavit (14 July 1982) demonstrates how neither Harris unit is needed to meet peak load on the CP&L system. Appropriate conservation and load management measures beyond those in CP&L's present conservation/load management program can reduce CP&L peak loads by 2600 MW in the year 1995. (R #1, Fig 4, p.30; see also pp 4,6 (CP&L forecast load 1995 = 9300 MW) and 31, load held to 6700 MW by the measures discussed therein.[7]

These measures have no net cost to consumers: all interest and capital costs of each measure is repaid from the savings in electricity use that result, or from the savings (on a time-of-day rate) obtained by shifting load off-peak. The rates used to figure these savings were CP&L's rates in effect in spring 1982.

The conditions under which all of Reeves' affidavits were made include: CP&L [illegible] load forecast is assumed correct as a baseline before the additional conservation and load management Reeves shows; only options beyond CP&L's current plan for conservation and load management are considered; electric rates are assumed to stay the same in real terms (i.e. be the same in constant dollars); and only

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[1]Developed by Dr. G. George Reeves, former assistant professor of electrical engineering at NC State University, and described in his three affidavits (listed in Appendix under 1.) Dr. Reeves' professional qualifications are attached to his third affidavit.

[7]No-net-cost loan concept, storage bin and efficient air conditioners, (residential, commercial, industrial), residential active solar (air system, new homes and retrofits on old ones), water heating off peak, and winter solar/fuel and heat storage substitution for electricity. See Appendix under item 7 for citations.

conservation and load management measures that exist today are used to lower CP&L peak loads and requirements for electricity generation.

Under those conditions, Reeves affidavit #1 shows a reduction of 2600 MW in CP&L peaks in the year 1995. This reduction exceeds the combined capacity of both Harris units (1800 MW total), plus Mayo 2 (720 MW). (Reeves #1, pp30-31).

The total system load on the most severe heating or cooling day is held to 6700 MW. This is within CP&L's 1982 capacity allowing for 20% reserves. (Reeves Fig. 4, p.30, Affid #1) CP&L has since added the Mayo #1 plant, 720 MW, in spring 1983.

If we assume that the Reeves conservation measures continue in effect, CP&L peak load growth will be at most half of **the** 2.9%/yr CP&L has predicted.[8] That is because the cooling load, the hardest one to reduce, is cut in half by thermal storage (Reeves #1, p.17). Thus CP&L peak load after 1995 will grow at most 1.5% per year, or 100 MW per year.[9] Thus, to need the capacity of Mayo 1, added in 1983, will take until the year 2001.[9] Harris capacity would not be needed at all until after that year.

At CP&L's growthrate for peaks under Dr. Reeves' peak-reducing program, it would take at least 15 more years to fully utilize the 1800 MW capacity of 2 Harris units.[9] That brings us to the year 2016, 2 years after the end of the life of the Harris project according to CP&L's environmental report. (ER amendment 5, p. 8.2.1-1, last paragraph, gives Harris project termination in the year 2014.)

This completes the explanation of why the Harris plant isn't needed for capacity in the foreseeable future. Power company planning horizons are rarely as long as 20 years, and Harris is

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8CP&L 1981 and 1982 forecasts are nearly identical: See appendix.
9 Calculation in appendix, under #9.

off that horizon, as far as need for capacity is concerned.

Reeves affidavit #1 also shows why Harris would not be a sensible choice to provide additional capacity after the year 2001. Figure 4, p.30, shows that CP&L's weather-independent peak load will only be about 6200 MW in the year 1995. True base load (around-the-clock load) will only be about 3600 MW then. CP&L's existing capacity is over 5000 MW for base load, and includes 3500 MW of baseload coal plants that will still be around in the year2000. (See R#1, p.5). Thus, there is no base load (year-round) for the Harris units to meet.

Duke Power Co. president Bill Lee[10] has recently explained why you don't build nuclear units for other than base load, in testimony to the NC Utilities Commission. He said one consideration in Duke's decision to cancel the Cherokee nuclear plant[11] was that you "don't build a Cherokee for peaking or intermediate load." Similarly, you don't build a Harris unit for peaking or intermediate load.

In sum, a Harris baseload unit (or both units) simply isn't needed to meet CP&L peak loads through the year 2014. This is the principal conclusion of Reeves affidavit #1 (p.31) and is used in the scenarios comparing costs and benefits below.

Reeves affidavit #2 (2-11-83)[1] details the net costs and benefits of the **load-shifting** and efficiency improvements described in his first affidavit. The results are summarized in Table 1 on page 6.

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[10] Copy attached; Docket E-7 sub 358, June 1983, reference in full in the Appendix.

[11] Recommended for cancellation along with Harris 2 by Public Staff of NCUC, 1983 report. Reference, details in appendix.

Table 1 

Table of Dr. Reeves' program benefits
(from his 2d affidavit, Feb. 1983)
Million Dollars Per Year
Constant Dollars

| Year | HIGH EER A/C (p.2) | ACTIVE SOLAR NEW HOMES (p.3) | ACTIVE SOLAR RETROFITS (p.4) | STORAGE BIN A/C (p.5) | STORAGE BIN A/C COMMERCIAL (p.6) | WATER HEATING OFF PEAK (p.7) | TOTAL (p.8) |
|---|---|---|---|---|---|---|---|
| 1983 | (8.31) | (6.58) | (22.68) | (1.38) | (10.78) | (2.18) | (51.91) |
| 1984 | (4.74) | -0- | (18.42) | (.47) | (8.17) | (0.90) | (32.72) |
| 1985 | ( 1.17) | +6.57 | (14.15) | +.45 | (5.57) | +0.37 | (13.52) |
| 1986 | +2.40 | +13.15 | ( 9.89) | +1.36 | (2.97) | +1.55 | + 5.67 |
| 1987 | +5.97 | +19.72 | (5.62) | +2.28 | (.36) | +2.92 | +24.87 2 |
| 1988 | +9.54 | +26.30 | (0.36) | +3.19 | +2.24 | +4.19 | +44.07 |
| 1989 | +13.10 | +32.87 | +2.91 | +4.11 | +4.84 | +5.47 | +63.26 |
| 1990 | +16.67 | +39.45 | +7.18 | +5.02 | +7.45 | +6.74 | +82.46 |
| 1991 | +20.24 | +46.02 | +11.44 | +5.94 | +10.05 | +8.01 | +101.65 |
| 1992 | +23.41 | +52.60 | +15.71 | +6.85 | +12.65 | +9.27 | +120.85 |
| 1993 | +27.38 | +59.17 | +19.97 | +7/77 | +15.26 | +10.56 | +140.00 |
| 1994 | +30.95 | +65.75 | +24.24 | +8.69 | +17.86 | +11.84 | +159.24 |
| 1995 | +34.52 | +72.32 | +28.51 | +9.60 | +20.56 | +13.11 | +178.44 |
| 1996-2014 | 732.68 | 1623.93 | 1053.74 | 226.10 | 642.96 | 249.09 | +4529.22 |
| any year after 1995 | +38.68 | +85.47 | +55.46 | +11.90 | +33.84 | +13.11 | +238.38 |

(typo corrected gives 24.87 in 1986

Source: Reeves affidavit of 2-11-83, tables therein.

The above net costs and benefits assume that the real price of electricity stays the same; if it rose, the constant-dollar benefits above would be larger.

Table 1 shows the savings from Reeves affidavit #1 measures in constant 1982 dollars, assuming the price of electricity does not rise. Numbers in parenthesis are negative. Note that the conservation program commences in 1983. Since its components are available to go on-line immediately, it should not wait for the Harris plant to become operable. The earlier a program to implement these measures starts, the more consumers will save. Consumers are the ones who pay the costs (and receive any benefits, i.e. electricity and capacity that is needed, plus any fuel savings) of the Harris plant. All economic comparisons herein use the costs and benefits seen by the consumer (assuming the real price of electricity is constant at 1982 levels) for this reason.

For the years 1983-2014, the measures in Table 1 produce a net saving to the consumer of $5.252 billion (1982 dollars). If the year 1983 is omitted, the 1984-2014 benefits are still over $5 billion, net of all costs of implementing and maintaining the measures. Details are in Reeves' second affidavit.[12]

This number, developed under the assumptions described above[12] is used in comparisons of costs and benefits which follow.

Dr. Reeves' third affidavit[1] (June 28, 1983) describes the costs and available savings from the use of measures beyond those in his first 2 affidavits. These measures are also specifically beyond those included in CP&L's current conservation/load mgt. plan.[13]

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[12] Assumptions are given on page 1; high efficiency air conditioners costs and benefits, pp 1-2, Table I thereof; active solar new homes p.3, Table II thereof; Active Solar Retrofits, Table II, p.4; Residential Storage Bin Air Conditioning (without solar) p.5, Table IV. Non Residential (i.e. Commercial/Industrial) Storage Air Conditioning, p.6, Table V; Water Heater Load Control p.7 Table VI; summary table VII, p.8, additional savings p.9 (no dollars calculated).

[13] Reproduced in Public Staff 1983 report, copy attached, Table II-1. See App.

The costs and net benefits (compared to purchasing electricity at 1982 prices) are set forth in Table 2 below, which covers only the kilowatt-hour savings from measures in Reeves 3d affidavit that are not included in his other affidavits. The net benefits are in constant 1982 dollars, assuming that the real price of electricity does not rise beyond 1982 levels. If it did, benefits would be greater.

TABLE 2

Net 1982 Dollars Cost Savings from Reeves Affidavit #3 Measures beyond CP&L Conservation/Load Management Plan and Beyond Reeves' affidavits #1 and #2

| Source | GWH/yr Saved | Cost/ kWh | Net Saving v. 5¢/kWh real | Real $/year saved |
|---|---|---|---|---|
| Solar HW (net of CP&L) | 800 | 1.98¢ | 3.02¢ | $24,160,000 |
| Solar Gain (nonsolar homes) | 192 | 0.87¢ | 4.13¢ | 7,840,000 |
| Shading | 78 | 0.91¢ | 4.09¢ | 3,190,000 |
| Lighting | 185 | 1.25¢ avg. | 3.75¢ | 6,768,000 |
| Motors | 143 | 1.43¢ | 3.57¢ | 5,100,000 |
| TVs | 444 | -0- | 5¢ | 22,200,000 |
| Bath Water | 152 | -0- | 5¢ | 7,600,000 |
| TOTAL | 1994 GWH/yr | | | $75,658,000 |

Source: Reeves Affidavit #3, 6-28-83, pp4-5 solar HW (adjusted to remove CP&L plan GWH), 5-7 shading and solar gain, 7 Lighting, 7-8 Motors, 8 Bath Water Space Heat, 8-9 TVs, Summary p.10 for all measures.

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| TOTAL | 1994 GWH/yr | | | $75,658,000 |

Source: Reeves Affidavit #3, 6-28-83, pp4-5 solar HW (adjusted to remove CP&L plan GWH), 5-7 shading and solar gain, 7 Lighting, 7-8 Motors, 8 Bath Water Space Heat, 8-9 TVs, Summary p.10 for all measures.

Reeves affidavit #3, p.10-11, shows a total saving of 4452 GWH per year (equal to a Harris plant at 56% capacity factor) from the measures included in all 3 of his affidavits. This amount of capacity displaced, and GWH generation displaced, are used in some of the scenarios below.

Assuming the measures of Table 2, which do not overlap previous affidavits' measures in Table 1, were adopted uniformly over the 12 years 1984-95, and then remained in effect for the years 1995-2014, the constant dollar benefit of these GWH savings over the period 1984-2014 is $1.891 billion 1982 dollars.[14]

The sum of Table 1 and Table 2 constant dollar savings, 1984-2014, is $6.905 billion in 1982 dollars. This figure is used in economic comparisons with the Harris plant below.

To summarize: The alternative to the Harris plant is a combination of load-shifting (mainly energy-storage and load control), solar energy, and energy-efficiency-increasing measures. As described in Section III, these have minimal environmental impacts among the alternatives possible to nuclear power generation. Dr. Reeves' affidavits show that the Harris plant is not needed for capacity, that $6.9 billion can be saved by using the alternative from 1984 until the end of Harris plant life in 2014, and that the kilowatt-hours generated by a Harris unit at 56% capacity factor can be displaced by the alternative.

[14] Details of calculation, in Appendix. The Table 2 figure is basis.

B. FOUR COMPARISONS OF HARRIS vs. THE ALTERNATIVE

1. As shown above, there is no need for Harris capacity. Thus the only benefit of the Plant is its ability to generate power at economic costs below that of coal. See NRC rule, 47 FR 12941 and 12942. Using CP&L's assumptions of 70% capacity factor and 25-year unit life, with the maximum $ savings from producing power from Harris instead of other CP&L units, all as given in ER Amendment 5, I compute a 1982 constant-dollar benefit of $4.03 billion from both Harris units in the period 1986-2014.[15]

The alternative not only eliminates need for Harris capacity (through 2001 at all, and through 2016 as a baseload plant); it saves $6.9 billion 1982 dollars by the year 2014. This completes the first comparison,[16] in which all Harris construction costs are considered sunk.

2. Harris 2 really isn't a sunk cost. This comparison and #3 below depend on that fact. Here's why Harris 2 isn't a sunk cost now: (a) The unit is only 3 or 4% complete (NUREG-0030 6/82[17]; transcript of 2-24-83 prehearing conference). (b) CP&L hasn't invested any money in actively constructing it during 1982 or 1983.[17] (c) CP&L will reassess it this fall (copy of relevant article attached)[17]; (d) The NCUC Public Staff recommended cancelling it in its 1983 report.[17] Cherokee 1, on which the Public Staff took a similar position, is already cancelled.[17] (e) DOE has identified Harris 2 as a candidate

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[15] The details of the computation are in the appendix, item 15. Cost to customers is larger than the cost to CP&L, so benefits are adjusted upward accordingly in the calculation.

[16] As shown in appendix item 15, 2d page, even if CP&L's claimed fuel savings at 70% capacity factor were not discounted at all from their 1986-dollar basis to 1982 dollars, the alternative wins by $6.9 billion to $6.3 billion in savings delivered to customers. QED.

[17] A list of sources and citations is in Appendix item 17. Copies of documents are attached except for NRC transcript and DOE report.

for cancellation along with Cherokee 1 and other units. (DOE/EIA-0392,"Nuclear Plant Cancellations" April 1983). (f) Harris 2 is a hole in the ground today. McGuire, the leading NRC case on sunk costs, identifies units 52 and 69% complete, or more, as "substantially completed." There is no way a hole in the ground is a "substantially completed" nuclear plant. (g) Finally, consider the position of having ruled that Harris 2 is a sunk cost, and then Having CP&L cancel it.

Accepting that Harris 2 is not a sunk cost, it's easy to show that Harris 1 shouldn't be allowed to operate. McDuffie Figure 6[18] from CP&L shows that to complete Harris 2, $1,721,174,000 must be spent after the end of 1983. Adding this sum, appropriately discounted, to the alternative's benefits gives about $8 billion[19]; the benefits of Harris 1 operation vs. coal sum to about $2 billion plus in the constant 1982 dollars used for comparison.

Why not complete Harris 2? It isn't needed and it's not cost-effective if it were needed, according to the Public Staff 1983 report, copy attached,[20] see cover letter, pp i-ii and Table III-5 underlying discussion pp34-35.

This completes the second scenario, in which Harris loses out by about $6 billion in 1982 dollars.

3. The third scenario is similar, but relies on the Public Staff's construction schedule (see Appendix ref. 20) at pages 32-35.

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[18] From recent 1983 NC rate case. Full citation in appendix, copy attached.

[19] Computation into 1982 dollars not performed. Can be done on request. 11.7% is appropriate discount rate (CP&L's cost of funds, see Appendix at item 15). This should be added to savings since it is a cost consumers don't have to pay if Harris 2 isn't built.

The Public Staff determined, based on cost-effectiveness and need for power, that Harris 1 should be delayed until 1992 and Harris 2 should never be built. (Ref. 20 at i, ii, 32-35)

If we delay Harris 1 until 1992, it still will produce its $ 2 billion in 1982-dollar fuel-cost savings from production by nuclear instead of coal or some other fuel source. But now, by the end of Harris 1's operating life, the alternative has had 6 more years to work. From Tables 1 and 2 above, each year adds $314 million [21] to the alternative's benefits. So the alternative gains another $1.9 billion in 6 years[21] for economic benefits of about $8.75 billion versus a bit over $2 billion for Harris (1982 dollars). According to the Public Staff, not building Harris 2 saves money, even if a coal plant has to be built to substitute for it (after the year 2000).(ibid.) And of course, Harris isn't needed for capacity.

This completes the third scenario.

4. All the above scenarios assume that price elasticity of demand has less effect than it actually may. According to Profs. John Blackburn and E. Roy Weintraub[22], the long-term price elasticity of demand for electricity is -1. That means that adding Harris units to rate base could sharply reduce electric demand, given their cost of $4.5 billion for 2 units, per CP&L.

This is no idle academic concern. LILCO chief engineer Adam Madsen, commenting on the results of rate-basing the $3.2 billion Shoreham plant, said "If we realy did this, sales would go down." (NY Times,6/7/83 "Easing Utility 'Rate Shock'" by Matthew L. Wald, p.1 of business section). (Reference supplied by Dr. Blackburn 6/30/83). Of course, such a sales reduction would not affect CP&L's fixed costs (including fixed charges and depreciation on $4.5 billion of Harris)

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[21] See Appendix item 21. [22] Testimony to NCUC, see App item 22.

so CP&L rates would then rise even more, suppressing sales further.

Wells Eddleman computed additional costs to ratepayers 1986-95 based on CP&L ER Amendment 5.[23] The 1986-dollar added cost is $3.368 billion. (ibid).

CP&L's 1982 revenues were $1.538 billion (1982 annual report). If revenues hit $ 2 billion a year in 1986 and then stay constant in real terms, CP&L will have revenues of $20 billion (1986$) from 1986-95. The $3.368 billion is about a 16.8% increase therein. It thus will produce a demand (1-1/1.165) or .86 as large. This 14% decrease in electricity sales compared to 1986 base, works out to be about 5 billion kWh a year (output of a Harris unit at 63% C.F.).[23A]

This price-caused reduction may overlap Dr. Reeves kWh-savers in his third affidavit, which amount to a Harris unit's output at 56% C.F.[24] It doesn't matter. If both units are there and saving fuel costs at CP&L's maximum assumptions, the alternative is still more cost-effective and no Harris capacity is needed -- see case 1 above, p. 10. If demand is reduced the fuel savings will be less because the fuel displaced will be cheaper fuel. (Cheaper fuel is used first in the loading of rational power-generating systems, and more expensive fuel is then used for meeting additional demand).

If, on the other hand, Dr. Reeves' kWh savings do not overlap with the elasticity-induced drop in demand, the output of neither Harris unit is needed. They are displaced at about 60% C.F.

This completes the 4th scenario, with elasticity effects.

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[23] Cited in Appendix item 23 [23A] Calculation in Appendix

[24] See Appendix. It turns out this is an underestimate, but no credit for the underestimate is taken in this affidavit.

## III. ENVIRONMENTAL EFFECTS COMPARISONS [25]

Comparing the environmental effects of different energy sources can be like comparing apples and oranges. Nevertheless, it is possible to choose. This section describes the environmental effects of the alternative to Harris set out in Section II.A above, and compares them to nuclear energy's risks via the work of Holdren, Beyea, & von Hippel, as well as by comparison of effluents with Table S-3 for the case where nuclear generation is used to displace coal-burning power generation. Simply put, the environmental effects of the Harris alternative are much less than those of average renewable energy alternatives. The risks of such average alternatives, in turn, are less than the risks of nuclear energy, both for accidents and for environmental and human health effects.

The Harris alternative does not add to insulation levels or reduce the air circulation through houses. Thus, indoor air pollution is avoided. As discussed below, it can be mitigated if it arises. As a worst case, adding an air-to-air heat exchanger (cost $200, 1982) to affected houses would only cost $145 million for every home on the CP&L system in 1995. The running cost would be about the same as for existing fans and heating system blowers. This would not tip

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[25] This section is based on extensive research by Wells Eddleman. The most important references on environmental effects of renewables used herein are "Side Effects of Renewable Energy Sources" Dec. 1982, by Dr. Larry Medsker for National Audubon Society (Med 82 as cited herein) and Holdren et al, Risk of Renewable Energy Sources (ERG-79-3 from Energy & Resources Group, U.Calif. Berkeley, 1979. Copies of these documents are included complete in the materials served on Judge Kelley (who will evaluate this petition/affidavit), Applicants, Staff OELD, and the 3 copies to NRC Docketing and Service. I will supply (continued next page)

the cost-benefit balance in Section II above. Substituting the heat exchanger blower for another blower has no net cost, and the heat exchanger recovers heat in winter and cool in summer.

The basic conclusion is that the total environmental effects of a combination of renewables (especially those discussed in Reeves' affidavits 1,2 and 3, ) are less than the total environmental effects of nuclear energy production, on the basis of useful energy made available (by production, load-shifting or savings). See Holdren et al, pp i-ii and 68. (Referenced hereafter as ERG 79-3).[26]

Even among these renewables, those with large land requirements such as wind power, and photovoltaics, are not included here. (See Medsker, hereinafter "Med 82" at 9). No additional biomass is included -- though nearly 16% of all CP&L residential customers were already using wood as their primary heating fuel in 1982, according to CP&L's appliance saturation survey. (See Med 82 at 13-15 for effects thus avoided). Since the solar systems included by Dr. Reeves sit on existing roofs (or roofs of new buildings), they do not involve additional land use except for storage bins.

If all 775,000 CP&L residential customers in 1995 had 10' x 10' storage bins for heating and cooling, this would add up to 78 million square feet or about 1800 acres. Each bin would be a bit larger than a typical outbuilding. If all the CP&L commercial customers then had

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footnote continued from page 14:

copies of them to any other party who requests them. Due to their voluminous size (ERG-79-3 is 232 pages, Side Effects is 73pp) it was not considered cost-effective to serve the other parties without determining whether they needed them. Trees being a renewable resource, I wanted to conserve them.

[26] The only possible exception is the steel tank, oversized solar technology for Canada. ERG-79-3 at 191-205 critiques this choice. It is simply not comparable to the fiberglass-glzed, air-handling system with masonry block storage bin used by Dr. Reeves.

storage bins for thermal energy also, each 10 feet by 40 feet, there would be around 150,000 400 square foot bins, or 60 million square feet -- about 1400 acres. This totals 3200 acres. More land than that would be freed by not operating the Harris plant, which has over 4000 acres of woodland on its site. The storage bins could be integrated into the design of new buildings, without necessarily taking up additional space, so the 3200 acres is a maximum.

Other than this, there are no other significant land-use effects of the proposed combination of alternatives to Harris ("the alternative") as detailed above and in Reeves' 3 affidavits. This is important because (see Med 82 p. 9) land use is one of the most significant side effects of renewable energy sources. The alternative to Harris minimizes this side effect, given its energy delivery.

Of course, load-shifting, efficient appliances, solar water heating, moving screens, growing shade plants, and hanging onto heated water have minimal direct environmental impact. Only the solar water heaters, solar space heaters and storage bins affect the appearance of things. Since these methods do not generally involve adding insulation, tightening houses for air leakage (infiltration), additional heat pumps or forest product use, the side effects of energy efficiency improvements discussed (Med 82 at 22-24) are minimized.

There may be some radon exposure risk associated with the storage bins (using rocks) and the tendency of people to try to increase their energy savings by reducing air infiltration in their homes. No additional insulation or reduced infiltration is assumed in the alternative to Harris. The most straightforward mitigation strategy is to use rocks low in the precursors of radon (eg. radium, thorium, uranium) and test each rock bin for radon. As to housing, the method

proposed by Anthony Nero and Jan Beyea[27] (copy of Feb. 1981 Bulletin of the Atomic Scientists pp61-64 attached) is best: equip the residence auditors (e.g. in CP&L's own program and the Residential Conservation Service) with radon-detection equipment. Dr. K.Z. Morgan, former director of health physics at Oak Ridge, has pointed out that covering the earth under homes with plastic sheeting (current cost 1.5¢/$ft^2$ or $24 for a ... NC house of 1600 $ft^2$, assuming larger houses are more likely candidates for solar systems) can usually reduce radon exfiltration to levels such that indoor air quality in the house above is not adversely affected. The extra cost of such programs is modest if intergrated into energy-auditing programs that exist. In extreme cases, vapor sealers (e.g. Hypalon® ) can be used to seal off radon-emitting stone, brick or earth from access to living spaces. The result is that a good energy-saving program will detect those homes with higher levels of radon, and provide mitigation measures to reduce its harmful effects. Thus, the energy-conservation program will reduce radiation exposure. For rock beds, any found to be emitting too much radon can simply have the rocks replaced. The rocks can be re-used outdoors, or as highway fill, or be landfilled, if they emit radon in quantities enough to be raising the indoor radon concentrations above normal levels as cited by Beyea (5 x outdoor normal concentratiON). It would certainly be possible to set "trigger" radon levels lower than this, thus reducing radon exposure below its present general level for average houses, by a conservation program as described above.

Since the alternative to Harris does not assume ANY change in infiltration of air (it simply supplies the needed heat from solar energy instead of electricity in most cases), the radon issue is not significant with respect to it. In conjunction with good energy

27 See Appendix item 27

conservation practices, it would reduce radon exposure at modest cost. Assuming it cost $1 million to set up house energy auditors to detect radon and get readings on radon levels in rock beds, and that half of homes required a mitigation measure, the cost of plastic would be (for 450,000 homes) about $10.8 million and the cost of coatings ($10/500 ft$^2$ typical price) for 10% of the homes would be $3.6 million. These costs are very modest compared to the multi-billion dollar benefits delivered to customers by the alternative to Harris, and do not significantly change the $1 billion or more advantage of that alternative versus operating the Harris units at 70% capacity factor.

Medsker (Med 82 at 27-29) discusses the risks of solar heating and recommends the radon mitigation measures noted above. The solar collectors recommended in the alternative to Harris do not use glass glazing (so no breakage hazard); air is the working fluid, and the system minimizes use of toxic materials. These systems do use blowers and electronic controls, and rock storage is an option. However, the effects of the systems for solar energy in the alternative to Harris are less than those on pages 27-29 of Med 82 because the effects of glass, toxics, and working fluids are avoided in general.

In summarizing the high-risk side effects of direct solar heating/cooling, and of conservation (Med 82 p.60), construction materials and insulation manufacturing hazards, glass breakage, working fluid leaks, toxic chemicals released, radon release, disposal of working fluids, storage ponds, indoor air pollution, and aesthetics of solar systems are listed. All of these except materials manufacturing, aesthetics, and radon are eliminated in the Harris alternative by not using the materials involved, or not tightening up houses. Radon mitigation is discussed above. The result is that only materials impacts and aesthetics are left as significant side-effects. Since the materials of

the alternative's solar heating system include ducting and blowers like any conventional forced-air system (including heat pumps), the only additional materials required are the collector (fiberglass glazing and sheet metal) some additional ducting to and from the collector, and the storage bin (masonry, rocks and insulation, plus roofing material). Allergy problems can be reduced by filtering (as in a conventional system) or by electrostatic air-cleaning if necessary.

Minimizing radon effects from rocks has been covered above. Rock mining, assuming 10 tons of rocks for each dwelling in CP&L's service area in 1995, would be 7,750,000 tons. That sounds like a lot, but compare it to the mining required to run Harris. Each Harris core contains the U-235 from about 350 tons of natural uranium; each unit takes about 8 cores (full) to run 25 years. Thus both units need 5600 tons of natural uranium to be dug up to run for 25 years[28] Uranium ores have a content of about 1 lb U per ton, so 2000 tons of ore make 1 ton of pure uranium metal. That means 11.2 million tons will be mined to run Harris.

More efficient air conditioners involve more copper and frame metal (compared to inefficient air conditioners of the same size), but they only need to be half as big in capacity (Reeves affidavit #1, p.17). This more than offsets the extra materials in the high-EER (high-efficiency) but smaller sized air conditioners. Efficient motors also involve more copper. Again, the savings of not building the bigger inefficient air conditioners' compressor motors frees up most of the copper required for more efficient motors on the smaller units.

In sum, then, the environmental effects of the materials used in the alternative are minimal compared to Harris or existing appliances, and readily mitigated.

Since the Harris plant is not needed for peak loads, the only positive environmental effect of operating it would be to reduce the amount of coal burned on the CP&L system. (The Harris plant uses more water and more O&M material than a comparable sized coal burning plant, so it has no other environmental advantages. Harris also produces more waste heat per unit of electricity than a coal plant would.) The hazards of coal pollution are significant. Here, a comparison with Table S-3 of 10 CFR 51.20 is useful. That table includes a 45-Mwe coal plant (for enrichment of uranium, mostly) emitting 1154 tons per year of particulates, 4400 tons of sulfur dioxide, 1190 tons of nitrogen oxides, 14 tons of hydrocarbons and 29.6 tons of carbon monoxide (all metric tons). If one of CP&L's modern coal plants (Roxboro 3 or 4, or Mayo 1), able to hold emissions to 0.03 lb/MBTU for particulates, produced the 5.5 billion kWh that a Harris unit at 70% capacity factor could produce, it would emit (10,000 BTU/kWh x 5.5 x $10^9$ kWh x 0.03 lb/MBTU) or 1.62 million lb or 730 metric tons of particulates a year. Likewise, burning ½% sulfur coal (which CP&L gets from captive mines), the coal plant would burn 2.25 million tons of coal a year to equal a Harris unit at 70% C.F., and thus emit22500 tons of $SO_2$ a year ($SO_2$ per mole weighs twice what sulfur does, so the sulfur oxide emissions is 2 x ½% of the coal tonnage burned, or 1% of it). The nitrogen oxide limit for the new coal plant is under 2000 tons a year. Since particulates in conjunction with sulfur and nitrogen oxides case the illness effects of coal, whereas the particulates themselves cause cancer, the effects of the new CP&L coal unit's emissions are not significantly worse than those included in Table S-3 for the nuclear plant. Thus if the Table S-3 emissions' effects are not sufficient to avoid licensing a nuclear plant (NRC's past licensing decisions certainly accord with this view), then the

new CP&L
additional emissions from a coal plant are also not significant enough to turn the NEPA balance against an alternative that eliminates the use of the Harris nuclear plant and allows the new CP&L coal plants to generate the energy instead. Indeed, this is what CP&L has been effectively doing with its Brunswick and Robinson nuclear plants in recent years. For 1982, CP&L's nuclear performance was 35% of design capacity (35% DER capacity factor) see Baseload Power Plant Performance Report to NCUC, Eddleman testimony docket E-2 sub 461. That's half of the 70% CP&L assumes for Harris. In effect, 1½ of CP&L's 3 nuclear units were thus "not used" and the other 1½ ran at the expected 70% capacity factor. Coal units, particularly those at Roxboro, made up the output of the "missing" nuclear units. From this example, it is clear that licensing a nuclear plant to operate does not avoid the environmental effects of coal burning to produce power. If the nuclear plant breaks down, the coal will still be burned.

To summarize, if the Harris plant is solely used to displace coal combustion, the coal emissions from CP&L's modern coal plants will be comparable to the emissions associated with coal-burning for the nuclear fuel cycle in NRC's Table S-3. Thus, there is no significant environmental gain from running the nuclear plant. The additional fission product emissions of the nuclear plant would be avoided, however, if the nuclear plant did not run. Thus, running the Harris plant is not environmentally superior to the alternative discussed above. This is particularly so since Harris is not needed for peaking capacity, and most of Harris's output can be displaced entirely by the alternative and by the economic effects of amortizing Harris 1 (a sunk cost). Thus, the real situation is that less electricity will be required with the alternative in place, and thus Harris's output can only be used to avoid coal combustion. As shown above, this gain is not significant

because the Harris operation entails the coal effluents in Table S-3 associated with the nuclear fuel cycle.

One other environmental difference between Harris and the alternative is worth noting. Although many systems have been designed to help reduce the chance of a catastrophic nuclear reactor accident, only not having a reactor near you is a guaranteed method of keeping it from happening in your area.[29] Expensive mitigation methods have been proposed for such an occurrence, but the alternative is an absolute preventative since Harris won't operate if the alternative is used instead. That would leave the Research Triangle "safely" over 100 miles from any other operating reactor.

Whatever the likelihood of nuclear reactor accidents, the loss of the seat of NC government, 4 major universities (Duke, NC. Central, NC State and UNC), Duke Hospital, NC Memorial hospital, and the entire Research Triangle Park, a center of corporate research, all within the danger area described for serious accidents in reference 29, is just unacceptable. Precluding this possibility is clearly another point in favor of the alternative.

## IV. CONCLUSION

The alternative is $2.8 billion 1982 dollars better than the maximum savings from Harris at 70% capacity factor, on economics. It avoids the need for Harris capacity, has less environmental impact, and eliminates the chance of a nuclear reactor catastrophe in the Research Triangle area of NC, The alternative is clearly better, both environmentally and economically.

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[29] Beyea and von Hippel, Bulletin of the Atomic Scientists, Aug-Sept 1982 at 52-58. See particularly "an area the size of Connecticut", box and charts of risk.

APPENDIX
TO AFFIDAVIT IN SUPPORT OF 2.758 PETITION BY WELLS EDDLEMAN
June 30, 1983

1. #1, Conservation and Load Management Substitutes for CP&L Generation, July 14, 1982; #2, Costs and Savings from Conservation and Load Management Substitutes for CP&L Generation, 2-11-83; #3, Additional 1995 CP&L Conservation Energy, June 28, 1983.

2. 1982 dollars are used throughout because those were the dollars Dr. Reeves used in his studies cited in note 1 above. The only exception is the elasticity case II.B.4 where both CP&L and Eddleman used 1986 dollars, so conversion to 1982 dollars was superfluous since the dollars were of comparable year (the same one: 1986) and thus the same value. The elasticity effect depends only on the relative increase of cost due to the Harris plant, not on the year of the constant dollars.

3. SHNPP Environmental Report, Amendment 5, December 1982, at 8.1.1-3; see also at 8.1.1-1

4. Dr. Reeves used CP&L's 1981 December forecast in developing affidavit #1 above. The December 1982 forecast (current forecast) is virtually identical. Both have a 2.8% per year increase in sales and 2.9% per year increase in peak demand.

5. See discussion of Harris 2 costs not really being sunk now, pp 10-11 of affidavit, and note 17 of this Appendix.

6. 10 CFR 51.20 Table S-3, Summary Table of Effluents from Nuclear Fuel Cycle.

7. Reeves 1st affidavit, 7/14/82, ref. 1 above, includes the following measures used to cut peak load:

efficiency improvements vs. new capacity (discussion of relative advantages of efficiency improvements) p.10
no-net-cost loan (efficient air conditioner example ) 12-15
no-net-cost load applicability to rental and leased property, 16
Storage Bin Air Conditioning, 17-19, 24-25
Active Solar New Homes, 20-21
Active Solar Retrofits (existing homes) 22-23
Commercial and Industrial Storage Bin, 26 (cooling)
Air Conditioner Efficiency Improvement, 27, 12-15
Winter Peak Reduction (heating) 28
Water Heating Off-Peak, enhanced storage, 29

8. CP&L forecasts of December '81 and December '82 have identical projected growth rates. 2.9%/2 is about 1.5%. See note 4 above. 1/2 of CP&L growth, Reeves #1, p. 17, air conditioner half as big does the same job.

9. CP&L 1995 peak 6700 MW (Reeves p.31 #1 affidavit) x 1.5%/yr growth (this affidavit, p.4, Reeves #1, p.17; note 8 above) 1.5% x 6700 MW is 100 MW per year. Add 20% reserves, 120 MW/yr growth. 720 MW for Mayo 1, divide by 120/yr, gives 6 years. 1995 + 6 = 2001. Harris 1 and 2, 900 MW each, 1800 MW total (ER 5, 8.1.1-1), divide by 120 MW/yr gives 15 years to need capy of both of them. 2001 +15 = 2016.

10. Supplemental testimony of W.S. Lee, chairman, Duke Power Co. NC UC docket E7 sub 358, filed June 1983. Copy attached.

11. Public Staff Report 1983, Analysis of Long-Range Needs for Electric Generating Capacity in North Carolina. Two excerpts are attahced. One includes the comparison of coal vs. nuclear costs, Table III-5, with the conclusions of the report to scrap Harris 2. The other includes the capacity addition schedule and CP&L's conservation/load management program as it is now. Cherokee I and Harris 2 are pushed off the planning horizon, see at 32-35. Nuclear units are not preferred as substitutes for Harris 2, see at 1-2 (i-ii) and 32-35.

12. Reeves 2d affidavit, 2-11-83. Seenote 12 on p.7 of this affidavit.

13. CP&L plan is Table II-1 of 1983 Public Staff report, copy attached, see note 11 above.

14. Calculation: smoothly implement savings over 12 years gives equivalent of 6 years of full savings (12/2) since average saving will be half the 1995 total. Add to this 19 full years, 1996-2014. Total is 25 years x 75.658 million a year (Table 2, bottom right). This is 1891.4 million dollars, constant 1982 dollars. See Reeves #2, p.1 for constant dollar assumption.

APPENDIX 8.3

15. Computation of constant-dollar production savings from operating Harris: based on Environmental Report Amendment 5, Sec. 8, December 1982: CP&L's numbers.

ER section 8.1.1 (page 8.1.1-1) gives $2.J021 billion (1986$) fuel/production savings for operating the CP&L system with both Harris units (one 1986-95, 10 year, the other 1989-95, 7 years) at 70% capacity factor. At 70% C.F., each unit produces 5.52 billion kWh a year, or in 17 reactor-years, 93.8 billion kwH. Dividing the constant dollar benefits by total kWh, we get 2.15¢ per kWh (CP&L used a slightly higher number of kWh in Attachment B to their answers to W.F. interrogatories, 94.7 billion for the 10 years. That produces a lesser figure per kWh).

It turns out that 2.15¢/kWh is the largest 1986 dollar saving claimed in ER Amendment 5. Calculating as above for the other cases (total kWh for unit-years at given capacity factor) yields lower numbers for 2 units at 60% C.F., 2 at 50% C.F., and slightly less for 1 unit at 70% C.F.

To convert this cost per kilowatt-hour into 1982 dollars, we must use a discount rate. In NCUC Docket E-100 sub 41 (Dec. 1982) CP&L used 11.7% (its cost of funds) to discount fuel costs from future periods. Using this rate for 4 years means dividing by $(1.117)^4$ or by 1.565, which yields a 1982 dollar figure of 1.373¢ per kilowatt-hour.

What the customer sees is the fuel savings (assuming they are passed through at full value -- no higher value is reasonable since it would mean CP&L was deliberately losing money) times the tax factor for gross receipts tax - 1.06383. This yields a customer cost of 1.46¢/kWh in 1982 dollars.

Not having rel[illegible]e data on fuel costs beyond 1995, (not to say

THAT CP&L's is), the safest assumption is that the constant-dollar fuel savings would be the same in the future. (This assumption may compensate somewhat for CP&L's over-optimistic 70% DER capacity factor used herein; then again, it may not compensate for it.)

At 70% capacity factor, each Harris unit produces 5.52 billion kWH per year (.70 x 8760 hours/year x 900,000 kW/unit). Multiply this by 1.46¢ per kWh and you get a constant-dollar production saving (1982 $) of 80.6 million per unit-year.

Taking 2 units operating 25 years at 70% capacity factor, then, is 50 unit-years times $80.6 million per unit/year. The total Harris benefit over its operating life (per ER Amendment 5, which uses 25-year lives, see p.8.2.1-1, last paragraph) is thus $4.03 billion in 1982 dollars.

It turns out, based on the savings shown from the Reeves affidavits and summarized on p.9, that the discount rate used to convert Harris 1986 dollars from ER Amendment 5, into 1982 dollars, doesn't matter. To see this, assume the discount rate is zero (i.e that it costs nothing to borrow money, and future costs and benefits are ~~exactly in todays dollars~~ in dollars with the same value as today's dollars. This is the same as undoing the division by 1.565 above. (That took the 11.7% discount for the 4 years 1982-86) $4.03 billion times 1.565 is about $6.31 billion. This is less than the $6.9 billion (1982 dollars) saved by the alternative.

However, I use the $4.03 billion number to be consistent with CP&L's assumptions in fuel-related matters before NCUC (discount rate) and NRC (ER Amendment 5 claimed savings). This entire calculation is made according to CP&L's assumptions of capacity factor, lifetime, and discount rates, then, and yields a $4.03 billion 1982-dollar benefit from running 2 Harris units (instead of coal, etc. on the CP&L system) for 25-year operating lives.

16. See second from last paragraph under item 15, Appendix p.4.

17. NUREG-0030 6/82 is the latest version. Applicants agreed H2 was only 3 or 4 percent complete at the 2/24/83 conference in this case. Charlotte Observer article "CP&L To Rule This Autumn on Nuclear Unit" tells of scrapping of Cherokee 1 and CP&L plan to reassess Harris in October 1983, copy attached. Public Staff report, at pp 1-2 and 32-35, see also Table II-5. cited above in note 11. McGuire case ___ NRC ___.

18. CP&L witness McDuffie (in charge of all construction for CP&L) prefiled testimony, NCUC Docket E-2 sub 461 (1983) Fig. 6 is between pages 22 and 23. Copy attached. This gives year by year costs for Harris and is the basis for Dr. Reeves conclusion at the end of his affidavit 3 that if you didn't consider the cost to finish Harris 1 (from 1984 on) to be sunk, the alternative could be bought for just that cost and displace Harris 1's generation (and twice its capacity) at a capacity factor greater than the Staff used in NRC's Harris DEIS of May 1983.

19. Computation not performed, can be done on request. 11.7% is appropriate discount rate, year-by-year numbers are in reference 18 above (the Figure 6). 11.7% is the discount rate CP&L used for future cost discounting in NCUC Docket E-100 sub 41 in late 1982, for the purpose of computing present values of future avoided fuel costs -- exactly the type of computation done for Harris fuel in note 15, and ER amendment 5, and the computation being done for capacity where this note appears.

20. Public Staff 1983 report at cover letter, 1-2, 32-35, Table II-1. See note 11 above for more info.

21. $75,658,000 -- Table 2 of this affidavit, right column at bottom
$238,380,000 -- Table 1 of this affidavit, right column at bottom
$314,038,000 : sum of the above numbers, is total saving of the alternative for any year after 1995, net of all its costs.

22. Blackburn and Weintraub testimony, NCUC Docket E-100 sub 35, 1979, copy attached. Dr. Weintraub reconfirmed the present validity of the -1 long-term price elasticity for electricity demand, and -0.2 for the short-run, 6/26/83. He can execute an affidavit to that effect.

23. W.E. testimony Docket no. E-100 sub 46, NCUC, 1983, copy of relevant pages and Table I thereof attached. The table shows how the $3.368 billion in 1986 dollars was computed.

23A. 35 billion kWh sales (CP&L forecast) x.14 reduction is 4.9 billion kWh a year. Harris at 60% C.F., 1 unit, is 4.7 billion. 4.9 billion is about 63% C.F. for a Harris unit. See note 24 below.

24. Actually, a kilowatt-hour saved at the customer's point of use saves more than a kilowatt-hour of generation, because transmission and distribution losses are avoided too. This is true for peak and total generation, but sales are after-loss numbers. Loss factor for CP&L is about 5% on average, see FERC Form 1s, pp401 1981-82 and 431 1978-80. NO CREDIT FOR LOSSES IS ASSUMED IN THIS AFFIDAVIT OR IN DR REEVES' AFFIDAVITS. This is a conservatism.

25 These appear to be the most comprehensive treatments available, though as they point out, all studies to date are incomplete. This is not surprising considering the amount of information involved in assessing environmental impacts of widely varying technologies throughout their production, including inputs into them like materials and energy from other sources.

26. See discussion on page 19: The alternative system actually adds only a controller, some ducting, sheet metal, fiberglass, and the rock bed to a conventional heating system. It is not at all the oversized Canadian water-storage monster of Inhaber's report. It handles air only.

27. Beyea and Nero, letters re radon issue, Bulletin of the Atomic Scientists, Feb 1981 , pp 61-64, copy attached.

28. 100 tons $UO_2$/core, 88% U, 88 tons U/core, enriched to 4 times natural, thus 352 tons U metal needed per full core. Full core lasts 3 years, plant life is 25 years. 25/3 gives 8 cores. 2 plants for 25 years, thus 16 cores, conservatively. 16 x 352 tons = 5612 tons U metal. 1 lb U metal per ton of U ore, or 1 ton U metal per 2000 tons ore. 2000 x 5600 = 11.2 million tons mined for Harris plant. Of course, U tailings are harder to handle than ordinary rocks, also.

29. See Beyea and von Hippel, Bull. At. Sci. 8/9-1982 at 52-58, re meltdown mitigation, copy attached. Particularly relevant are the area at risk (see charts and graphs), and the box "An area the size of connecticut".

STATE OF NORTH CAROLINA

COUNTY OF DURHAM

Today Wells Eddleman appeared before me and affirmed: (1) That the affidavit in support of his 2.758 petition was written by him in consultation with Drs. G.George Reeves and John O. Blackburn and the same is true and correct to the best of his knowledge and belief; (2) That Dr. Reeves examined said affidavit in draft form and verified the statements concerning his affidavits and the conditions they were made under, and also verified the calculations of net constant dollar costs and benefits, contained in said affidavit in support of 2.758 petition, and Dr. Reeves will later supply an affidavit to that effect; (3) That Dr. Blackburn verified the validity of the energy-economics and elasticity approaches used in said affidavit in support of 2.758 petition, and will supply an affidavit to that effect; (4) that said petition is being filed with the Nuclear Regulatory Commission under its rule in 10 C.F.R. 2.758.

This 30th day of June, 1983

Wells Eddleman

Wells Eddleman

My commission expires July 14, 1987.

Belinda Lee

Notary

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of CAROLINA POWER & LIGHT CO. Et al. )
Shearon Harris Nuclear Power Plant, Units 1 and 2 )

Dockets 50-400
and 50-401 O.L.

## CERTIFICATEOF SERVICE

I hereby certify that copies of 2.758 petition and affidavits and supporting documents **, and of "Contention 15AA" re capacity factor HAVE been served this 30 day of June 1983, by deposit in the US Mail, first-class postage prepaid, upon all parties whose names are listed below, except those whose names are marked with an asterisk, for whom service was accomplished by ______________

** The extensive documents ERG-79-3 and "Side Effects of Renewable Energy Sources" are served herewith on Judge Kelley, Applicants, Staff, and 3x to NRC Docketing & Service; available on request to all other parties.

Judges James Kelley, Glenn Bright and James Carpenter (1 copy each)
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Robert Fischbach
Executive Director

Office of Executive
Director
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Dear Chairman Koger and Commissioners:

On behalf of the Public Staff, I am pleased to submit the 1983 report on the long range needs for electric generating facilities in North Carolina. This report covers Carolina Power & Light Company and Duke Power Company, which together account for approximately 95% of the electricity sales in the State.

This report projects load growth through the year 2000 for both CP&L and Duke of below 2% per year, substantially less than our 1981 forecast of 4.0 to 4.5% per year. Proposed construction schedules have been adjusted accordingly, with significant delays recommended for certain units in the late 1980's and 1990's. In addition, our analysis indicates that no new nuclear units are justified after Harris 1 for CP&L and Catawba 2 for Duke.

We consider this report a marked improvement over prior years' efforts. Our forecasts represent our best evaluations of electric power requirements in the future based on a continuation of existing and anticipated policies and regulatory activities. We continue to encourage conservation and load management activities to achieve the projected reductions in growth while at the same time providing low cost and reliable electric service for the continued economic development of the State of North Carolina.

The Public Staff stands ready to discuss this report at the appropriate time.

Sincerely,

Robert Fischbach

Robert Fischbach

RF/lab

cc: Governor James B. Hunt, Jr.

# ANALYSIS OF LONG RANGE NEEDS FOR ELECTRIC GENERATING FACILITIES IN NORTH CAROLINA


## Public Staff Report
## 1983

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## SUMMARY

This is the fourth report by the Public Staff to the Utilities Commission on the long range needs for electric generating facilities in North Carolina. This report covers the two largest electric utilities in the state, Carolina Power & Light Company and Duke Power Company which, together account for 95% of the electricity sales in North Carolina.

By our analyses the expected annual growth rates in demand for electricity to the year 2000, including the effects of conservation and
2.0 83-2000 1.7 83-2000
load management programs, are 1.9% for CP&L and 1.5% for Duke. These results are substantially lower than our 1981 forecast. Based upon this growth, CP&L and Duke will need to add only three generating facilities apiece between 1983 and 2000 in order to provide electricity in the most economic and reliable manner. The Public Staff's construction schedule calls for the addition of CP&L's Mayo 1 coal fired unit in 1983, Harris 1 nuclear unit in 1992 and Mayo 2 unit in 1998. For Duke, the schedule calls for the addition of three nuclear units: McGuire 2 in 1984, Catawba 1 in 1996 and Catawba 2 in 1999. Even at demand growth greater than our forecast, our analysis shows no justification for nuclear units after Harris 1 for CP&L and Catawba 2 for Duke.

In developing our economic forecasts (Chapter I), our approach has been somewhat different and improved over past studies. Peak load has been forecast independently; an end use model has been used to estimate industrial sales; quarterly data have been used where possible;

and most equations have been based on data from 1973 forward. As in past studies, reductions to the economic forecasts have been made to account for conservation and load management effects believed not to be captured by the economic model. In past years such reductions relied upon results from studies performed by outside consultants working under Federal grants. For this year's report we have used the utilities' own projections for conservation and load management with only modest refinements (Chapter II). Plant construction schedules (Chapter III) were developed using our load impact and supply model, as has been the case for previous reports.

It should be noted that the development of the Public Staff's load forecast and capacity expansion plans is an iterative process. First the econometric/structural models are developed, the results of which are then modified by the load management/energy conservation deductions, and a capacity expansion plan is produced. The results of the analysis is then fed into a price forecasting model to see the impact of the construction schedule on the price of electricity. If the resultant price growth is different from that assumed in the econometric/structural models, these models are run again. The entire process is repeated until a construction schedule produces a price of electricity equal to the input to the econometric/structural models.

# COST ESTIMATES

## New Coal Units

| | |
|---|---|
| Capital Cost | $300/KW (1982 $) |
| Capital Inflation | 6.8% |
| Production Cost | 24.2 mills/KWH |
| Production Inflation | 9% |
| Heat Rate | 10,500 Btu/KWH (CP&L) |
| | 9,665 Btu/KWH (Duke) |

## New Nuclear Units

| | |
|---|---|
| Capital Cost | $1350/KW (1982 $) |
| Capital Inflation | 6.8% |
| Production Cost | 11.7 mills/KWH |
| Production Inflation | 9.5% |

# ANALYSIS OF LONG RANGE NEEDS FOR ELECTRIC GENERATING FACILITIES IN NORTH CAROLINA

## Public Staff Report

## 1983

curves, determined that the proper mix for the two utilities would be approximately 50% base, 30% cycling and 20% peaking. Another commonly used technique sets daily standard operating conditions for type of capacity and requires an hourly load curve for the utility's peak week. This approach generally assumes that peaking capacity cannot operate for more than twelve consecutive hours on any day and that base capacity operates continuously. Using the hourly loads for the peak week through the summer of 1981 yields a capacity mix of approximately 50% base, 35% cycling and 15% peaking.

From the aforementioned analyses, we conclude that the two major utilities in North Carolina should maintain a capacity mix of approximately one-half base, one-third cycling, and one-sixth peaking. This is consistent with earlier conclusions of the Public Staff.

As shown above, the determination of the proportion of each operational mode is based upon a load pattern. The utilities in North Carolina are involved with load management programs which are expected to decrease the amount of required peaking capacity and increase the amount of required base capacity to provide adequate and reliable service.

D. CONSTRUCTION SCHEDULES

Our determination of construction schedules was based on the goal of providing electricity in the most economic and reliable manner. Data used for determination of the construction schedules was obtained from major utilities in North Carolina and the Public Utility

Commissions of other states. Parameters required by the ICF program to perform the economic comparison include estimates by the Public Staff of capital cost, production expense, escalation rate for capital cost and escalation rate for production expense (Table III-5). The factors included in the formulation of these plans are projected reserve margins (Table III-6), loss of load probability (Table III-7) and operational mix.

The construction schedules presented below are the result of this study. They reflect our best economic evaluation and judgments but do not attempt to address questions concerning financial integrity of a specific utility and environmental or safety problems associated with a particular type of unit.

CONSTRUCTION SCHEDULE

| | CP&L | Duke |
|---|---|---|
| 1982 | | |
| 1983 | Mayo 1 (720) | |
| 1984 | | McGuire 2 (1180) |
| 1985 | | |
| 1986 | | |
| 1987 | | |
| 1988 | | |
| 1989 | | |
| 1990 | | |
| 1991 | | |
| 1992 | Harris 1 (900) | |
| 1993 | | |
| 1994 | | |
| 1995 | | |
| 1996 | | Catawba 1 (1145) |
| 1997 | | |
| 1998 | Mayo 2 (720) | |
| 1999 | | Catawba 2 (1145) |
| 2000 | | |

These construction schedules display the absence of a need for the capacity of CP&L's Harris 2 and Duke's Bad Creek 1 & 2 and Cherokee 1 to meet system peaks.

The possibility of our forecasted system peak being on the low side has to be considered. Therefore, we have run a sensitivity analysis to check our construction schedules. The analysis uses the peak demand forecast, shown on Table I-8 for CP&L and Table I-17 for Duke, and the respective company's own conservation and load management peak reductions. Since the company's own conservation and load management reductions are less that that of the Public Staff, a higher demand results. The results show CP&L first requiring a plant other than those in our construction schedule in 1995. This plant and others that might be required by the year 2000 should be fueled by coal and not uranium. Results for Duke show no new plants required beyond those shown in our construction schedule. Since the analysis for Duke resulted in a demand similar to our forecasted demand , an analysis based on a higher growth rate indicates that any other power plant required by the year 2000 should also be fueled by coal and not uranium. Our conclusion is that no nuclear units can be economically justified after Harris 1 for CP&L and Catawba 2 for Duke.

NRC "ratcheting" of nuclear plant design specifications and out-dated design technology make Harris 2 and Cherokee 1 less of a viable alternate than a plant of new design. Consideration should also be given to the effect of carrying these plants on the books for long periods of time while no work is being performed and AFUDC is being

accrued and/or CWIP is being paid by ratepayers. The companies should perform studies on this matter, if they have not already done so, and present such studies to the Commission to justify continued construction delays and funding of these plants.

## CAROLINA POWER & LIGHT COMPANY
## CONSERVATION AND LOAD MANAGEMENT PROGRAM

| | Summer 1995 Demand Reduction[(1)] |
|---|---|
| **Residential Programs** | |
| Water heater load control | 69 MW |
| Air conditioning load control | 100 |
| Time-of-usage rate | 31 |
| Insulation loans | 67 |
| Common sense program | 99 |
| Passive solar home construction | 38 |
| Efficient air conditioners and heat pumps | 93 |
| Efficient water heaters, refrigerators and other appliances | 46 |
| Reduce strip heaters in heat pumps and tune-up | 4 |
| Solar water heaters | 29 |
| Home audits | 50 |
| Apartment audits | 4 |
| | 630 MW |
| **Commercial Programs** | |
| Energy management review for new and remodelled buildings | 68 MW |
| Energy management development programs | 7 |
| Commercial energy audit program | 24 |
| Agricultural research and development | 5 |
| Time-of-use rate | 43 |
| CP&L field facilities program | 1 |
| Energy saving lighting program | 12 |
| Commercial standby generation program | 35 |
| Cooperative commercial load curtailment program | 4 |
| Commercial thermal storage | 51 |
| | 250 MW |
| **Industrial Programs** | |
| Reschedule plant shutdowns program | 12 MW |
| Time-of-use rate | 126 |
| HVAC optimization | 14 |
| Industrial energy audit program | 90 |
| Large load curtailment program | 40 |
| Cooperative industrial load shedding program | 38 |
| Energy efficient industrial plants | 29 |
| Emergency generation | 10 |
| Hydroelectric generation | 18 |
| Cogeneration | 480 |
| Industrial thermal energy storage | 13 |
| | 870 MW |
| **Total Programs** | 1750 MW |

(1) CP&L, Conservation and Load Management Strategy for Insuring Reliable Electric Supply in the 1990's, January 1982

# DUKE POWER COMPANY
## CONSERVATION AND LOAD MANAGEMENT PROGRAM

| | Summer 1994 Demand Reductions[1] |
|---|---|
| **Residential Programs** | |
| "RC" Rate and energy efficient structure | 691.6 MW |
| Energy efficient appliances | 543.4 |
| Central air conditioning load control | 409.8 |
| Improved insulation in "R" and "RW" structures | 244.6 |
| Conversion of existing structures to "RC" | 150.0 |
| Time-of-usage rate | 125.0 |
| High efficiency central cooling systems | 117.0 |
| Water heater load control | 113.8 |
| Improved insulations in "RA" structures | 70.8 |
| **Commercial Programs** | |
| Energy generation | 75.0 MW |
| Reduced lighting levels - existing buildings | 67.0 |
| Conservation rate | 61.1 |
| Chain store accounts | 56.0 |
| Others - individual custom designed programs | 42.8 |
| Removal of large existing loads at peak | 42.2 |
| Additional insulation - new buildings | 35.0 |
| Reduced lighting levels - new buildings | 33.0 |
| Time-of-usage | 40.0 |
| Improved HVAC design - existing buildings | 19.0 |
| Interruptible rate | 17.0 |
| Improved HVAC design - new buildings | 10.0 |
| Additional insulation - existing buildings | 8.0 |
| **Industrial Programs** | |
| Load control | 229.0 MW |
| Base load reduction | 147.0 |
| HVAC load reduction | 130.0 |
| Cogeneration | 100.0 |
| Emergency generation | 100.0 |
| Conservation rate | 100.0 |
| Interruptible rate | 79.0 |
| Time-of-usage rate | 60.0 |
| **Resale Programs** | |
| Central air conditioning load control | 165.0 MW |
| General conservation | 124.4 |
| Time-of-use rate | 30.0 |
| Water heater load control | 28.8 |
| Emergency generation | 7.0 |
| **Total Programs** | |
| Conventional | 3313.0 MW |
| Emergency | 995.0 |
| | 4508.0 MW |

(1) Duke Power News, June 1981

# COST ESTIMATES

## New Coal Units

| | |
|---|---|
| Capital Cost | $800/KW (1982 $) |
| Capital Inflation | 6.8% |
| Production Cost | 24.2 mills/KWH |
| Production Inflation | 9% |
| Heat Rate | 10,500 Btu/KWH (CP&L)<br>9,665 Btu/KWH (Duke) |

## New Nuclear Units

| | |
|---|---|
| Capital Cost | $1350/KW (1982 $) |
| Capital Inflation | 6.8% |
| Production Cost | 11.7 mills/KWH |
| Production Inflation | 9.5% |

But, he added, they differed with Lawri- "over emphasis in the graphic department," -person graphic-design operation that is run wrimore's wife, Elizabeth.

e will not have a graphic department," said "We feel we can better serve our clients by individuals to do that work."

rimore said he will operate as the sole it executive until a second counselor is this summer. He said the departures arose his plans to restructure the firm using a -building approach." That would involve lors more in each others' accounts, he said. more's firm had been structured as a pro- al practice, with counselors handling cli- dividually.

t and the other departing executives will veral Lawrimore clients with them, open- new firm with annual billings of about 00, he said.

rimore, with a total of six employees, said will have about 20 clients and billings of 360,000.

rimore said the loss of his management the beginning step in a redirection of the wing agency he founded as a one-person 1980.

imore had said last year, after hiring om a public relations job at Springs Indus- . in Fort Mill, S.C., that he planned to add to his staff every six months.

he said, he wants a smaller firm. "You certain point of awareness and you real- e are more important things in life than of your billings and number of employ- wrimore said. "Personally, I was con- hat I was spending 80% of my time in rative work. I didn't start the business to ministrator of a large firm."

# aid-Off Workers

lant manager in Charlotte for six years, said specially heartened by one caller who saw ednesday morning.

aid, 'I always see criticism of industry. This hing changes my opinion.' I though that was ice," Gill said.

# CP&L To Rule This Autumn On Nuclear Unit

By PETER W. BARNES
Observer Staff Writer

RALEIGH — Carolina Power & Light Co. (CP&L) said Wednesday it likely will decide this fall the fate of a partially built nuclear reactor that consumer advocates contend is unnecessary.

At the company's annual meeting, CP&L Chairman Sherwood Smith didn't indicate whether the utility intends to cancel the reactor, the second unit of its two-unit Harris nuclear station near Raleigh.

But he told shareholders, "As we continue to assess our needs for future generations, we will evaluate later this year whether Harris 2 should remain on its present schedule or whether plans for it should be changed."

In February, the N.C. Utility Commission's Public Staff, which represents consumer interests in utility matters, said energy conservation efforts have made the second unit unnecessary.

In the same report, the Public Staff had taken a similar position on Duke Power Co.'s Cherokee unit 1, about 10 miles east of Gaffney, S.C. Though Duke disputed the recommendation, at its annual shareholder meeting in Charlotte last month the company announced it would cancel Cherokee.

CP&L, which serves 770,000 residential and commercial customers in Piedmont and Eastern North Carolina, already has scrubbed four unbuilt nuclear reactors because of slowing demand for electricity and climbing construction costs. They were two units of the South River plant near Fayetteville, canceled in 1978, and Harris units 3 and 4, scrapped in late 1981. Cost of cancellation amounted to about $200 million.

The company says it has invested about $280 million in Harris 2, which is 4% complete, and further construction has been postponed. The first Harris unit is 78% complete and scheduled for operation in 1986.

## 1983 CONSTRUCTION BUDGET
## EXPENDITURES FLOW[1]
## ($000'S)

| | Prior To 1983 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | Total Project |
|---|---|---|---|---|---|---|---|---|---|---|
| **Harris Unit No. 1** | | | | | | | | | | |
| Gross Budget Estimate | 1,378,423 | 384,693 | 397,376 | 329,012 | 98,481 | - | - | - | - | 2,587,985 |
| Less: CWIP in NCRRB[2] | 42,864 | 29,506 | 47,650 | 52,537 | 9,266 | - | - | - | - | 181,823 |
| Power Agency's Share | 222,891 | 62,205 | 64,256 | 53,201 | 15,924 | - | - | - | - | 418,477 |
| Net Cost to CP&L | 1,112,668 | 292,982 | 285,470 | 223,274 | 73,291 | - | - | - | - | 1,987,685 |
| **Harris Unit No. 2** | | | | | | | | | | |
| Gross Budget Estimate | 272,931 | 37,472 | 149,884 | 238,736 | 314,143 | 331,805 | 310,275 | 295,720 | 80,611 | 2,031,577 |
| Less: CWIP in NCRRB[2] | 4,959 | - | - | - | - | - | - | - | - | 4,959 |
| Power Agency's Share | 44,133 | 6,059 | 24,236 | 38,604 | 50,797 | 53,653 | 50,171 | 47,818 | 13,035 | 328,506 |
| Net Cost to CP&L | 223,839 | 31,413 | 125,648 | 200,132 | 263,346 | 278,152 | 260,104 | 247,902 | 67,576 | 1,698,112 |
| **Total Units No.'s 1 & 2** | | | | | | | | | | |
| Gross Budget Estimate | 1,651,354 | 422,165 | 547,260 | 567,748 | 412,624 | 331,805 | 310,275 | 295,720 | 80,611 | 4,619,562 |
| Less: CWIP in NCRRB[2] | 47,823 | 29,506 | 47,650 | 52,537 | 9,266 | - | - | - | - | 186,782 |
| Power Agency's Share | 267,024 | 68,264 | 88,492 | 91,805 | 66,721 | 53,653 | 50,171 | 47,818 | 13,035 | 746,983 |
| Net Cost to CP&L | 1,336,507 | 324,395 | 411,118 | 423,406 | 336,637 | 278,152 | 260,104 | 247,902 | 67,576 | 3,685,797 |

[1] Expenditure Flow is based on 1983 Construction Budget data.

[2] CWIP - Construction Work in Progress
NCRRB - North Carolina Retail Rate Base

Figure No. 6

SUPPLEMENTAL TESTIMONY
OF
WILLIAM S. LEE
FOR
DUKE POWER COMPANY
NCUC DOCKET NO. E-7, SUB 358

Q. PLEASE STATE YOUR NAME AND ADDRESS.

A. My name is William S. Lee. My business address is 422 South Church Street, Charlotte, N. C. 28242.

Q. ARE YOU THE SAME WILLIAM S. LEE WHOSE DIRECT TESTIMONY WAS PRE-FILED ON FEBRUARY 1, 1983, IN THIS CASE?

A. Yes.

Q. WHAT IS THE PURPOSE OF THIS SUPPLEMENTAL TESTIMONY?

A. This testimony will discuss the cancellation of Cherokee Nuclear Station, Unit 1 (Cherokee 1) which has occurred since the filing of my direct testimony and the circumstances surrounding that cancellation.

Q. IS THE COMPANY ASKING FOR ADDITIONAL REVENUES OVER AND ABOVE THAT ORIGINALLY REQUESTED IN THIS PROCEEDING BECAUSE OF THE CANCELLATION OF CHEROKEE 1 AND THE PROPOSED RECOVERY OF THE ABANDONMENT COSTS ASSOCIATED WITH THAT CANCELLATION?

A. No. Our total revenue request as well as our requested 15.5 return on common equity are exactly the same as originally filed. As Mr. Stimart will demonstrate in his supplemental testimony, we have made changes in the filing to provide for the amortization of Cherokee 1 abandonment costs over a ten-year period on a basis that represents a sharing of these costs between our stockholders and our customers.

Q. WHAT WAS THE STATUS OF CHEROKEE 1 WHEN YOUR FEBRUARY 1, 1983, TESTIMONY WAS FILED?

A. In that testimony, I indicated that the new generation capacity represented by Cherokee 1 was needed, but we may not be able to provide the generation necessary to meet our customers demands by the

mid-1990s. At that time Cherokee was under limited construction without a completion schedule because there were uncertainties as to whether the additional funds could be raised to complete construction and whether the inclusion of construction work in progress (CWIP) in rate base would be assured to completion.

Q. WHAT ALTERNATIVES DID THE COMPANY HAVE WITH RESPECT TO COMPLETION OF CHEROKEE 1?

A Construction of Cherokee 1 was undertaken when we all, including the regulatory commissions of both states, thought it would be needed to supply electricity to consumers. The load forecasts for this decision were based on a dynamically growing economy and the construction and operation of Cherokee 1 would have been cost effective. Subsequent forecasts continued to support the need for Cherokee 1 generation through the early 1990s. Current forecasts now show that with the construction of the Bad Creek Pumped Storage Project, Cherokee 1 will not be needed until the mid-1990s. The Company as a result of these changing conditions realistically had three alternatives:

1) The Company could stretch out construction and bring the plant on line as needed, which would have the impact of dramatically increasing the total cost.

2) The Company could accelerate construction and complete the plant by 1990 at a much lower cost/kw; however, the plant would not be needed as a base load unit at time of initial operation.

3) The Company could cancel the construction of the plant.

Q. IN EXAMINING THESE ALTERNATIVES, WHAT MAJOR FACTORS DID YOU CONSIDER?

A. 1) The uncertainty in North and South Carolina about the treatment of carrying costs for large investments in any major generating project adds grave risk to a long-term undertaking. Cherokee 1

could not be financed without CWIP in rate base.

2) Uncertainties about nuclear regulation could increase Cherokee Unit 1's cost, but a decrease is highly unlikely.

3) Discussions with other electric companies in the region told us that we could not expect major sharing of the costs of completing Cherokee 1.

4) For alternative types of needed generating capacity, we have about five years before we need to commit, giving us time to see more of the future unfold with respect to economic development, electricity usage, regulatory commission treatment, and alternative choices.

5) Although new generating capacity represented by Cherokee 1 will be needed in the mid-1990s, that capacity can be more inexpensively provided in that time frame by other types of generation.

6) Because of lower than previously forecast growth in electric usage, our 'round-the-clock, base-load generation from the highly efficient Marshall and Belews Creek coal plants plus Oconee, McGuire and Catawba nuclear stations will probably cover our base-load requirements for the balance of this century.

7) Alternative generating capacity that can meet fluctuating daily and seasonal demands will cost half or less to build than Cherokee Unit 1, will have hourly fuel costs much higher than Cherokee, but on balance could provide the type of generation needed at lower overall cost.

Q. WHAT ALTERNATIVE DID THE COMPANY SELECT?

A. At a meeting of the Executive Committee in October, 1982, we reviewed our 1982 long-range peak load forecast and determined that the generating capacity represented by Cherokee Unit 1 would not be needed until the mid-1990s time frame; and that the financial strain would be severe if that unit were built in that time frame.

It was then clear that Cherokee Units 2 and 3 would not be needed until beyond the mid-1990s and those two units were cancelled by our Board of Directors at its meeting concluded on November 2, 1982. In view of the postponement of need for Cherokee 1 to the mid-1990s, we launched the development of up-dated estimates of its cost of completion in that time frame and the cost of alternatives. We also undertook discussions with other utilities to determine the extent of their need for capacity that might be helped by Cherokee 1. We expected our complete evaluation to be finished by July, 1983. However, in late April, 1983, review of initial results intended as input to on-going evaluations made it clear that Cherokee 1 should be cancelled. Our Board did this on April 29, 1983.

Q. ON AN OVERALL BASIS, WHAT EFFECT WILL THE CANCELLATION OF CHEROKEE 1 HAVE ON RATES?

A. We expect rates in the long run to be lower, not higher, as a result of the cancellation. This is because alternative forms of generation will have a cost advantage because of shorter construction time and the fact that alternative generation construction will not need to be commenced for several years. This decision, therefore, will benefit our customers.

Q. WHAT DOES THIS DECISION REFLECT ABOUT YOUR CONFIDENCE IN NUCLEAR ENERGY?

A. Cancellation of Cherokee in no way diminishes our confidence in the continuing outstanding contribution of nuclear energy to our region for many years to come. For base-load, round-the-clock operation, nuclear generation is preferred and our Oconee, McGuire and Catawba plants will produce electricity at lower costs than any other choice. In the years ahead, with higher public understanding of its importance and low risk, I believe our nation can resume its essential commitment to nuclear power.

Q. DO YOU HAVE A FIRM FIGURE FOR THE CAPITAL INVESTMENT IN CHEROKEE 1 TO DATE?

A. As of March 31, 1983, the North Caroina retail allocated investment, net of taxes, was $199,637,000. There will be additional cancellation costs, as well as some salvage value, but neither can be determined until negotiations are complete.

Q. PLEASE EXPLAIN FURTHER THE FINANCIAL CONSIDERATIONS THAT CONTRIBUTED TO THE DECISION TO CANCEL CHEROKEE 1.

A. Cost was the major, and decisive, consideration. For some time we have been concerned about the Company's ability to attract the necessary capital to complete construction of Cherokee. At the root of this financial concern is the fact that for several years the Company's earnings have been insufficient to support a common stock price equal to its book value. This, coupled with uncertainty about whether construction work in progress would be allowed in rate base, has reduced the odds that Cherokee could have been

financed on reasonable terms. In short, in addition to its greater cost, the financial risk of Cherokee was becoming intolerable.

Q. WHAT HAPPENS TO THE CHEROKEE SITE AND THE PURCHASED MATERIAL?

A. We will conduct a study to determine the best use of the site. It is still a potential generating site and we will sell all salvageable material.

Q. ON WHAT BASIS ARE YOU SEEKING TO RECOVER YOUR INVESTMENT IN CHEROKEE 1 IN THIS CASE?

A. When we undertook to build Cherokee, the need for that generating capacity was fully documented. Initially, the Cherokee Nuclear Station was part of what we called the "six-pack" -- three units of 1280 MW each at Cherokee and three identical units at the Perkins Nuclear Station in Davie County, North Carolina. The Company applied to the North Carolina Utilities Commission for a Certificate of Public Convenience and Necessity for construction of its Perkins Nuclear Station on July 16, 1975. Substantial opposition arose and several parties intervened in this proceeding. Hearings were held in October 1975, January 1976 and February 1977. Based on the Commission's and Duke's analyses of the need for future requirements, the Commission issued the Certificate on March 4, 1977, finding that the public convenience and necessity required Duke to construct 3840 MW of additional generating capacity before 1989. The intervenors appealed this decision to the courts. In July 1978, three years after making the Application, the North Carolina Court of Appeals affirmed the Commission's action in

granting this Certificate. Because of the long delay in receiving regulatory authority to proceed with Perkins, we elected instead to begin construction of Cherokee, which represented the same generating capacity as Perkins, in July 1976. In its 1977, 1978 and 1979 "Analysis of Long Range Needs for Electric Generating Facilities in North Carolina," adopted after hearings under G.S. 62-110.1, this Commission determined that Cherokee 1 was needed in the mid-1980s. Although the forecasted peak load demand was dropping, the Commission in each of the orders resulting from these hearings reaffirmed its belief that nuclear was the most economical baseload generation for the future. As late as April 20, 1982, in its latest analysis of the need for electric generation in North Carolina, this Commission determined that Cherokee 1 would be needed in the early 1990s. As I have stated, our long-range peak load forecast now indicates that Cherokee 1 will not be needed until the mid-1990s and I have previously explained our decision to cancel that unit.

The Company believes that the facts support that it is entitled to recover its investment in Cherokee since it was a prudent decision to commence planning and construction in view of the early 1970 load growth forecasts of the future demands upon its generating system and the need to construct generating facilities to adequately serve its present and future customers. It was also reasonable to select nuclear generation due to environmental advantages and lower fuel costs. The Company's initial decision to stretch out its construction and its ultimate decision to cancel Cherokee 1 were both reasonable and prudent in view of revised load growth forecasts, the likelihood that we would

be unable to raise the huge amounts of required capital at reasonable costs, and the financial condition of the Company. The cost-based methodology of utility ratemaking generally precludes investors in regulated companies from receiving any of the benefits of improved service or reduced cost. For this reason, the Company believes that under cost-based methodology it is entitled to recover its costs, at least to the point of not assessing the common stockholder further.

Q. WHAT PROCEDURE DOES THE COMPANY PROPOSE TO USE TO RECOVER ITS INVESTMENT IN CHEROKEE?

A. The Company proposes to recover its sunk costs not including any return on common equity during the period of recovery. This includes outlays for the interest on its debt and dividends on the preferred stock over a ten-year period on a levelized basis net of taxes. We believe this is an equitable sharing of the cost of this investment. We are not seeking a return on the equity component which is in excess of 40 percent of the investment. Mr. Stimart will discuss this in more detail in his supplemental testimony.

Q. HOW WAS THE CONSTRUCTION OF CHEROKEE FINANCED?

A. In the past this Commission has issued orders approving the sale of securities the proceeds of some of which were invested in Cherokee Unit 1. Investors relied on such orders and the Commission's orders finding that the generating capacity represented by Cherokee Unit 1 was needed to meet the demands of Duke's customers and that construction should be undertaken. It would, therefore, seem equitable that investors should at least be allowed to recover cash outlays for preferred dividends and interest on the debt components of the cost of cancelling Cherokee Unit 1.

Q. IS THE GENERATION THAT CHEROKEE WOULD HAVE PROVIDED STILL NEEDED ON THE DUKE SYSTEM IN THE MID-1990s?

A. Our current forecasts show that the electricity that this unit would have provided will still be needed in the mid-1990s. As I have indicated, in that time frame Cherokee 1 is not the most economical alternative. We do not need new base load capabilities for the early 1990s and under no circumstances would we build a Cherokee for peaking and cycling load. Since other generation requires less time to construct, we will have the opportunity to explore alternative methods of providing needed generating capacity in the 1990s.

Q. DOES THAT CONCLUDE YOUR SUPPLEMENTAL TESTIMONY?

A. Yes.

Before The

North Carolina Utilities Commission

Docket No. E-100, Sub 35



Testimony of

Dr. John O. Blackburn, Professor of Economics, Duke University
Dr. E. Roy Weintraub, Professor of Economics, Duke University

## Introduction

As professional economists, we are naturally concerned with economic analyses of important public issues. For this reason we welcome the Public Staff Report on the Analysis of Long Range Needs for Electric Generating Facilities in North Carolina, 1979. The research design, general methodology, and analysis in this third annual Staff Report are commendable, especially in such a rapidly evolving and complex field. The North Carolina Utilities Commission is fortunate to have access to such a study. The Public Staff deserves congratulations for the trained intelligence they have brought to bear on complicated issues.

Such a comprehensive study requires many assumptions, many analytical decisions, and much careful exercise of judgment. We do not wish to take issue with all minor details of the Report. We are, however, concerned about some major issues raised by the Report, related to the role of inflation-adjusted (real) electricity prices between 1979-2000. We shall show that rising inflation-adjusted electricity prices can have powerful effects on electricity demand. We believe that rising real prices of electricity, not

assumed beyond 1981 in this Report, are more likely than stable real prices. Therefore, we believe that the various estimates for electricity systematically understate real price influences, and thus overstate future demand for electricity in North Carolina. As a consequence, we believe that the Report's forecasts of future generating capacity needs will, if implemented, produce an inefficient outcome: too much electric generating capacity for future State needs.

We hope that the Commission will accept the proposition that there is no fixed long-run relationship between any or all energy inputs and output of goods and services. Such ratios may be inflexible in the short run, but given time, adjustments can be made. In a market economy, these adjustments are carried out through changing relative prices.

In a later section, we shall present our findings - that future electricty outputs are overstated, and considerably so, in the Public Staff's "most likely" forecast.

It is important to note what we are not saying. We are not saying that economic growth will cease in the U.S. or in North Carolina. We are not saying that a slower growth rate in electricity production will result in slower growth in the N.C. economy or fewer jobs. Those who assert that slower growth in energy production must mean deprivation and unemployment do not know their economics, nor have they examined the abundant evidence to the contrary. In modern industrial economies, persistently higher relative energy prices are invariably associated with greater efficiency in its use.

An analogy may be helpful. There is no fixed, long-run relationship between labor inputs and outputs of goods and services. We are all used to the notion of rising labor productivity over time, stimulated by and resulting in rising real wages. We need now only think of rising energy productivity,

stimulated by rising real energy prices.

Role of Prices in Staff's Report

The primary role of prices in the demand forecast results from the specification of the demand functions by class of user for each power company. In the case of Duke Power Company, the residential demand is partitioned into baseload demand by: a) non-electric space heating customers; b) electric space heating customers; and further by use as for: 1) space heating; 2) water heating; and 3) air conditioning. The natural logarithm of real electricity price and per capita income are used in most demand equations, and thus yield estimates of price and income elasticities of demand. Real appliance prices and real electricity prices also are explanatory variables, as are real prices of oil and gas where appropriate, or relative gas/electricity prices. All signs of the estimated price relationships are as expected. Real electricity price increases reduce demand and reductions in either electricity prices or electric appliance prices stimulate demand for electricity.

Cojoined to these price variables are other independent variables which play a role in estimating demand not only by residential users but also by commercial and industrial electricity users: per capita income, family size, employment, industrial production, textile production, and trend variables on appliance saturation.

Given the estimated demand functions, demand is then projected through the year 2000 by using various assumptions about the growth of the independent variables. For electricity prices, for instance, this means using calculated future electricity prices, and the Data Resources, Inc., consumer price index (CPI) forecast of 6.1% per annum through A.D. 2000 together with a 1980

recession forecast which generates a 1% real electricity price rise through 1981 and a 0% real electricity price rise from 1981-2000. The real price of air conditioning units is similarly forecast to fall at an annual rate of 3.1% from 1979-2000. These forecasts are assumptions, or inputs, into the demand forecasting model.

Part III of the Report provides a Generation Capacity Model designed to determine the (non-stochastic) least cost expansion path for electricity generating facilities which will meet the forecasted demand for both baseload and peak.

Part IV investigates, using the consultants' reports, the analytical modifications that will impinge on the demand forecasts, and thus the supply side, under scenarios involving various peak-load pricing schemes, load management, conservation programs, solar penetration, cogeneration, etc.

The important point is the critical role of the assumption about the future course of real electricity prices and the demand equation coefficients of the real price variables in the demand forecasts. If either the coefficients or the price assumptions are in serious error, the demand forecasts are misleading, the expansion path is inefficient, and the construction schedules are uneconomic. Moreover, the consultants' estimates of electricity conservation and displacement are considerably understated (since they, too, are dependent on electricity prices) thus further reducing the "best estimate" demand for electricity.

In the next section we shall attempt to show how the demand forecasts overstate the future electric power needs for North Carolina.

Critique of Public Staff's Demand Forecast

The first point to consider is the manner in which price enters into the regression equations for residential demand.

Electricity price elasticities in the residential sector are negative (as expected) and sizeable for space-heating, water heating, and air conditioning. While they do not appear to be large for baseload residential demand, price does enter into the space heating acceptance equation and this, as we shall see, strongly conditions the results of the staff study.

Commercial demand also has a sizeable elasticity, while indicated use elasticities, especially long-run elasticities, are substantial. The Duke and CP&L elasticities are given on pp. 45-65* and 73-88 respectively.

It should be noted that many other investigators find much higher long-run price elasticities for electricity (see Appendix I: EPRI Task Force 2, Table 6-3. Summary of Studies of Price Elasticity of Demand for Electricity.)

The forecasts of future demand growth are based on the estimated relationships and forecasts of important independent variables. Table II.A.2 on page 43 is fundamental. The starred Public Staff Forecasts are of the various real prices for the models. The real price growth was estimated using the Data Resources, Inc., estimate of a 6.1% per annum CPI growth between 1980-2000 and the Public Staff's forecast of nominal electricity price growth at 6-7%. The fundamental result which emerges is the forecasting assumption that real electricity prices will grow by 1% per annum until 1981, and 0% per annum from 1891-2000.** The sensitivity analysis of the forecast to changes in the

*Unless noted otherwise, page references are to the 1979 Public Staff Report.

**We ignore the other projected price growth rates, which, in our view, are equally misleading.

forecasted growth rates of the independent variables, performed in section II.A.7, p. 121 et seq., is based on allowing variables which grow (or decline) more than 2% per annum to vary by ± .5% per annum and those growing (or declining) by less than 2% per annum to vary by ± .25% per annum. The effect of this methodological choice is to simulate the demand model with real price varying from -.25% per annum to +.25% per annum. This is an unreasonably narrow range of price variability for several reasons, but of paramount importance is just one reason: even assuming the Public Staff's expertise in forecasting nominal electricity prices over the next two decades, small variations in the DRI forecasts of the Consumer Price Index around a 6.1% per annum growth rate will destroy the forecast methodology. What confidence should we have in the DRI forecast? Some old words are still best:

> "It would be foolish, in forming our expectations, to attach great weight to matters which are very uncertain. It is reasonable, therefore, to be guided to a considerable degree by the facts about which we feel somewhat confident, even though they may be less decisively relevant to the issue than other facts about which our knowlege is vague and scanty." Keynes, J.M., The General Theory of Employment, Interest, and Money, 1936, p. 198.

So, too, with the DRI forecast. The fact that real electricity prices have been stable or falling over a long past period is no reason for them to be stable in the future, especially when that past period consists of a distant past period of declining real electricity prices and a more recent period of increasing real electricity prices. As for CPI forecasts over a twenty-year future, we are, as professional economists, simply astounded at the alacrity with which the DRI forecast has been embedded in the Public Staff's work. Of all macroeconomic forecasts, CPI forecasts are the most notoriously unreliable, even one or two quarters ahead, let alone twenty years. Not only do we not know,

we do not as professional economists have any widely accepted theory of the inflationary process with which to judge. For this reason alone the lack of real electricity price variability in the sensitivity analysis is grossly misleading.

We think that, whatever the general inflation rate, real electricity prices are likely to rise more rapidly than was assumed in the Staff Report, as indeed they have on the average for the last eight-nine years.

New plant costs have consistently risen more rapidly than prices in general, or, for that matter, construction costs elsewhere in the economy. Fuel prices are more likely to rise in real terms than to fall, especially those of uranium. Safety and other environmental requirements will continue to add to escalation in plant costs. All of these factors have operated strongly for most of the last decade, and we see no reason to suppose that they will abate. With respect to insurance costs, it would be imprudent to base policy decisions on continuance of the Price-Anderson Act.

Other costs for nuclear operations (such as waste disposal) can be estimated but cannot be based on historical experience; there is none. They will probably turn out to be understated.

Our views are not original: An article in the Wall Street Journal (April 24, 1979, p. 1) quotes industry sources who expect nuclear electricity prices to triple in a decade - an annual rate of 11%.

We agree with the Public Staff assumption that real natural gas prices will rise. We see no reason not to assume similar increase for real electricity prices. Some estimates of these effects, which are large, need to be done with more care and staff than is possible for us. We give one estimate later in our testimony.

This lacuna in the Report is highly significant. Forecasting using a zero percent per annum real electricity price growth rate drops out price effects from the econometric forecasting model. No matter what the price elasticity turns out to be, the responsiveness of the dependent variable is irrelevant if the independent variable does not change. Consequently all the demand equations turn out to be driven by other non-price variables which are assumed to be positively related to demand growth, and which are assumed, as per page 43, to be growing at non-zero rates over the next two decades.

Some examination of the estimates of future electricity demands in gigawatt hours and their components are illuminating. They show the powerful effect of the assumptions (p. 43) and the coefficients from the econometric analysis, as well as the structure of the forecasting model.

(Our detailed discussion is for the Duke Power estimates, though similar observations apply to CP&L as well.)

The "base case" forecast for Duke Power (Staff Report, p. 71) indicates a tripling in electricity sales from 1979 to 2000; from 52,307 GWH to 157,682 GWH. The total forecasted increase is 105,375 GWH. The largest single component is Industrial, from 20,499 GWH to 71,303 GWH, an increase of 50,804 GWH, or nearly half of the forecasted increase. Residential and Commercial uses have forecasted increases of 21,231 GWH and 20,813 GWH, respectively. (All of the figures are North Carolina and South Carolina combined, since we are dealing with one entity for electric generation purposes.) Within the residential sector, the dominant component of the increase is "baseload" electricity (nearly 13,000 GWH out of the above 21,000 + GWH) rather than space heating, air conditioning, or water heating.

The industrial results follow directly from the assumptions of growth

of independent variables (p. 43) and the estimated coefficients (pp. 63-65). Electricity use rises (outside of textiles) more rapidly than production (long-run coefficients, p. 65), further rises both under the influence of ever-more-expensive natural gas (nearly doubling in real terms by 2000) and <u>no increase in the real price of electricity</u> (except for 1% in 1979-81).

The commercial forecast follows in like manner. A rapid rise in non-industrial employment with a high coefficient on that variable and <u>no increase in the real price of electricity</u>, lead directly to a three-fold increase in commercial use.

These two customer groups account for two-thirds of the forecasted increase in electricity demand. Both are quite sensitive (downward) to increases in the real price of electricity, <u>but that important variable, by assumption, has virtually no impact on the result</u>.

In the residential sector, the largest component in the increase between 1979-2000 is in baseload electricity. This results from a substantial penetration of electric heat (55%), the apparent higher baseload consumption of space heating customers, and the importance of appliance prices, assumed (p. 43) to decline steadily in real terms throughout the period. Both the penetration rate of space heating and baseload use for such customers respond to price. <u>The price assumption therefore enters twice into the most rapidly growing segment of residential use, but that important variable, by assumption, has virtually no impact on the results</u>.

To repeat, the narrow range (+.025 to -.025) in which the price variable is permitted to move in the sensitivity analysis loses important information. The failure to apply sensitivity analysis to the important coefficients just mentioned likewise loses important information.

Implications of Price Sensitivity

The sensitivity analyses already carried out (pp. 121-130) show that seemingly small changes in the variables examined produce enormous results on forecasting demand. For Duke Power (p. 123) the range between high and low estimates is 72,412 GWH, or nearly half the "base-case" forecast.

As we have seen, electricity prices are varied by ± 0.25 percentage points, being, in this study, the one variable which hardly changes over time.

Consider now an additional step. Let the real price of electricity grow at 2.5% annually through the forecast period. This is much less than the rate assumed for natural gas (p. 43) and slightly less than the actual rate for electricity from 1970-78. Further, let long-run price elasticities of 1.0 be considered. This is larger than most elasticities found in this study, but well under the median of all estimates in other studies shown in Appendix I. This would lower the "base case" forecast for Duke Power to about 90,000 or 100,000 GWH.

This is a very rough calculation, and is shown only to emphasize the necessity for examining these issues before a forecast is adopted.

It is also interesting to note that the rough estimate above is much closer to the results of engineering forecasts on p. 147. Using present rates of demand in GWH, engineering forecasts done with linear and exponential trending, and averages of trends, yield growth in GWH between 1979 and 1995 for the power companies as follows (see p. 147)

(GWH in thousands)

| | Duke | | CP&L | | VEPCO | |
|---|---|---|---|---|---|---|
| | 1979 | 1995 | 1979 | 1995 | 1979 | 1995 |
| Linear | 30 | 50 | 51 | 78 | 38 | 60 |
| Average | 30 | 64 | 51 | 90 | 39 | 85 |
| Exponential | 30 | 78 | 52 | 101 | 40 | 104 |

Further, the scenarios sketched in Volume II by the consultants at RTI and ICF both use percentage reductions in demand as a result of the various conservation, retrofit, peak-load pricing, solar penetration, and cogeneration studies. Thus the effect of a lower base case forecast through real price growth results in an even lower drop in the "most likely cast" analysis of demand growth. This is probably the best example of the interrelated nature of the Public Staff's Report through the treatment of price variables. Modifications of the price scenario do not simply modify the basic analysis, but indeed ramify throughout the Report in a complex and interrelated fashion.

One complicated point deserves mention here. The basic uncertainty so far discussed in long-term forecasts was analyzed by a sensitivity study using variations in the projected time paths of the independent variables. It is important to remember, however, that the parameter estimates of the demand relationships, which usually had elasticity interpretations, are indeed statistical estimates. The parameters can be thought of as most likely estimates from a probability distribution with certain characteristics. There are thus two sources of potential forecast error: statistical error in the parameter estimates and error in the projected time paths of the independent variables. Only the latter has been analyzed in the Public Staff's

Report, and that inadequately. It would take a moderate amount of extra work for the Public Staff to attempt a Monte Carlo study of the demand forecast to deal with parameter "uncertainty." Such a study would, however, lend much weight to the Staff's conclusions if the results were very robust. Since real electricity price variations are "washed out" of the equations, uncertainty about estimates of the responsiveness of industrial demand to industrial production indices, or residential demand to family size, may produce forecasts with enormously wide bands of confidence which will necessitate considerable care in presentation. Identical baseline demand forecasts, with wildly different 1% confidence intervals, are not equivalent forecasts.

Discount Rates

Only partially related to our primary concern about the report are several other issues which we would like to identify and comment upon.

We note than in the RTI study on insulation retrofit, payback periods under existing and modified rate schedules were developed using three separate real interest rates. In these studies, real interest rates of 4-6% were used. Using the DRI anticipated CPI growth rate of 6.1%, these real rates correspond to nominal discount rates of 10% to 12%. We note however (page 189 of the Staff Report) that some capital costs are discounted at an 8% nominal rate, or a 2% real rate. Certainly, current 10% inflation rates translate into 16% nominal rates using the 6% RTI real rate. With savings accounts yielding 5-6% in nominal terms, a 16% nominal return on insulation retrofit seems to be an overly stringent yield requirement for market penetration of insulation retrofit packages. This procedure (2%-4% real rate for utility capital costs

in the Report and 4-6% real rate for conservation in the Appendix) is an inadmissible inconsistency. Certainly the Public Staff did not intend to set higher hurdles for conservation than for new plants! We take it to be the accidental result of two studies by two staffs, studies which are difficult to reconcile in every detail.

These penetration scenarios by RTI are further weakened by the no real electricity price rise assumption discussed earlier.

Comparison of Electricity Cost from Nuclear and Coal Plants

Figures are frequently quoting assering that nuclear-generated electricity is less expensive than coal-generated electricity. These hearings are no exception. With respect to plants already operating, this appears to be so, but external effects weaken this result, given the costs and risks borne by others rather than utility companies and their customers.

The key question is: Will this still be the case for facilities now being planned to meet future demand for electricity?

The Public Staff concludes that such will be the case, though by a narrower margin than that calculated in its 1978 study (page 162).

While this is not the main concern of our testimony, we wish to point out that in at least two respects the Staff's calculations understate nuclear costs relative to coal costs (both discounted to 1978).

With respect to capital costs (Staff Report, p. 190) nuclear capital costs are based on units already under construction or well along in licensing. Coal plant capital costs, on the other hand, are based on higher-cost possible future units, since, except for CP&L until 1985, no coal units are under construction or under serious consideration.

The utilities' nuclear decisions, then, are self-validating! Since they are building or planning mostly nuclear plants, the nearer-term (relatively cheaper) nuclear capital costs are compared with more-in-the-future (relatively expensive) coal capital costs.

The proper comparison is, of course, between capital costs for coal and for nuclear plants that would be brought into service in the same year.

With respect to fuel costs, a 10% discount rate is applied to estimated future nuclear fuel costs (creating a relatively low present value in 1978) and estimated future coal costs are discounted back to 1978 at an 8% rate (creating a relatively high present value).

The proper procedure is to estimate future nuclear and coal costs, and then discount them both back to 1978 at the same discount rate.

We do not have either the time or access to enough data to estimate the effect of these two biases, both of which operate to understate nuclear costs relative to coal. Moreover, nuclear insurance costs are understated; other costs such as waste disposal and plant decommissioning probably are also.

The relative cost advantage of nuclear power is debatable, especially for new plants. (See again the Wall Street Journal, April 24, 1979, p. 1.) One authority, Charles Komanoff, calculates that nuclear power has no cost advantage.

We therefore urge the Commission to seek new estimates of future comparative costs in order to assure that the least costly mode is selected.

Summary

1. We find the Public Staff Study to be comprehensive, soundly designed, and enormously helpful to those seeking to reach judgments about future electricity demand. The staff is to be complimented. Our differences, it should be noted, are generally within the structure of the study.

2. We note an inconsistency in the use of real discount rates for generation as opposed to conservation or displacement. Though obviously unintended, they have the real effect of understating conservation or overstating generation.

3. We note computational procedures which have the effects of overstating the cost of coal-based electricity relative to nuclear electricity, though we have not had the data nor the time to compute the size of these effects.

4. Our major difference lies in the treatment of the inflation-adjusted price of electricity. We urge the Public Staff to extend its sensitivity analysis by examining, say, 1%, 2%, and 2.5% average annual growth rates in real electricity prices. We urge that at least one larger set of elasticities also be examined for the real price changes selected. <u>We have shown that one plausible combination of these leads to a reduction in estimated demand of approximately 40%</u>.

5. We urge the Commission to accept no long-range forecast until it has examined the effect of rising real electricity prices on future demand.

**Table 6-3** Summary of Studies of Price Elasticity of Demand for Electric Energy

| Analyst(s)* | Price Elasticity Short-Run | Price Elasticity Long-Run | Type of Price Analyzed | Other Important Variables in Study | Type of Data |
|---|---|---|---|---|---|
| *Residential* | | | | | |
| Houthakker | −0.89 | NE | M | Household income, gas price, appliances | City |
| Fisher and Kaysen | −0.15 | 0.0 | A | Income, gas price, stock of appliances | States |
| Houthakker and Taylor | −0.13 | −1.89 | A | Personal consumption per capita | Aggregate U.S. |
| Wilson | NE | −2.00 | A | Gas price, family income, degree days, number of rooms per house | SMSA |
| Mount, Chapman, and Tyrrell | −0.14 | −1.20 | A | Population, income, gas price, temperature | States |
| Anderson | NE | −1.12 | A | Gas, oil, and coal price, income, average family size, temperature | States |
| Lyman | (−0.90)** | | A | Gas price, price index, income, temperature | Utility service territory |
| Houthakker, Verleger, and Sheehan | −0.90 | −1.02 | M | Personal consumption per capita | States |
| Halvorsen | NE | −1.33 | A | NA | NA |
| Griffin | −0.06 | −0.52 | M | NA | NA |
| Tyrrell and Chern | NE | −0.99 | A | Income, population, gas price | States |
| Nelson | NE | −1.6 | A | Gas price, income | Cities |
| Berman and Grauband | 0.0 | −1.0 | A | Income, appliances, gas price, temperature | Customer |
| Woods | NE | −1.5 | A | Income, appliance saturation, oil and gas price, price index | County |
| FEA | NE | −0.77 | A | Gas and oil price, income, population | Census region |
| *Commercial* | | | | | |
| Mount, Chapman, and Tyrrell | −0.17 | −1.36 | A | Population, income, gas price, temperature | States |
| Lyman | (2.10) | | A | Gas price, price index, income, temperature | Utility service territory |
| Halvorsen | NE | −0.944 | A | NA | NA |
| Griffin | −0.04 | −0.51 | M | NA | NA |
| Tyrrell and Chern | NE | −1.23 | A | Income, population, oil, coal, and gas price | States |
| Woods | NE | −1.0 | A | Commercial employment, gas price | County |
| FEA | NE | −0.87 | | Gas and oil price, income, population | Census Region |
| *Industrial* | | | | | |
| Fisher and Kaysen | NE | −1.25 | A | NA | States |
| Baxter and Rees | NE | −1.50 | A | Capital, labor inputs | By industry (SIC) |
| Anderson | NE | −1.94 | A | Coal, coke, and oil price, manufacturing wage rate | States |
| Mount, Chapman, and Tyrrell | −0.22 | −1.82 | A | Population, income, gas price, temperature | States |
| Lyman | (−1.40) | | A | Gas price, price index, income, temperature | Utility service territory |
| Halvorsen | NE | −2.37 | A | NA | NA |
| Griffin | −0.04 | −0.51 | M | NA | NA |
| Tyrrell and Chern | NE | −1.28 | A | Gas price, industrial output | States |
| Woods | −0.3 | −0.7 | A | Industrial output, coal, oil, and gas price | SIC, county |
| FEA | NE | −0.33 | A | Gas, residential oil, and coal price, economic variables | Census regions |

Source: Task Force 2, *Elasticity of Demand*, Topic 2, January 31, 1977, p. 12a.

Note: NE = not estimated, NA = not available, A = average price, M = marginal price, SMSA = standard metropolitan statistical area, and SIC = standard industrial classification.

*Grouped by customer class

**Values in parentheses are estimates of combined short-run and long-run price elasticity

BEFORE THE NORTH CAROLINA UTILITIES COMMISSION
Docket No. E-100 sub 46

Direct Testimony of Wells Eddleman
for Intervenor Kudzu Alliance

My name is Wells Eddleman. I am an independent energy and pollution control consultant residing at 718-A Iredell St., Durham, NC. My business address is Rt. 1 Box 183, Durham NC 27705.

I have testified as an expert in energy systems, energy conservation, or both, in numerous NCUC dockets including the 1980-81 load forecast, general rate cases, fuel rate cases, and "used nuke" powerplant sale cases. A copy of my qualifications is attached as Eddleman Exhibit Q.

I continue to provide consulting services and reports to Energy Research Foundation, Columbia SC concerning costs, environmental and other effects, and availability/implementation of various forms of energy for useful work (end-use), with a particular emphasis on efficiency/conservation/renewable energies and their cost-effectiveness via-a-vis expansion of, or continued high use of, electrical energy. I have and continue to make load forecasts, critiques of utility load forecasts (e.g. Duke Power, CP&L), and computer programs and services for load forecasting, for the Foundation.

Palmetto Alliance Inc. has used my services as a consulting energy systems expert for some years now. I currently am providing them with analysis of power plant sales, costs/availability and planning for energy alternatives, conservation and load management, and other information. Jesse Riley and I like to joke about how the NC Utilities Commission has never recognized anyone as an expert forecaster whose forecast has been much, if any, good. In my 1983 Exhibit IONCOE-1, you'll see Jesse's 1973 and 1976 ones are still ok

If Duke Power and CP&L can indeed achieve the additional conservation they and the Public Staff estimate, the facing page shows the possible levels of peak loads and sales through the 1990s that would result assuming the Kudzu '83 forecast is correct. The results are confirmation that new powerplant construction can be delayed indefinitely if conservation, efficiency and load management are really put to work. (When new generators are needed, they should be smaller units, which are more reliable for the electric system and more suited to use of waste heat by industrial and commercial --e.g. shopping mall -- cogeneration, district heating/cooling, and the like. Such units could be fluidized bed coal-fired plants, or burn waste wood or municipal wastes as well as other renewable resources. There is plenty of time to plan for such a set of new power resources before the 1965 generation of power plants wears out around the year 2000 - 2010, if the Commission and companies will provide some leadership in the planning.)

The facing table shows CP&L peak could be held to about 7300 MW in the year 2000. Including 20% reserves, 8760 MW of CP&L resources would then be required for all times from now until the year 2000. That is less than CP&L's summer capability including Mayo 1 (8800MW). I conclude that all further CP&L powerplant construction can be cancelled. Mayo 2, not yet built, might be kept on hold as a contingency reserve, since it won't cost customers anything much in CWIP if it is delayed. Harris 1 and 2 should be scrapped as soon as possible so that the tax loss on them can be sold, to the benefit of customers and stockholders.

The situation for Duke Power is similar, except that it would be cheaper to decommission McGuire 1 now, while it's not too radioactively messy, since it won't be needed for peak (purchases Ok thru 1989 or so) and new GWh output won't really be needed until the mid-late 90s. Cherokee and Catawba are clearly avoidable, as McGuire 2. Sell tax losses.

Table 1
EXCESS COSTS OF SHEARON HARRIS PLANT OPERATION
all figures in million $

| YEAR | (1) HARRIS 1 DEPRECIATION | (2) H. 1 FIXED CHARGES | (3) H. 2 DEPR. | (4) Harris 2 FIXED CHGS. | (5) H 1 & 2 TAXES | (6) NUKE INSURANCE | (7) ADDL O&M | (8) TOTAL CHARGES[1] | (9) CP&L CLAIMED SAVINGS | (10) NET LOSS TO RATEPAYERS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 96.24 | 481.2 | -- | -- | 11 | 6 | 23 | 617 | 100 | 517 |
| 1987 | 96.24 | 462 | -- | -- | 12.5 | 6.5 | 25 | 602 | 125 | 477 |
| 1988 | 96.24 | 442.7 | -- | -- | 12.5 | 7 | 27.5 | 586 | 185 | 401 |
| 1989 | 96.24 | 423.5 | * | * | 12.5* | 7.5* | 30* | 570 | 304* | 266* |
| 1990 | 96.24 | 414.2 | 81.1 | 405.4 | 20.0 | 13 | 67 | 1097 | 311 | 786 |
| 1991 | 96.24 | 395.0 | 81.1 | 389.2 | 21.3 | 14 | 73 | 1070 | 488 | 582 |
| 1992 | 96.24 | 375.7 | 81.1 | 373 | 21.3 | 15 | 80 | 1042 | 509 | 533 |
| 1993 | 96.24 | 356.5 | 81.1 | 356.8 | 21.3 | 16 | 88 | 1016 | 504 | 512 |
| 1994 | 96.24 | 337.2 | 81.1 | 340.6 | 21.3 | 17 | 97 | 990 | 521 | 469 |
| 1995 | 96.24 | 318 | 81.1 | 324.4 | 21.3 | 18 | 107 | 966 | 485 | 481 |

TOTAL Loss: $5.024 billion

This table almost entirely based on CP&L-supplied data

constant '86$ @10%: 3368 million

Footnote 1: Conservative for reasons below and because nuclear repair, refit costs omitted

* CP&L claimed savings assumes Harris 2 operation in 1989. I have included its '89 savings but not costs.

Column 1: 4%/year depreciation times 2.406 billion CP&L 2-83 estimate of Harris 1 costs
Column 2: 20%/year fixed charge rate on undepreciated part of Harris 1 cost, each year
Column 3: 4%/year depreciation times 2.027 billion CP&L 2-83 estimate of Harris 2 costs
Column 4: 20%/year fixed charge rate on undepreciated part of Harris 2 cost, each year
Column 5: Taxes from CP&L Harris Environmental Report, page 8.1.1-2
Column 6: Nuclear liability from CP&L Environmental Report, Section 8; Nuclear property insurance at NEIL rates of about $5 million/unit per year, escalation $500000/yr
Column 7: Nuclear O&M set at 5 mills/kwh above coal, escalation 10%/year. CP&L's 6-30-82 FERC Order 48 filing with NCUC, 290.302(b)(1-24) gives (item 15) a difference of 2.8 mills/KWh for Harris nuclear above Mayo coal in variable nonfuel O&M, and (Item 10) a difference of fixed O&M (nuclear above coal) of over $17/KW-year which, using Item 22 thereof for hours/year operation (5000+ for both types) adds another 3.5 mills. I believe CP&L escalates O&M about 9%/year.
Column 8: Sum of first seven columns. Column 9: CP&L Harris Enviro. Report page 8.1.1-3 (December 1982); Column (10) is difference between columns 8 and 9.

## EXCESS COSTS OF SHEARON HARRIS NUCLEAR POWER PLANT

The Public Staff has analyzed the cost of coal and nuclear plants in this proceeding, for total cost of power produced. Their estimates of coal plant costs are consistent with Warren Owen's E-100 sub 40 testimony for Duke Power ($550/kW without additional pollution controls, 1981$, minimum) and the cost of electrostatic precipitators and with the historical 14% per year inflation rate of coal plant capital costs shown in the Staff's King (CP&L) cross-examination Exhibits in Docket No. E-100 sub 41 in December 1982.

But the Staff's nuclear capital costs are low. Consider Harris unit #1, which was $2000/kW at 12.31.79, $2222/kW at 12.31.80, and $2673/kW at 12.31.82. This unit's total cost is inflating about 10% per year compounded, below the historical 20-25% per year rate for nuclear plants. Yet the lowering may be error in CP&L's cost estimates just quoted above. At any rate, the Harris plant's cost in 1983 dollars if and when it might finally come on line, should be no less than $2700/kW. This is double the Staff's estimate for a nuclear plant.

Harris Unit 2 is inflating even faster, and has gone from $1400/kW at the time of the last load forecast, to $2252/kW at 12.31.82. I think a reasonable cost estimate for a nuclear unit in 1990 or later is now about $4000/kW in nominal dollars (as completed) and may go higher. Deflating that back to 1983 gives $1814/kW, still well above the Staff estimate. (That uses 12% discount rate, which is too high to use.) My conclusion is that CP&L's nuclear units under construction will be uneconomical.

This conclusion is also based on the Table 1 facing this page, which shows (using CP&L assumptions) that operation of Harris 1 and 2 would increase net costs to CP&L customers by over $3.3 billion in 1983 dollars by the year 1995. That's $5 billion in current dollars.

Comments on Indoor Air Pollution

Henry Hurwitz, Jr.
Anthony V. Nero, Jr.
Jan Beyea

Commentary

**Indoor air pollution**

Allegations that there has been deception in the discussion of the risks of nuclear power seem to me to carry a deception of their own.[1] Casualty projections from uncontained nuclear meltdowns, management of nuclear wastes, and mining of uranium are based primarily on the assumption that exposure to ionizing radiation is dangerous at any level. But when it develops that the seemingly benign program of encouraging people to save energy by sealing up their homes could cause even greater incremental public exposure to ionizing radiation, the nuclear power critics are inconsistently silent.

The home radiological problem arises because radioactive radon gas, which is prevalent in the natural environment, can enter buildings from the underlying soil, the water supply, and building materials. The decay products of radon are also radioactive and, being chemically active, can adhere to sensitive lung tissues. Epidemiological studies of uranium miners who worked in poorly ventilated mines have indicated that radon decay products play at least a contributory role in the incidence of lung cancer. The concentration of radon and its decay products in buildings is increased by reductions in ventilation so that, if effective mitigative measures are not deployed, energy conservation by reduced ventilation can significantly increase public exposure to this form of ionizing radiation.

Scientists in governmental laboratories and agencies such as the U.S. Environmental Protection Agency have been candid in reporting their estimates of the potentially large impact of energy conservation on lung cancer rates in the United States.[2] These estimates, based on precisely

the same methodologies that have been used to estimate the hazard of nuclear energy, have received comparatively little publicity, presumably because of the mind-set that associates increased radiological exposure with nuclear energy, but not with other human activities. EPA risk estimates published in the *Federal Register* indicate that even a modest reduction in ventilation in some fairly typical U.S. homes could cause an added lifetime risk of death by radiologically induced lung cancer of order one in a thousand.[3] (In some energy efficient homes the theoretical risk could be still greater.)

It was on the basis of this same magnitude of theoretical risk from low-level radiation that the American Physical Society Light Water Reactor Safety Study increased the draft WASH-1400 casualty estimate for a severe uncontained nuclear reactor meltdown from zero to a few hundred to over 10,000, thereby helping to congeal public perception of such an accident as an unprecedented disaster.[4]

The validity of the methods used to theoretically quantify the hazards of low level radiation has not been verified by direct observation. Therefore, the resulting estimates should be viewed as being prudent upper limits to the actual hazard. On the other hand, the recently issued report of the Committee on the Biological Effects of Ionizing Radiation (the BEIR III report) suggests that although standard methodologies probably overestimate the hazard of some types of radiation, the estimates are more likely to be correct (or possibly even underestimate) for the case of the alpha radiation emitted by radon and its decay products.[5]

Proponents of energy conservation believe that the home radiological problem can be solved with air to air heat exchangers that make it possible in principle to maintain good ventilation with minimum expenditure of energy. But, as of now, the public has not been systematically apprised of the desirability of such mitigative measures.

Perhaps as a result of efforts of the various research groups and committees studying the indoor air pollution problem,[6] more energetic mitigative actions will be taken.[7] Meanwhile, the contrast between the relatively low key approach to the indoor radiological problem and the frenetic concern over low level radiation from the nuclear industry is giving the public an entirely incorrect perspective of relative hazards from energy conservation and energy generation.[8]

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1. Bruce L. Welch, "Deception in Nuclear Power Risks: A Call to Action," *Bulletin*, Sept. 1980, pp. 50-54.

2. Lisa B. Belkin, "Warning: Home Energy Conservation May Be Dangerous to Your Health," *National Journal* (Aug. 2, 1980), p. 1274.

3. *Federal Register*, 45 (April 22, 1980), Table I(A), p. 27371. The EPA uses the working level (WL) unit to measure concentration of radon decay products. On the basis of relative risks methodology, the lifetime risk estimate for residence in a home with an 0.01 WL radon decay product concentration is quoted as 1 percent. Measured radon decay product concentrations in homes frequently exceed 0.004 WL so that a further 25 percent increase due to reduced ventilation could occasion an added 1 in 1,000 imputed lifetime risk. While this may be an overestimate of risk by an order of magnitude, similar or larger factors of conservatism probably exist in estimates of the risks from nuclear energy. (See note 5.)

4. *Reviews of Modern Physics*, 45, sup. 1 (Summer 1975), Table XLIII, n.a., S108.

5. BEIR Committee, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," (Washington, D.C.: Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, July 1980), p. 4.

6. The Federal Radiation Policy Council has established a task force to consider problems associated with control of naturally occurring radon. See *Federal Register* 45 (June 27, 1980), p. 43509.

7. One possibility is to require that government subsidies or tax incentives for home energy conservation be contingent on actual measurements of indoor radiological levels, and the adoption of remedial actions where appropriate. The action level will probably be established in the radon decay product concentration range of 0.01 WL. This would imply acceptance of a prudently estimated upper limit to incremental lifetime risk of 1 percent.

8. Lack of concerted action to mitigate the indoor radon problem might be justified by increasing radiological exposure levels to the general public by a substantial factor. On the other hand, R. Alvarez has criticized the European Economic Community for adopting a 5 rem single organ exposure limit (*Bulletin*, Nov. 1980). This corresponds to approximately 5 picocuries per liter radon concentration which has been found to be exceeded in some energy efficient homes.

• • •

The risk estimate that Henry Hurwitz attributes to modest decreases in ventilation rates in U.S. homes is substantially correct. As he notes, there are considerable uncertainties about it, as there are about the effects of doses that would be associated with nuclear reactor accidents.

What Hurwitz does not point out is that although the health effects attributed to alpha doses may have a firmer foundation than those associated with penetrating radiation, the actual dose and dose distribution associated with exposures to radon daughters is highly uncertain. Hence it is possible—because of the size distribution of particles to which radon daughters are attached, because of possible synergisms with smoking, and so on—that the actual doses from radon daughters, and hence the estimated health effects, are substantially different from EPA estimates (and those of Hurwitz). Hence, even presuming that the dose response model for alpha irradiation is correct, the actual doses and health effects could be considerably lower. As it turns out, however, they can't be considerably higher, because the observed lung cancer rate among those who don't smoke is so low.

Furthermore, Hurwitz neglects to point out that even modest attention to present indoor radon levels (for

example, a screening element associated with programs to save energy) could identify areas in which levels significantly higher than 0.01 working level, which Hurwitz suggests as an "action level," occur with some frequency. The result would be that energy conservation programs, by directing remedial action to those who need it, could actually *lower* indoor exposures to radon daughters. This constitutes a notable difference from nuclear power, where in fact most of the concern is over potentially large exposures that are much more significant than those that occur in homes—energy-conserving or not.

Nevertheless, Hurwitz is certainly correct in suggesting that the public is much more ready to believe risks attributed to nuclear power than those risks attributed to other technologies, including energy conservation. A consistent treatment of these risks requires that, within each technology, the social costs and benefits be properly treated, after which the various technologies may be compared. Although Hurwitz may not realize it, that is what happened for nuclear power and what is now happening for energy conservation.

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• • •

To avoid confusion about the health risks from energy conservation, it should be noted that only those energy saving measures which actually reduce ventilation rates in buildings increase exposure to radon and other indoor pollutants. Some conservation measures (such as the addition of weather stripping) are aimed at reducing ventilation rates while others (such as the addition of insulation to hollow walls) may do so in some houses as a by-product of reducing conduction losses.

In any case, it turns out to be difficult to decrease ventilation rates in existing U.S. buildings *even if one tries very hard to do so.* I say this based on several years' experience in the energy-conservation-in-housing program at Princeton University.

In the past, most U.S. houses have been built with so many openings in the frame that, unless special equipment is available, it is virtually impossible for the ordinary contractor doing business today or the ordinary homeowner to locate enough of the openings to decrease the ventilation rate by more than about 10 percent. Thus, current retrofit efforts by insulation contractors and homeowners are not likely to cause a serious increase in the radon problem. Any slight potential increase in risk corresponding to a slight decrease in average ventilation rates can be eliminated by telling people to keep a few extra windows open in those seasons when the heating and cooling systems are turned off.

In the future, experienced "house doctors," using special equipment, may well be able to prescribe house-specific conservation measures with the potential of 25 to 50 percent decreases in ventilation. However, we can insist—as Anthony Nero and others have suggested—that such house doctors be equipped with radon detectors to identify those houses with large concentrations of radon and to prescribe remedial measures when necessary.

Typical radon concentrations in U.S. houses are only about five times the average outdoor radon concentration,[1] but some houses register readings 30 times the median value.[2] Reduction of the radon source strength by the use of sealants or use of forced ventilation techniques in high-risk houses would cause a net reduction in the total number of delayed health effects attributable to radon.

Although I am not overly concerned about *older* housing, I am worried about the tighter construction techniques that are being used in the frames of *new* houses. Here, I believe, we will see a significant lowering of natural ventilation rates as a result of energy conservation efforts. Perhaps, to avoid increased risk from indoor air pollutants, it will be necessary to require forced ventilation or to advise residents of new housing to keep some windows open slightly—even in winter.

However, concern about indoor air pollution need not compromise U.S. energy conservation efforts. In the first place, the amount of energy needed to condition incoming air is generally less than the conduction losses through the frame and windows, so that maintaining average ventilation rates at historic levels will still leave an enormous potential for energy savings. Furthermore, outgoing energy in ventilation air can be recovered and transferred to incoming air by using the air-to-air heat exchangers mentioned by Hurwitz.

As an alternative to increasing ventilation in new housing, we can insist (through regulation) that tight construction practices in basements be used at the same time that tight construction practices are used above ground. Such regulations would reduce the radon source strength and, therefore, the net risk in those (many) parts of the country where radon seepage from soil is a much larger contributor to the total concentration than the contribution from building materials and other sources.

It should be clear from the discussion that there are a number of remedial measures which can be taken to eliminate the unwanted side effects from energy conservation efforts in housing. However, if the knowledge that such techniques exist serves only to relax policy-makers and environmentalists rather than to guide them to action, Hurwitz will be correct in his

accusations that the approach to the radon problem has been "low key."

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1. A. C. George, A. J. Breslin, "The Distribution of Ambient Radon and Radon Daughters in Residential Buildings in the New Jersey-New York Area," paper presented at DOE/UT Symposium on the Natural Radiation Environment III, Houston, Texas, April 23-28, 1978.

2. J. Rundo, F. Markun, and N. J. Plondke, "Some Determinations at Argonne National Laboratory of Radon in Houses," *Radon in Buildings*, National Bureau of Standards, Special Publication 581 (Washington, D.C. 20402: GPO, 1980).

Jan Beyea and Frank von Hippel

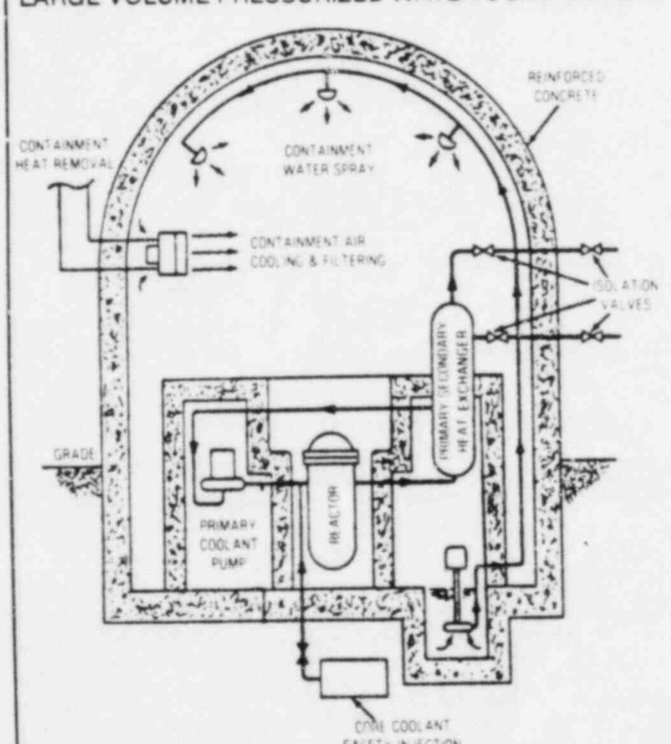
# Containment of a reactor meltdown

Any good scientist or engineer believes implicitly in Murphy's law: "If something can go wrong, sooner or later it will go wrong." The U.S. Atomic Energy Commission, which until 1975 had the responsibility for ensuring the safety of U.S. civilian power reactors, had many good scientists and engineers involved in its work. And during its history it repeatedly considered the consequences of all the safety systems in a nuclear reactor failing, the fuel melting and the volatile radioactive isotopes in the fuel being released to the atmosphere.

The answer which came back from major studies in 1957 [1], 1965 [2] and 1975 [3] was always that the consequences could be very serious indeed. This finding underlined the importance of preventing nuclear reactor meltdown accidents. As a result, the Atomic Energy Commission and the Nuclear Regulatory Commission (NRC), its successor in the area of nuclear safety regulation since 1975, required so many redundant safety systems on nuclear power plants that both nuclear regulators and the nuclear industry became convinced that the likelihood of a reactor meltdown accident had been reduced to a negligible level.

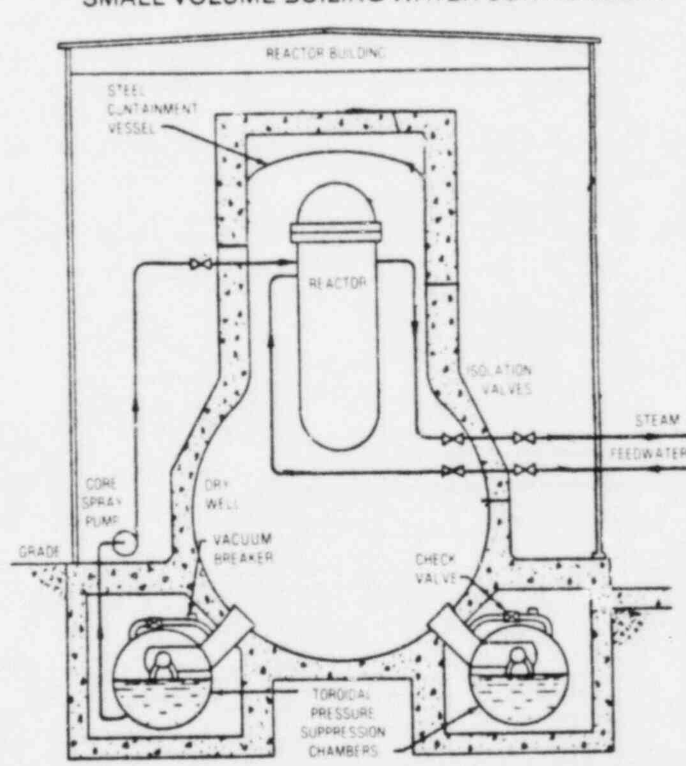
The massive failure of safety systems and the associated confusion which has occurred repeatedly at nu-

Figure 1
LARGE VOLUME PRESSURIZED WATER CONTAINMENT




Because of its large volume (about 60,000 cubic meters), this containment can hold all of the steam released in the first minutes of a loss of coolant accident. Subsequently steam pressure should be reduced by the containment water sprays.

Figure 2
SMALL VOLUME BOILING WATER CONTAINMENT




The combined volume of the dry well and the connected free space over the pressure suppression pool is only one eigth that of the containment shown in Figure 1. Steam from the dry well bubbles through the water in the pressure suppression chamber and is condensed. This could prevent overpressurization by steam but not by other noncondensable gases such as hydrogen and carbon dioxide.

*Source*: T.J. Thompson and J.G. Beckerly, *The Technology of Nuclear Reactor Safety*, vol. 2, chap. 21 (Cambridge, Mass.: MIT Press, 1973).

**So many tens of billions of dollars had been invested in plants which were already operating or in an advanced stage of construction that nuclear safety authorities were unwilling to question the basic safety design features of nuclear power plants.**

clear power plants since 1975 – with serious damage resulting at Brown's Ferry in 1975 [4] and Three Mile Island in 1979 [5] – have, however, thrown this confidence into question. Our purpose here, therefore, is to draw wider attention to the possibilities for increased public protection offered by the last barrier between the radioactivity released from a molten core and the outside world: the reactor containment building.

*The containment.* Reactor containment buildings are both massive and well-equipped (Figures 1 and 2). Most are designed to withstand internal pressures of three to four atmospheres and may maintain their integrity at more than six atmospheres internal pressure. They also have water sprays, water pools or compartments full of ice – whose purpose is to reduce pressures by removing steam from the containment atmosphere.

Reactor containment buildings today are not designed to contain a reactor core meltdown accident, however. Their "design basis accident" is a loss-of-coolant accident in which large amounts of volatile radioisotopes are released from a temporarily overheated core, but in which the uncontrolled release of energy from the core into the containment atmosphere is terminated by a flood of emergency core cooling water before an actual meltdown occurs. This is essentially what happened during the accident at Three Mile Island although, due to various errors, the core remained only partially cooled for a period of hours.

*The threat of overpressurization.* If for any reason the emergency core cooling system were not effective and a core meltdown occurred, the build-up of internal pressure in a sealed reactor containment building could rupture it within a matter of hours. The threat would come from steam, hydrogen and other gases.

For an extended period of time after a reactor shutdown, the radioactive fission products in a reactor core generate heat at a rate great enough to turn hundreds of metric tons of water into steam per day (Figure 3). It would take only about 300 metric tons of steam to increase the pressure inside even a large (60,000 cubic meter volume) Three Mile Island type of containment building by about ten atmospheres. It is apparent, therefore, that unless the containment cooling system operates reliably and effectively to keep this steam pressure from building up, the containment will quickly be overpressured by steam alone [6].

Hydrogen is another potential contributor to the pressurization of the containment. It is produced when water or steam comes into contact with a metal which binds oxygen so strongly that the metal can take oxygen away from water molecules. Because it absorbs relatively few neutrons, one such metal, zirconium, is the structural material of choice used in the cores of water cooled reactors. Zirconium starts reacting rapidly with steam at temperatures above 1,100°C. About one half the zirconium in the core of Three Mile Island Unit No. 1 was oxidized during the accident there [7].

For a small volume (boiling water reactor type) containment, the mere pressure developed by the amount of hydrogen generated at Three Mile Island would have been enough to raise the containment pressure by one to three atmospheres.

For a large volume containment, the principal hazard associated with the hydrogen would be fire or explosion, and in fact the hydrogen did burn at Three Mile Island. Fortunately, however, the initial pressure in the containment building was such that the containment was able to withstand the resulting pressure increase of about two atmospheres. Some existing reactor containments would not have withstood the pressure rise associated with the burning of this much hydrogen – even given an initially low pressure.

In small boiling water reactor containments the probability of a hydrogen fire is eliminated by "inerting" the containment with an atmosphere of pure nitrogen. This is not done, however, in ice condenser containments which are designed to withstand much lower internal pressures than most other containments. On September 8, 1980, during a final review of the design of Sequoyah Nuclear Power Plants, Units 1 and 2 (which are equipped with ice condenser containments) the NRC's watchdog, the Advisory Committee on Reactor Safeguards, pointed out in a letter to the Commission that: "For events involving more than 30 percent oxidation of the zirconium, hydrogen control measures may be necessary to avoid containment failure."

The remaining threat to containment integrity from overpressurization during a core meltdown accident would arise from the carbon dioxide and carbon monoxide liberated as the molten core melted its way down through the concrete basemat of the reactor building [8; 9].

This listing is sufficient to suggest why one of today's small volume reactor containment buildings would probably rupture during a core meltdown accident and why there is a significant, although less certain, probability of failure for a large volume pressurized water reactor type containment [3].

*The regulatory response.* The situation we have just described was first explored by an Atomic Energy Commission advisory committee in 1966 when the AEC was just beginning to license the construction of today's large commercial power reactors. The advisory committee recommended in its report, however, that the Commission should undertake only "a small-scale, tempered effort on [the]

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problems . . . associated with systems whose objective is to cope with the consequences of core meltdown. . . ." The committee did not recommend a crash program on the development of better containments because it felt that "to produce effective designs, if indeed feasible, might require both considerable fundamental research and practical engineering application." Instead, the committee advised the Commission that "for the time being, assurance can be placed on existing types of reactor safeguards, principally emergency core-cooling" [10].

The Commission accepted this advice and went ahead with the licensing of containment buildings whose integrity depended upon the successful functioning of emergency core cooling systems. A small amount of research was conducted for a time into the possibility of improved containment concepts. As the Commission certified time after time that existing containment designs were adequately safe, however, this research was phased out.

Periodically, the issue of improved containment designs was brought up by outsiders. For example, in 1975 the American Physical Society Study Group on Light Water Reactor Safety recommended that "more emphasis should be placed on seeking improvement in containment methods and technology" [11]. By that time, however, so many tens of billions of dollars had been invested in nuclear power plants which were already operating or in an advanced stage of construction, that the nuclear safety authorities were unwilling to question the basic safety design features of nuclear power plants.

This attitude was expressed in a memorandum written on September 25, 1972 by Joseph Hendrie, then Deputy Director for Technical Review of the Atomic Energy Commission. Hendrie was responding to the suggestion by a senior member of the Commission staff, Steven Hanauer, that because of the safety disadvantages of small volume containment buildings such as the General Electric boiling water reactor pressure suppression containment shown in Figure 2 and the ice condensor pressure suppression containment design being proposed at the time by Westinghouse, "I recommend that the AEC [Atomic Energy Commission] adopt a policy of discouraging further use of pressure suppression containments." Hendrie's response is reproduced in full below:

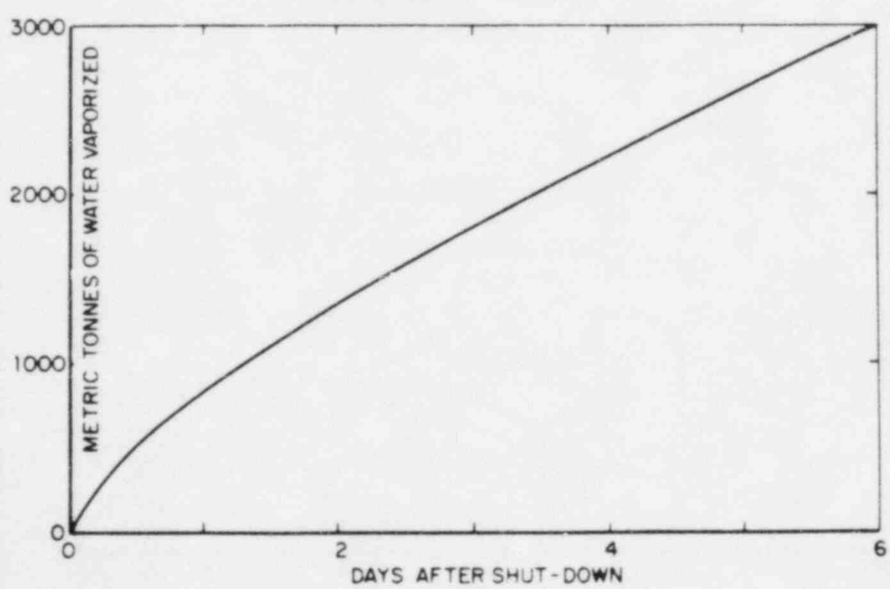
"With regard to the attached, Steve's idea to ban pressure suppression containment schemes is an attractive one in some ways. Dry containments have the notable advantage of brute simplicity in dealing with a primary blowdown, and are thereby free of the perils of bypass leakage.

However, the acceptance of pressure suppression containment concepts by all elements of the nuclear field, including Regulatory and the ACRS [Advisory Committee on Reactor Safeguards], is firmly imbedded in the conventional wisdom. Reversal of this hallowed policy, particularly at this time, could well be the end of nuclear power. It would throw into question the operation of licensed plants, would make unlicensable the GE and Westinghouse ice condensor plants now in review, and would generally create more turmoil than I can stand."

This memorandum became public as a result of a Freedom of Information Act suit by the Union of Concerned Scientists reinforced by Congressional pressure following Hendrie's appoint-

Figure 3

POTENTIAL STEAM PRODUCTION BY RADIOACTIVE AFTER-HEAT (1000 MEGAWATT REACTOR)




The figure shows the cumulative amount of water which would be evaporated by the radioactive after-heat generated after shut-down by the core of a typical modern 1,000-megawatt light water reactor. In the absence of heat removal from the containment, the steam pressure so generated would threaten the containment integrity within hours.

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ment to the chairmanship of the Nuclear Regulatory Commission in 1977.

*Filtered vents.* As more and more nuclear power plants went into operation, the attention of those who wished to improve reactor containment designs turned to safety systems which could be "retrofitted" onto existing plants and to one specific idea in particular. This was a "filtered vent" system which could relieve the pressures inside a dangerously pressurized containment building by releasing some of its radioactive gases to the atmosphere through a large filter system. There the most dangerous radioactive species would be trapped before the filtered containment gases were allowed to escape. It would be relatively easy to add such a system onto an already completed containment building because the filter system could be installed in a separate building outside the existing containment building and connected to it through a large valve and underground pipe (Figure 4 [12]).

The installed cost of one of these systems has been estimated to be between $1 million and $20 million per reactor, an amount which is small in comparison with the more than $1 billion total cost of a modern nuclear power plant [13].

Despite these attractive aspects of the vented containment concept, the Nuclear Regulatory Commission proceeded to investigate it extremely slowly and cautiously. While the Commission's slowness can only be deplored, its caution is appropriate: prescriptions for nuclear safety, like those for drugs, should be both safe and effective and the staff has concerns in both areas.

In the area of effectiveness the staff's concerns focus on the possibility that in certain accident sequences the pressure buildup inside the containment might be so rapid that no exhaust system of realistic size could release gas fast enough to save it. The pressure rise associated with a hydrogen fire could, for example, be very rapid. Rapid increases in steam pressure could also occur within the containment of a pressurized water reactor as a result of sudden contacts between large amounts of molten core and large amounts of water.

According to current ideas, a melting reactor core would not drip away. Instead, it is believed more likely that a large fraction of the core would suddenly collapse and fall into the water remaining at the bottom of the reactor pressure vessel. In the past there has been concern in the reactor safety community about such an event resulting in a "steam explosion" violent enough to propel the top of the reactor vessel through the shell of a containment building. This concern has been downgraded in most recent studies but inside even a large containment building a rapid increase in pressure of about one atmosphere could occur.

In some scenarios, where the primary pressure system around the reactor core and its attached piping remain intact until the core actually melts through the pressure vessel, the melt-through would relieve the steam pressure in the primary system, with the result that certain water in the system would be mobilized and pour into the pressure vessel on top of the molten core. This could cause a rapid pressure rise of one to three atmospheres. And finally, after melting through the pressure vessel, the molten core could, once again, fall into a pool of water collected in the cavity below the vessel. Another rapid increase in pressure could then result [9, 1].

There appear to be strategies that can reduce the threat of containment failures resulting from such pressure increases if in fact further analysis should establish this threat as a serious one: Indeed, the Nuclear Regulatory Commission is already beginning to require hydrogen "igniters" capable of burning any accumulating hydrogen in stages before concentrations can build to levels where a single fire will be intense enough to endanger the containment. The magnitude of some of the steam pressure rises associated with core meltdowns in pressurized water reactors could also be reduced by relieving the pressure in the primary system and flooding the

Figure 4[12]

GENERAL ARRANGEMENT OF A PWR FILTERED VENT SYSTEM


If the pressure inside the containment climbed to dangerous levels, the isolation valves could be opened and some of the containment gas released through sand and activated charcoal filters.

## As more and more nuclear power plants went into operation, attention turned to safety systems which could be retrofitted onto existing plants. . . .

containment building with water to a level which covers the pressure vessel when a meltdown appears inevitable. And, as we have seen, a filtered vent would make possible still another strategy: early venting so as to reduce the pressure base on which any subsequent sudden pressure increases would build.

The possibility of early venting is two-edged, however, because it requires a judgment that nothing else can be done to prevent a major release of radioactivity. That judgment might be wrong or the filtered venting system might even operate accidentally. The resulting releases would be dominated by the non-filterable radioactive noble gases which would contribute about one-thousandth of the cumulative radiation dose from an uncontained meltdown accident. The Commission's safety concern about filtered venting, therefore, focuses on the fact that a filtered vent system, while offering some protection against large releases of radioactivity to the atmosphere would also increase by an uncertain amount the frequency of public exposure to very much smaller releases.

This concern is akin to the one about automobile seat belts – that by slowing a passenger's escape from a vehicle in some accident situations, a seat belt could contribute to rather than prevent a death. But seat belts, as we know from statistics, save vastly more lives than they endanger. In the case of reactor core meltdown accidents we (fortunately) have no statistics yet. The Commission will, therefore, have to make a careful judgment. It seems likely that the final conclusion will be that, for a well-designed system, the reduction in the risks of large releases will greatly exceed the increased risk of small releases. At the current level of effort, however, it will take many years before thorough safety analyses have been concluded on each major type of reactor containment; and then more years may be taken up in conducting specific safety analyses on each plant chosen as a candidate for retrofit.

*The industry response.* In response to the Three Mile Island accident, the U.S. nuclear industry could have put

### An area the size of Connecticut

Among nuclear power opponents one of the most widely used characterizations of the hazard from reactor accidents is based on a quote from the files of the long-suppressed 1965 Atomic Energy Commission study on reactor accident consequences: "The possible size of such a disaster might be equal to that of the state of Pennsylvania"[2].

What exactly would happen over this area?

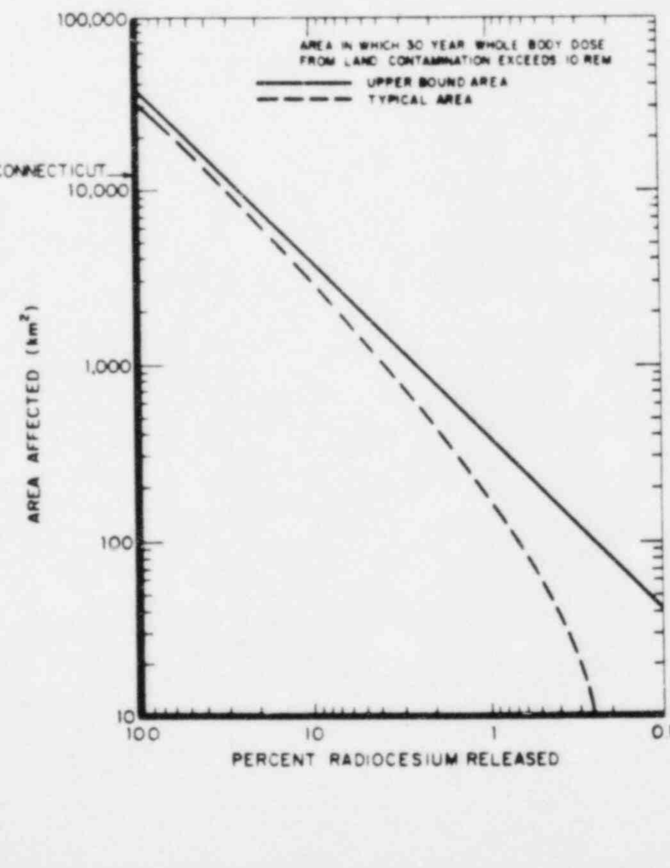
The study found – as have many studies since [3, 11, 20] – that the most widespread danger from a reactor accident would be thyroid damage from the ingestion of radioactive iodine. Milk might be contaminated with radioiodine above the protective action limits specified by the Federal Radiation Council over "areas which would range from 10,000 to 100,000 square kilometers" [2]. The area of Pennsylvania is 115,000 square kilometers; hence the comparison.

The problem of milk contamination by radioiodines appears to us to be a relatively manageable one [21], so we focus instead on two potential consequences of reactor core meltdown accidents which are less manageable than milk contamination and could also affect huge areas. These are the hazards of long-term contamination of land and property by radioactive cesium; and thyroid damage resulting from the inhalation of radioactive iodine-131.

For land contamination we have set the threshold at a standard level corresponding, in the absence of decontamination, to a cumulative whole-body dose from penetrating external gamma radiation of 10 rem to any resident population over the first 30 years following the accident. (The duration of land contamination will be dominated by 30-year half-life cesium-137.) This 10-rem dose would be approximately three times higher than the average whole-body dose from natural background radiation over the same period and might cause on the order of one extra cancer death among every 1,000 people exposed at that level [22].

In the case of thyroid irradiation we have chosen a

Figure 5



**. . . a filtered vent system could relieve the pressures inside a dangerously pressurized containment building by releasing some of its radioactive gases through a large filter system.**

its own resources into investigating the possibilities for the reduction of radioactive releases following core-melt accidents. Unfortunately, it did not. Instead, the industry mounted a concerted campaign to convince both the public and government that, even in case of containment failure, the resulting release of radioactivity to the atmosphere would be much less than has always been thought. In particular, the electrical utilities' Electric Power Research Institute published a study which concluded, in effect, that improved containments were not necessary [14].

The Institute report claimed that, even in the event of a core meltdown accident and a containment failure, "due to the solubility of the volatile fission product compounds and the aerosol behavior mechanisms, the off-site dispersion of radioactive materials (other than gases) following a major LWR [light water reactor] accident will be small." The electric utilities' public relations departments and the nuclear industry press sprang into action and advertised these claims with great fanfare, noting that "If findings like these are verified . . . it would go far toward deflating the doomsday predictions of anti-nuclear groups" [15]. The Nuclear Regulatory Commission, aside from a few staff comments in the trade press, expressed no public reservations concerning the significance of these claims, which tended to give them further credibility.

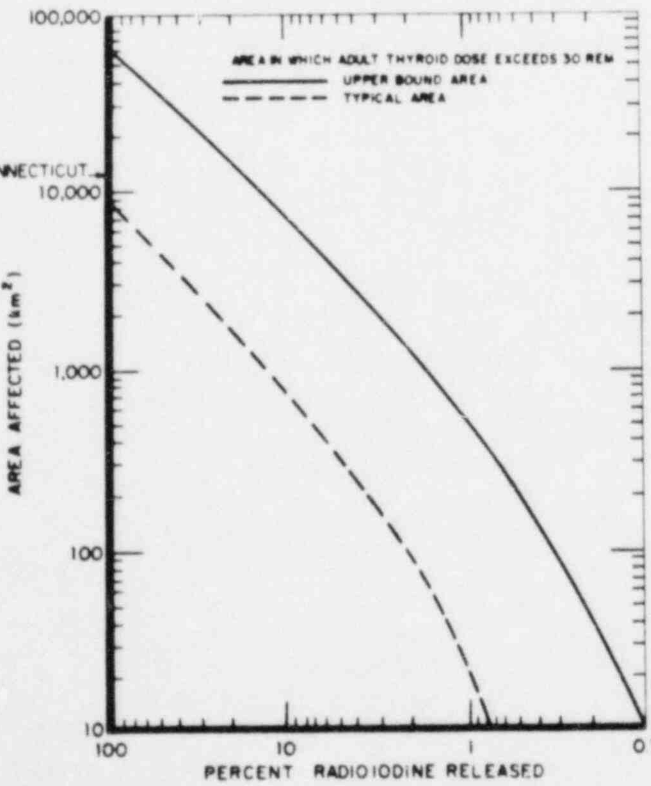
The Commission did, however, authorize an effort to examine the Institute's claims as a collaborative enterprise between Commission staff members and technical experts at three major national laboratories. In March 1981 this team stated in a draft report:

"The results of this study do not support the contention that the predicted consequences of the risk dominant accidents have been overpredicted by orders of magnitude in past studies. For example, the analysis in this report indicates that . . . 10% to 50% of the core inventory of iodine could be released to the environment" [16].

Under pressure from the industry, the

threshold dose from inhalation of 30 rem for adults. The Environmental Protection Agency's guideline threshold dose to the thyroid for mandatory evacuation is 25 rem [23]. The dose to the thyroids of exposed children in the same area might exceed 150 rem [24]. For an X-ray dose of

Figure 6




150 rem to a child's thyroid, the probability of subsequent thyroid surgery has been found to be on the order of a few percent [25].

There has been less follow-up on the consequences per rem to the thyroid of internal beta-radiation emitted by iodine-131. The U.S. Food and Drug Administration, therefore, assumes that iodine-131 irradiation is as damaging to the thyroid per rem as X-ray radiation [26].

Figures 5 and 6 show, as a function of the percentage released into the atmosphere of the inventories of radioactive cesium and iodine from the core of a modern commercial power reactor "typical" and realistic upper bound areas over which the long-term doses from ground contamination and the thyroid inhalation doses would exceed the thresholds specified above [27]. The upper bound curves in the figures are about the highest which can be obtained for reasonable choices of parameters using the standard simplified model for atmospheric dispersion. We show no lower limit for the area which could be affected because it could be essentially zero. A heavy rain could, for example, scrub the radioactive aerosols from the air soon after they were released from the containment.

For an uncontained meltdown, most studies predict that from 10 to 90 percent of the radioactive iodines and cesiums in the core could be released [3, 16]. It is apparent from figures 5 and 6 that the area affected by such releases with doses above the specified thresholds could be on the order of 10,000 square kilometers. Even if this is closer to the area of the state of Connecticut than Pennsylvania, it is still a very substantial area. It is also apparent that the areas at risk could, for example, be decreased by about one hundredfold if reactor containment systems could be made effective enough to reduce any releases to less than one percent of the core inventories [28]. □

**The industry is concerned that accident mitigation techniques, such as off-site preparations for emergencies and retrofitting with filtered venting systems, could be interpreted as tacit admissions that serious accidents can happen.**

Commission subsequently rewrote the summary language so that it no longer appeared to be a rebuttal to the Electrical Power Research Institute report. Nevertheless, the technical conclusions remained the same.

*The role of public pressure*. There are by now many examples of public pressure being required to offset the paralyzing effect of industry opposition to nuclear safety initiatives—especially when the purpose of the initiatives is to mitigate the consequences of nuclear reactor accidents. The industry is apparently concerned that the adoption of accident mitigation techniques, such as off-site preparations for emergencies and retrofitting containment buildings with filtered venting systems, could be interpreted by the public as tacit admissions that serious accidents can happen.

It was only after Congressional pressure developed for improved emergency planning in the aftermath of Three Mile Island, for example, that the Commission converted the recommendations of a Nuclear Regulatory Commission/Environmental Protection Agency task force report into Commission policy and extended the emergency planning zone for accidents out to 16 kilometers from reactors.

In Sweden, it appears that the political pressure of that country's debate over nuclear power may have already forced a decision in the case of filtered venting. Prior to that country's March 1980 referendum on the future of nuclear power the pro-nuclear side was eager to support every safety measure proposed by a special Swedish government committee of enquiry, created after the Three Mile Island accident. Filtered venting was one measure recommended by this committee. After the referendum, the Swedish government, noting that subsequent studies had failed to uncover any basis for a reconsideration of this decision, indicated in a parliamentary bill that it would move forward to implement filtered venting starting with the Barsebäck reactor located just 20 kilometers across the sound from Copenhagen [17].

Without the pressure of a political referendum, it is doubtful that progress on filtered venting would have been any faster in Sweden than it has been in the United States.

Unfortunately, there are no comparable political events on the horizon in the United States. It is possible, therefore, that it will take an accident more serious than Three Mile Island to overcome the inertia that is holding back further development of containment improvements in this country. If a large release of radioactivity occurs in such an accident, the U.S. nuclear industry may well follow the example of its Swedish counterpart and endorse containment improvements in an attempt to salvage a future for nuclear power in the United States.

The prognosis for our society will be bleak, however, if we protect ourselves only after experiencing every variety of disaster. It is, therefore, to be hoped that the Commission and its watchdogs will press ahead with work on accident consequence mitigation strategies from the "study" stage to the decision stage.

The Commission received exactly this recommendation from its Three Mile Island "Lessons Learned Task Force" in October 1979:

"The Task Force recommends . . . that a notice of intent to conduct rulemaking be issued to solicit comments on the issues and specific facts relating to the consideration of controlled, filtered venting for core-melt accidents in nuclear power plant design and that a decision on whether and how to proceed with this specific requirement be made within one year of the notice" [18].

The Commission, however, did not commit the necessary resources. Now, almost three years later, it is further away from such a decision than it was then.

The Commission could also be pressured into adopting the recommendation made to it in a September 10, 1980 letter from its Advisory Committee on Reactor Safeguards: that it proceed without further delay to require utilities to do design and risk reduction studies with regard to the installation of filtered vent systems on their nuclear power plants [19].

Of course the filtered vent strategy should not be pursued to the exclusion of other containment improvement strategies which may also prove useful. We have focused on the vented containment concept here because it is specific evidence for our more general contention that there is a great potential for enhancing the capabilities of reactor containment buildings to retain the radioactivity from accidents which might otherwise contaminate an area "the size of Connecticut." [See box.] □


1. U.S. Atomic Energy Commission, *Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants*, WASH-740 (1975).

2. U.S. Atomic Energy Commission, *Documents Relating to the Re-examination of WASH-740*. Approximately 200 unpublished documents, dating from 1964 to 1966, were made available to the public in the Commission's public document room in 1973 as a result of suits and threats of suits under the Freedom of Information Act. See also David Burnham, "A.E.C. Files Show Effort to Conceal Safety Perils," N.Y. Times (Nov. 11, 1974).

3. U.S. Nuclear Regulatory Commission, *Reactor Safety Study* (Washington, D.C., WASH-1400 or NUREG-75/014, 1975). Initiated by the Atomic Energy Commission, this study was published in its final form by the Nuclear Regulatory Commission.

4. U.S. Congress, Joint Committee on Atomic Energy Hearings, "Brown's Ferry Nu-

**It is possible that it will take an accident more serious than Three Mile Island to overcome the inertia that is holding back further development of containment improvements.**

clear Plant Fire" (Sept. 16, 1975); Daniel F. Ford, Henry W. Kendall, Lawrence S. Tye, *Brown's Ferry: The Regulatory Failure* (Cambridge, Mass.: Union of Concerned Scientists, 1976).

**5.** *Report of the President's Commission on the Accident at Three Mile Island* (1979).

**6.** We have assumed containment atmosphere temperatures of about 150 degrees Centigrade in these calculations.

The free volume in a containment typical of those used in most operating U.S. boiling water reactors is about 7,900 cubic meters. The *effective* free volume of boiling water reactor containments may be less than half of their nominal volumes, however, since the volume over the pressure suppression pool is connected to that of the "dry well" by what amounts to a one-way valve. Therefore, it would be possible, in principle, for steam to drive the "noncondensable" gases into the 40 percent of the total free volume over the pressure suppression pool, leaving the pressure in that chamber at a much higher level than in the dry well surrounding the reactor vessel after the steam condensed. (See Figure 2 for a representation of these chambers in a boiling water containment. The range of pressures cited in the text allows for this possibility.)

**7.** In the Three Mile Island accident an estimated 44 to 63 percent of the 22,600 kilograms of zirconium in the core were oxidized. See *Report of the President's Commission on the Accident at Three Mile Island*, (staff reports), II, p. 14.

**8.** For a "high-carbonate concrete" having 80 weight percent $CaCO_3$ and an initial radius of the core debris on the reactor cavity floor of 3.05 meters the "WECHSL" code predicts that the core will have penetrated 80 centimeters into the concrete 10 hours after it has landed on the surface and will have thereby released 27 metric tonnes of $CO_2$, 13 of CO, 9 of $H_2O$, and 140 kilograms of $H_2$. The carbon monoxide and hydrogen result from reactions between $CO_2$ and $H_2O$ and hot metals (steel and zirconium) in the melt. The oxides of carbon would add about two-thirds of an atmosphere to the pressurization of a small containment. A "medium-carbonate" concrete is characterized as having 46 weight percent $CaCO_3$ and therefore presumably would release about half as much $CO_2$ plus CO. Another code, "INTER," predicts about twice as much gas evolved as WECHSL. See also W.B. Murfin, I., p. 5. 18.

**9.** W.B. Murfin, *Report of the Zion/Indian Point Study* (U.S. NRC NUREG-CR 1409-1413, 1980), Summary, p. 49.

**10.** Report of the Task Force on Power Emergency Cooling, "Emergency Core Cooling," U.S. AEC, TID-24226 (1966), p.9.

**11.** "Report to the APS by the Study Group on Light-Water Reactor Safety," *Review of Modern Physics 47* Sup. No. 1 (1975), p. S7.

**12.** B. Gosset, H.M. Simpson, L. Cave, C.K. Chan, D. Okrent and I. Catton, *Post-Accident Filtration as a Means of Improving Containment Effectiveness* (University of California at Los Angeles, UCLA-ENG-7775, 1977). The principal radioisotopes which would not be removed by such a filtered vent system would be the noble gases: radioactive krypton and xenon.

**13.** D. Carlson and J. Hickman, *A Value-Impact Assessment of Alternate Containment Concepts* (Washington, D.C.: Nuclear Regulatory Commission, NUREG-CR-0165, 1978). The Murfin Report estimates a $20 million price tag. More elaborate versions would cost more.

**14.** M. Levenson and F. Rahn (Electric Power Research Institute), "Realistic Estimates of the Consequences of Nuclear Accidents," paper presented at the International Meeting of the American Nuclear Society, Washington, D.C. (Nov. 20, 1980).

**15.** John O'Neill, "Scientists Say NRC Greatly Overestimates Accident Risks," *Nuclear Industry* (Dec. 1980), p. 27.

**16.** U.S. Nuclear Regulatory Commission, *Technical Bases for Estimating Fission Product Behavior During LWR Accidents*, NUREG-0722, draft (March 6, 1981; final, June 1981). The basic points in the NRC experts' review were immediately apparent to knowledgeable readers of the Institute report. See Frank von Hippel, an invited briefing to the NRC as recorded in the transcript, "NRC Meeting on Iodine Release from Accidents and Estimates of Consequences," (Nov. 18, 1980), pp. 38-61. For accidents in which the damage is sufficient to open large pathways from the core to the containment, there will not be sufficient water available to trap the radioactive materials of concern, nor will the pathway be so tortuous that a significant amount will stick to surfaces before reaching the containment atmosphere. Similarly, if the containment fails early enough, there will be insufficient time for aerosols to settle to the reactor building floor. These three mechanisms are the basis for the claims made in the Electric Power Research Institute report.

**17.** Government bill to Swedish Parliament, 1980/81:90. It is expected that the Barseback reactor would be equipped with a filtered vent system by 1985.

**18.** Nuclear Regulatory Commission, *TMI-2 Lessons Learned Task Force Final Report* (Washington, D.C.; NUREG-0585, 1979), pp. 3-5.

**19.** Advisory Committee for Reactor Safeguards letter to the NRC on "Additional ACRS comments on Hydrogen Control and Improvement of Containment Capability" (Sept. 8, 1980). The point was reiterated in a Feb. 10, 1981 ACRS letter on "ACRS Report on Requirements for Near-Term Construction Permits and Manufacturing Licenses."

**20.** Jan Beyea, "Some Long-Term Consequences of Hypothetical Major Releases of Radioactivity to the Atmosphere from Three Mile Island," a report to the President's Council on Environmental Quality (Princeton University, Center for Energy and Environmental Studies Report #109, 1980).

**21.** The longest lived radioiodine of concern for reactor accidents is eight-day half-life iodine-131, of which only one-thousandth the original will remain after eight weeks. The area of land contamination will, therefore, have decreased after eight weeks by orders of magnitude from its original size. During the period of contamination it would be quite straightforward to arrange where necessary that dairy cattle be shifted from pasture to relatively uncontaminated stored feed, and to divert any contaminated milk to the production of powdered milk, cheese, etc., which could be stored until its radioactive contamination had decayed to negligible levels.

**22.** U.N. Scientific Committee on the Effects of Atomic Radiation, *Sources and Effects of Ionizing Radiation* (New York: United Nations, 1977), p. 414; U.S. National Academy of Sciences, Committee on the Biological Effects of Ionizing Radiation, *The Effects on Population of Exposure to Low Levels of Ionizing Radiation* (Washington, D.C., 1980); Eliot Marshall, "New A-Bomb Data Shown to Radiation Experts," *Science 212* (1981), p. 1,364 and the related letters in *Science 213* (1981), pp. 6, 8, 392, 602, 604.

**23.** U.S. Environmental Protection Agency, *Manual of Protection Action Guides and Protective Actions for Nuclear Incidents* (Washington, D.C.: EPA-520/1-75-001, 1975), Table 5.2.

**24.** U.S. Environmental Protection Agency, *Environmental Analysis of the Uranium Fuel Cycle II: Nuclear Power Reactors* (Washington, D.C.: EPA-520/9-73-003-C, 1973), Table 40.

**25.** L.H. Hempelmann and others, *Journal of the National Cancer Institute*, 55 (1975), p. 519.

**26.** U.S. FDA, *Proposed Recommendations on Use of Potassium Iodide as a Thyroid Blocking Agent in a Radiation Emergency* (April 1981). For an early release, the thyroid dose from the 21-hour half-life isotope iodine-133 would be approximately one-third that of iodine-131. In March 1954, 22 Marshallese children on Rongelap atoll received an estimated 700 to 1,200 rem thyroid dose from drinking water contaminated with such short-lived radioiodines from the "Bravo" H-bomb test. Almost all subsequently required thyroid surgery and were put on lifetime thyroid hormone medication. (Robert A. Conard and others, *Review of the Medical Findings in a Marshallese Population Twenty-Six Years After Accidental Exposure to Radioactive Fallout* [Brookhaven National Laboratory, BNL 51261, 1980].)

**27.** A detailed discussion of the derivation of Figures 5 and 6 may be found in, Jan Beyea and Frank von Hippel, *Nuclear Reactor Accidents: The Value of Improved Containment* (Princeton University, Center for Energy and Environmental Studies Report #94, 1980).

**28.** Although it is not possible to filter out the noble gases, doses in excess of 10 rem would be received from the noble gases over an area which would be smaller than 1 percent of 10,000 square kilometers.

STATE OF NORTH CAROLINA

COUNTY OF WAKE

Today Dr. G. George Reeves appeared before me and affirms that the attached analysis and information is true and correct to the best of his knowledge and belief and was prepared by him for Wells Eddleman.

Dr G George Reeves this 14th day of July 1982
Dr. G. George Reeves

Betty Hedrick
Notary
Wachovia Bank
Raleigh, N.C.

My Commission Expires 10-22-85

CONSERVATION AND LOAD MANAGEMENT SUBSTITUTIONS FOR CP&L GENERATION

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Raleigh, N. C. 27606

July 14, 1982

Introduction:

The fruits of electricity consumption are essential to our society. For example, the rapid improvements in industry, commerce and the diversity of life in our region in the past three decades has coincided with the widespread application of air conditioning. There is a good possibility that air conditioning was more a cause of these changes than a result. However, our electric economy is undergoing rapid changes and there are now many new ways to achieve the desired results. The best way is one that costs the least and therefore consumes the fewest resource and does the least damage to the environment.

It is essential that electric generating capacity be larger than the maximum essential load. There are two parameters, generation and load, and they are both subject to control. This report points out load controls that are very cost effective, non-intrusive to customers and not treated in CP&L's conservation and load management program.

Carolina Power and Light System:

The system peak loads are very weather dependent as shown by Figure 1. This is a plot of daily maximum and minimum loads for CP&L for every Wednesday from 7/11/79 thru 3/26/80. The figure is thus for high load working days for the most severe parts of a cooling season, a heating season, and the light load autumn in between. The units on the horizontal axis to the right are daily maximum temperatures at the Raleigh airport weather station during the cooling season. Raleigh data should be roughly representative of the system weather since it is near the load center. The horizontal scale pointing left has daily minimum temperatures at the airport during the heating season. Also shown for reference are the summer and winter seasonal peak loads. The maximum and minimum load data can be approximated by the straight line segments shown. Most of the scatter of the data about the straight lines is probably due to Raleigh weather not being the same as the system load weighted average weather. Note that the weather independent base load is about 2.4 GW or 41% of the annual peak. The weather independent peak is about 3.8 GW or 64% of the annual peak. Thus at the annual peak fully 36% of the load is due to the weather. This 36% is probably nearly all space conditioning load.

Figure 2 shows the hourly load for the annual peak day which was 8/9/79 with high temperatures in the mid and upper 90's. As expected the cooling load is heavy by noon and continues until late evening on such a day. In fact the load stayed above 95% of its peak value for

about 8 hours and above 90% of the peak for about 11 hours.

Figure 3 shows CP&L's management peak load forcast for 1995. The peaks have been put on the temperature axis at the same temperatures that correspond to the peaks for the line segment approximation in Figure 1. The weather sensitivity of the daily maximum loads has been assumed the same in 1995 as that observed in 1979-1980. Thus the weather independent maxima and base loads are taken as 64% and 41% of the forcast peak. This implies the same load factor in 1995 as '79-'80 and may predict the 1995 weather independent loads too high.

Also on Figure 3 are three dashed lines. The top horizontal line is the system generating capacity without either of the Shearon Harris reactors operating. This line is present capacity plus the two 720 MW Mayo units. The dashed lines above the lines for daily maximum loads are maxima plus the optimum 20% reserve generating capacity. Notice that the maximum loads plus the 20% reserve exceed the available capacity without Shearon Harris reactors only when the cooling season temperature exceeds 87.5$^{\circ}$F or the heating season temperature drops below 26$^{\circ}$F. In '79-'80 in Figure 1 these conditions were met for only 3 summer Wednesdays and 5 winter Wednesdays. If we assume that the plotted Wednesdays represent 8 6-day weeks of high load then there would be about 480 hours in 1995 when the system has less than optimum reserve capacity without the Shearon Harris reactors operating. The past experience with similar brief periods of sub-optimum reserves indicate the CP&L handled them competently by good management, power purchases from

nearby utilities with surpluses, small voltage reductions and rare appeals to the public to conserve. The third dashed line on Figure 3 is the horizontal line below the maximum load segments. It represents 1995 base capable generating capacity without Shearon Harris reactors operating. This 1995 base capacity would be 60% larger than the weather independent base load and in fact nearly as large as the weather independent daily maximum load in 1995. This 1995 base capable capacity would be 2.245 GW of nuclear generation and 3.530 GW of large coal generation.

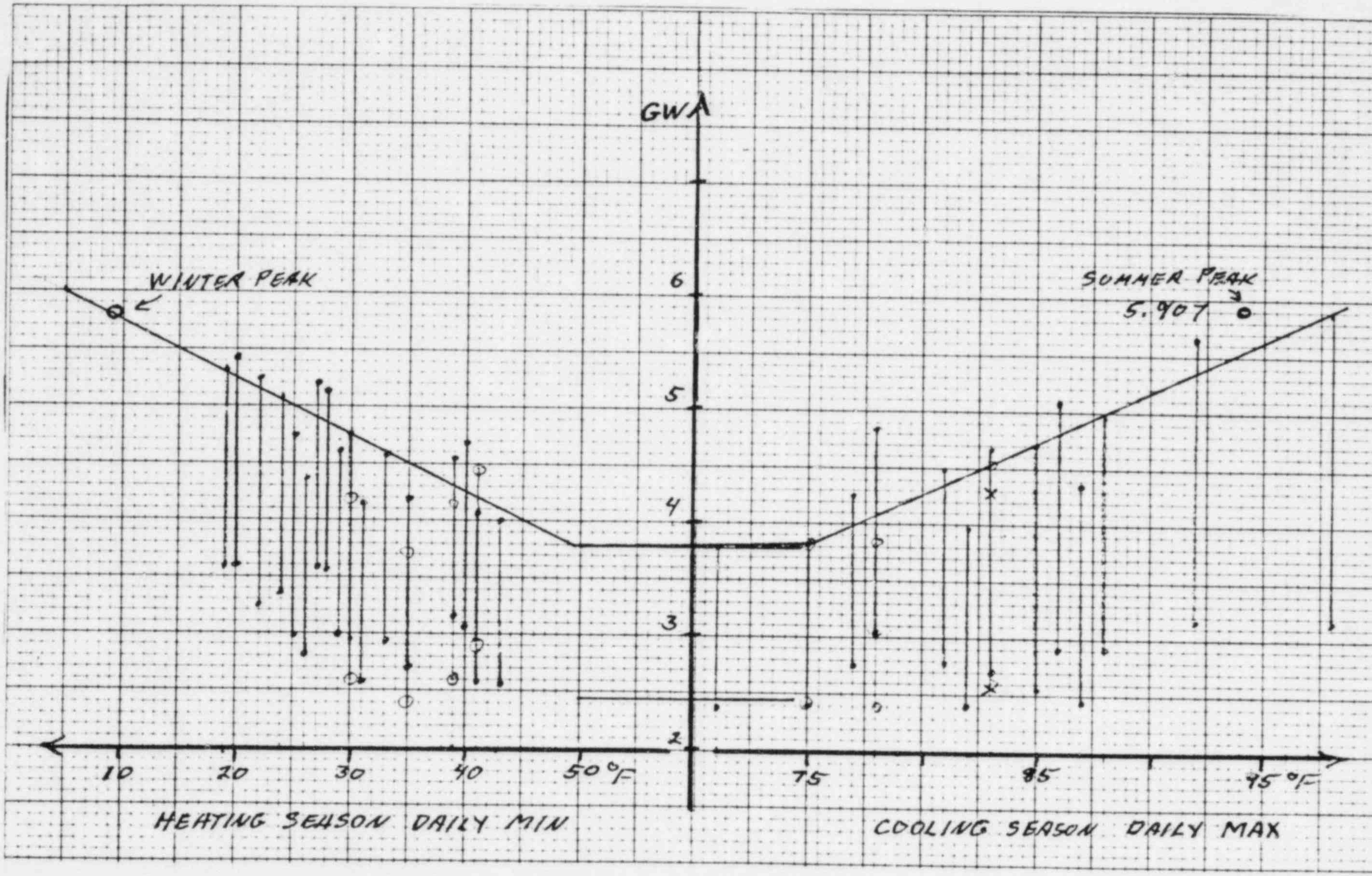



Figure 1 CP&L peak and minimum load for every Wednesday 7/11/79 thru 3/26/80 with Raleigh, N. C. air port temperatures.

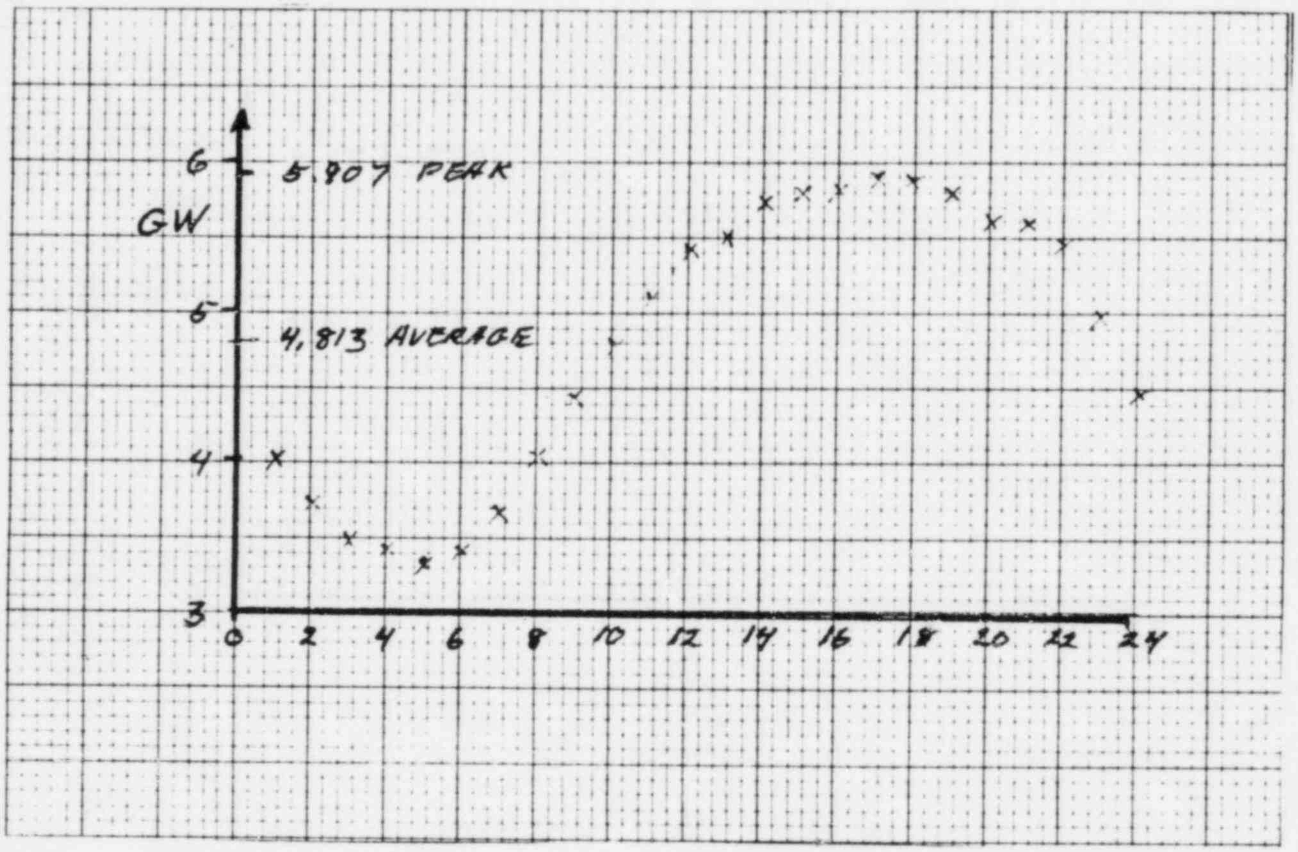



Figure 2 CP&L summer peak day hourly load 8/9/79.

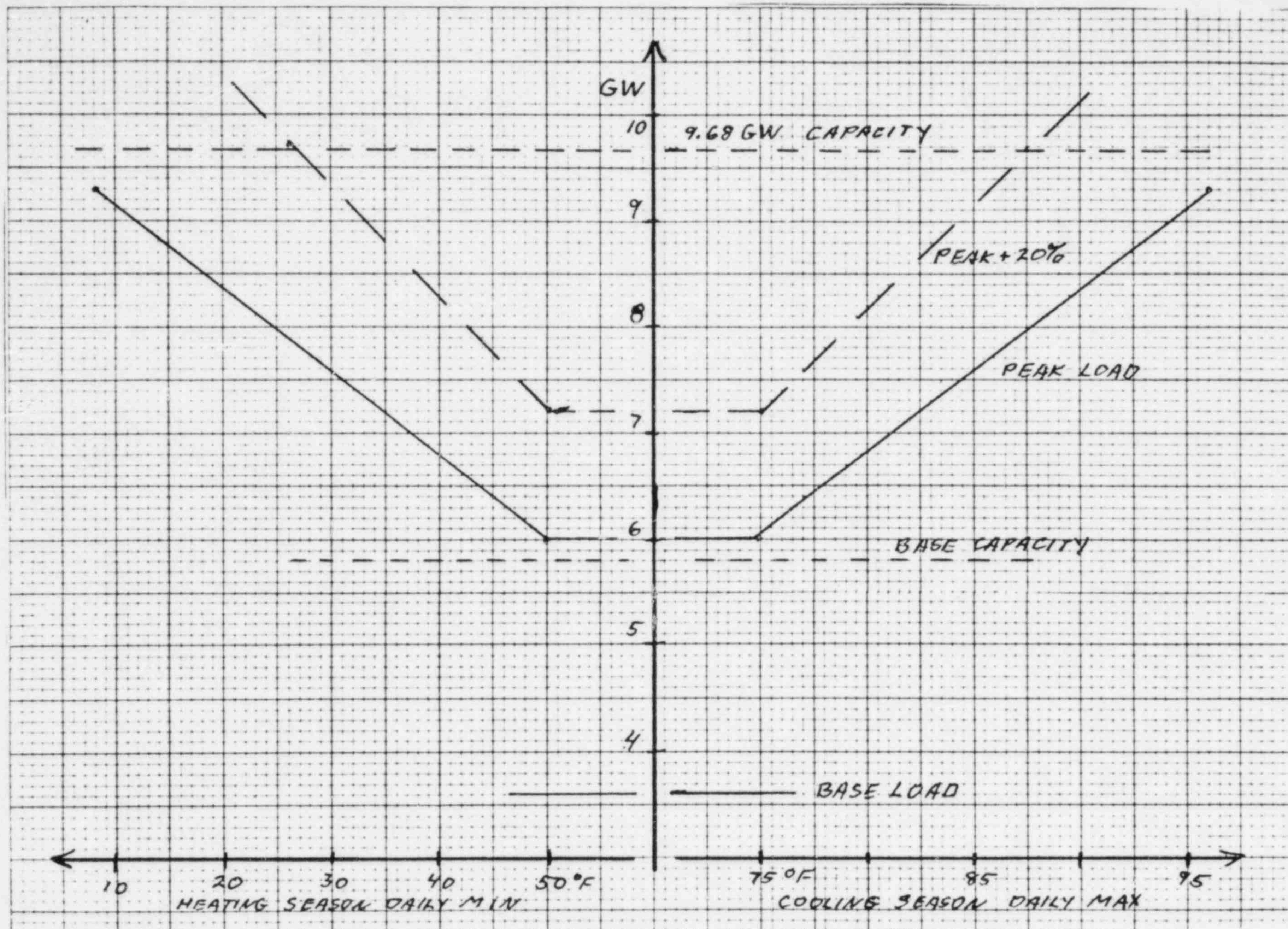



Figure 3 CP&L Forcast 1995 load and generation without Shearon Harris units 1 and 2 and or any further conservation and load management.

Customer Efficiency Improvements and Peak Reductions:

While the generating capacity margin for 1995 shown in Figure 3 is barely adequate it is not comfortable. It leaves little room for low estimates of future loads, management errors, or unreliability of large generators. There are three ways in which the desired 1995 optimum 20% generation margin can be achieved: spend about $2 billion* to complete and start operating Shearon Harris units 1 and 2; or spend about $500 million to buy 1.502 GW of conventional peaking capacity; or increase the efficiency improvements and load shifting beyond the amount planned by CP&L's management.

The first alternative is the most expensive. The annual cost to the ratepayers of the extra $2 billion to be spent in the future will be about $400 million.

The second alternative has an annual cost in 1995 of $100 million for capital and $43 million for fuel to operate the new peaking generation at an average of half its capacity for the 480 hours per year when reserves otherwise would be below 20%. The $43 million 1995 annual fuel cost assumes oil at $1.25 per gallon in 1982 dollars and 25% efficiency. There is an additional system cost associated with not finishing Shearon Harris units 1 and 2. If they were built they would displace some coal generated base load. Assuming that coal and nuclear plants have the same M & O Costs then coal generation would cost about

* Only one significant figure has been used for the cost of completing Shearon Harris units 1 and 2 because past construction cost estimates have not been accurate enough to justify more than one digit. It would perhaps be better to guess that the cost will lie somewhere between 1.5 and 2.5 billion dollars.

0.8¢ per kWH more than nuclear due to the difference in the fuel costs. The two nuclear units capacity would annually generate:

$$1800 \times 0.7 \times 8760 = 11.04 \times 10^6 \text{ MWH}$$

The additional coal would cost $88 million per year in 1982 dollars. Oil in 1995 would have to increase to $6.16 per gallon in 1982 dollars in order for conventional peaking unit option to be more expensive than Shearon Harris units 1 and 2. In addtion the conventional peaking option has the advantage of relatively short construction times. The money need not be spent until it is almost certain that the need exists. Interest charges do not start running more than a decade before the need exists. Also if only part of the capacity is needed then only that part need be purchased because the units are smaller. If the capacity is unneeded at some future time peaking units can be sold and moved.

The third alternative is by far the most attractive if it is possible. Good efficiency improvements have a zero or negative net cost because the energy saved is more valuable than the cost of the improvements. Many efficiency improvements can incorporate load shifting. Time of day rates can make further load shifting attractive. The only net cost to the system may be the coal not displaced.

From Figures 1,2 and 3 it should be apparent that the extreme weather loads are the most important item to examine. In particular the cooling peak load is the critical parameter since there are many easy ways to reduce the heating peak load. CP&L's presently planned Conservation and Load Management program is a step in the right direction. Already it has caused enough reduction in the forcast load to permit the cancellation of Shearon Harris units 3 and 4. The program is

relatively new. It is not surprising therefore that there are program changes, improvements and additions that can enhance its effectiveness. These changes, improvements and additions are discussed in succeding sections. Their total impact is enough to make Shearon Harris units 1 and 2 unnecessary.

No-Net-Cost-Loans:

There are many very cost effective energy investments that consumers could make but do not. They miss these opportunities out of ignorance, short sightedness, timidity or perceived lack of cash.

Very few people realize that a light bulb with a 50¢ price tag in a store really represents a $5 purchase because by the time it is burned out it will have used $4.50 worth of electricity. If people knew this the sales of fluorescent lights would increase faster. Few people know that a typical electric water heater with a $200 store price will use $5,000 to $10,000 worth of electricity during its life. If they did then many more solar, gas and wood fired water heaters would be sold. Many people who are aware of energy costs only think about their monthly bill and not about long term costs over a reasonable number of years.

Most consumers seem to think of their finances in the periodic cycle over which they are paid and pay their bills. They find it difficult to save much or take on substantial new loan payments. They also are completely unused to thinking in terms of borrowing a little in order to save more. It is mostly beyond their experience to borrow money to save. A loan with payments of $10 per month which reduces some other bill $20 per month is mysterious. Yet, this is precisely what many energy conservation expenditures do.

Consumer skepticism and timidity in this area is not surprising. They have been taught that "you don't get something for nothing",but

that is precisely what happens when you stop waste. Investing a dollar and getting back two dollars sounds a lot like the empty promises of a seller of snake oil or underwater Florida land. However, in many investments in efficiency a dollar put in can return ten dollors in saving.

Most of these problems of consumer information, cash flow and credulity can be overcome by getting the utility involved in efficiency promotions and financing. The basic idea is to have the company sell bonds and then use the money to finance consumer energy efficiency purchases. Consumers would pay the bond interest and repay the principal with the dollars that the extra efficiency subtracts from their energy costs. The cash to repay loan and interest comes from energy bill savings. The typical consumer does not have to provide any extra cash per month for the loan. For each kind of purchase guidelines would have to be established to ensure both dollar payback and the desired energy result. For example, consider room air conditioners. A 14,000 btu unit with EER= btu/WH = 6 costs $390 while one with EER= 10 costs $570. The more efficient unit saves the consumer 933 kWH worth about $56 per year for 1,000 hours use per year. If a bond interest rate of 14.3% and consumer income tax rate of 30% is assumed then the annual after-tax interest cost to the consumer is 10%. If the entire $570 cost of the more efficient unit is financed by a no-net-cost utility loan then two bad things happen. First, since the annual interest cost is $57 while annual saving is taken as $56 there is no cash left over to repay the principal. Secondly, by making extremely easy financing available to consumers more air conditioners will be added to the system and the

summer peak load will likely increase which is the opposite of the desired effect. If, on the other hand, the amount financed thru the no-net-cost utility loan is the $180 difference between the costs of the high and low EER units the picture becomes much more favorable. The $56 annual saving pays the $18 per year interest with $38 left over for the principal the first year. The principal is repaid in about 4 years and for the remainder of the air conditioner's life the consumer gets the full benefit of its economy. The money is repaid rather quickly so that it can be recycled into some other consumer efficiency investment. The overall apparent initial cost of the air conditioner is almost unchanged for the consumer at the time of purchase. The cash outlay for the good unit is the same as for the cheap unit and the cash cost of operation for the first four years is nearly the same. Thus, a substantial increase in the number of installed room air conditioners is unlikely. The more efficient unit has been made a little more attractive than the low EER unit. The 0.933 kW summer demand reduction causes the utility to sell $180 in bonds or $193 per kW. This is a much lower financing burden than any new generation and does not have to be repaid by the ratepayers. It is entirely repaid by the purchaser of the high EER air conditioner. The only costs to the ratepayers for the load reduction which substitutes for 0.933 kW of generation are the administrative costs of processing the bonds and loans and the cost of bad debts. Since people must pay their utility bills bad debts should be few. People who skip town can be detected when they apply for utility service elsewhere.

A useful technique in setting repayment schedules would be to set initial schedules for zerocash cost for the typical customer. For each succeeding year stretch the repayment time for new loans out a little to make it more attractive to customer with less than normal usage of the thing being financed.

Rental and Leased Properties:

The energy and cost saving benefits of this program can be extended to rented and leased space by simply making the past utility bills of the property available to prospective tenants. Where there are many similar units such as essentially identical south facing apartments in the same complex it would be more useful to give average past bills. With reliable utility cost information in hand when the lease is signed, efficient units will command proportionately higher rents. No net cost energy efficient loans would be paid by the person paying the utility bill since he is the utlimate beneficiary. It may be useful for rental property to offer somewhat stretched out payments so that early tenants get a larger share of the dollar benefits if they are paying the bills.

Building owners would always install the energy saving features since they have no net cost, may have tax benefits, and improve the property to allow higher future rents or resale value.

Storage Bin Air Conditioning:

Thermal storage air conditioning accomplishes three desirable ends. It reduces peak loads, improves load factor and increases efficiency. The basic idea is to use a cooling unit similar to a window air conditioner to chill an insulated thermal mass such as a bin filled with rocks or sealed bottles of water. When space cooling is desired room air is blown thru the bin to be chilled to create cool air for a supply ducting system. With proper controls the cooling unit can run mostly at night to take advantage of the fact that a high EER air conditioner improves about 1% in efficiency for each $1^{o}F$ decrease in outside temperature. The storage cooling unit can run 24 hours per day in severe weather rather than the 12 hours per day of a conventional air conditioner and thus need have only about half the btu per hour cooling capacity. The cooling unit is thus about half as expensive, has half the peak power demand and is more efficient on average. In addition, the presence of stored cool will make consumers more willing to have their cooling power cut during system peaks. In fact shutoffs of up to 6 hours can easily be tolerated so long as the house air moving blower continues to blow air to be chilled by the stored cool. Thus storage air conditioning would reduce the typical 4 kW demand for a conventional 28,000 btu, EER = 7 to 1.7 kW for a 14,000, EER = 10 bin cooler with a 300 W indoor fan. There is thus an automatic peak demand reduction of 2.3 kW at the time of summer system peak. In addition there can be a further reduction of 1.4 kW for several hours thru load control without the customer

being aware of it if the bin is adequately sized to the house cooling load. Typically the bin would be massive enough to absorb the full cooling capacity of the cooling unit for 12 hours with a 25$^{\circ}$F temperature decrease, For the 14,000 btu/hr unit this means a heat capacity of 6,720 btu per $^{\circ}$F. If rocks are used then about 336 cubic feet would be required. Typically this would be an 84 ft$^2$ bin that is four feet deep. The structure could be a concrete block box about nine feet square or a sheet metal cylinder like a stubby silo about ten feet in diameter. With R-20 insulation it would have an average heat gain of about 300 btu per hour or 7,200 btu per day or about 4% of a typical days cooling demand. This loss is more than compensated for by the fact that running at night improves the efficiency about 10%.

In principle enough sytem air conditioning could be converted to storage type and then direct control could be used to eliminate the peak on the hottest days. The maximum weather sensitive peak forcast in Figure 3 is 3.3 GW above the normal GW peak load and includes about 0.2 GW of peak reduction due to air conditioner efficiency improvement and load control. If the average EER of system air conditioners is raised from 7 to 10 by 1995 then the 1995 maximum weather sensitive peak would be 7/10 x (3.3+0.2) = 2.5 GW above the normal 6 GW peak. In '79-'80 the daily average load on a mild day was 87% of the peak; the maximum peak load was 2.107 GW above the weather independent peak; and the daily average load on the maximum day was 1.517 GW above the daily average load on a mild day. The weather sensitive increase in daily average load is thus approximately 1.517/2.107 = 72% of the weather sensitive increase in peak load. The 2.5 GW weather sensitive peak

increase would thus bring a 0.72 x 2.5 = 1.8 GW weather sensitive increase in the daily average load on the maximum day in 1995 with efficient air conditioners but no cool storage. Without storage the maximum summer day would then have a 6 + 2.5 = 8.5 GW peak and a (0.87 x 6.0) + 1.8 = 7.0 GW average load for the day. The most that storage could do on the maximum day is to shift enough load off-peak to maintain a constant load all day. In other words storage cannot do better than make the load constant all day long at the average load value that would otherwise exist. Any more storage would give a daytime minimum and a night peak. Thus with storage added to conversion to efficient air conditioners a maximum day peak load of 7.0 GW is possible. This gives a weather sensitive peak 7.0 - 6.0 = 1.0 GW above the weather insensitive peak forcast for 1995. This 1.0 GW increase is 40% of the 2.5 GW increase that would occur without storage. Thus the maximum possible system benefit from storage is obtained if 60% of the normal peak air conditioning load is shifted off-peak thru storage and load control. This presumes that there is to be no sacrifice in customer comfort or further improvement in insulation that would actually decrease the btu's of cooling delivered on the maximum day. Insulation improvements beyond those planned in CP&L's conservation and load management program are likely so that the actual 1995 maximum day peak could be less than 1 GW above the mild day peak.

Storage Bin Applications - Active Solar New Homes:

The goal is to move 60% of the air conditioning load off peak thru storage. The problem is then to identify which cases are the lowest in cost starting with those that are cost free to the rate-payers. Storage bins associated with active solar heating systems using low cost air collectors can be obtained as part of the heating system at no net cost to anyone.

The simplist and least expensive place to apply active solar air collector heating and hot water systems is new housing. About 33% of the housing expected in CP&L's area in 1995 has not yet been built. A solar heating system with storage bin cooling for a typical new home in this area can have a net cost under $1000 and save $500 per year from the first year's energy bill (see Appendix I). A 50% tax-free and inflation protected return on an investment is quite exceptional. Most new home purchasers would choose to make the $1000 extra investment if it were not for some informational and institutional impediments. The chief informational problem is that most consumers simply do not know that low cost reliable systems are now available. Most of the information published by "unbiased" sources has been about systems that cost too much and/or did not work. Consumers need to be warned that everything solar is not automatically good, but many now have the impression that everything active solar is bad. The chief institutional problem lies in the lending institutions. They typically consider neither energy costs nor tax credits when they compute mortgage eligibility. Most people buying new homes are trying to get as much house as they can qualify for without considering solar energy equipment

and features. The extra cost cannot be added to the mortgage unless the lender takes into account the extra tax cash which flows back quickly and the long term cash savings resulting from decreased energy bills. CP&L could erase both of these impediments. Billing inserts pointing out good active solar examples would overcome the information problem. No-net-cost financing of the extra construction cost of active solar energy systems with storage air conditioning would eliminate the lending institution problem. Repayment in this case should not be at a constant monthly rate. It would be better to tailor early payments to be larger to reflect the extra temporary cash flow due to tax credits. In this way the example house with $1000 net solar initial cost would repay its $4500 no-net-cost loan in a little over two years.

If we assume that two-thirds of new home purchasers will desire low cost solar heating with off-peak storage air conditioning then 20% of CP&L's residential air-conditioning load in 1995 can be moved off-peak by these new solar homes. The above fraction is 20% rather than 22% due to the circulating fans which would still be on during peaks. The only probable cost to CP&L is a continuing incentive payment for direct load control like the present one. If time-of-day off peak rates are attractive enough then even this incentive payment may be unnecessary. Competition, installation experience, mass production economics and future increases in energy costs will probably largely offset any future reduction in solar energy tax credits.

Storage Bin Applications - Active Solar Retrofits:

About 20% of the homes in CP&L's area in 1995 will be units that now exist and have an adequate southerly, sunny roof for a retrofit active air solar heating and hot water system. A 384 $ft^2$ air collector system without a storage bin can be installed on nearly any of these units at a total cost to the consumer of $6,300 before tax credits and a net cost of $2,800 after credits. In these simple systems heat is stored in the heat capacity of the house. Adding a storage bin beside or behind the home would add about $700 to the net making it $3,500.

Many people with working air conditioners would not be especially interested in the storage bin at the time the collectors are installed since it increases their cost by a fourth without much increase in energy saving. Later their air conditioner will need replacement or major repair. If they already had a bin they would probably save money and connect a smaller new unit to the bin rather than buy a new expensive large unit. To ensure that adequate storage for future cooling is installed with the solar collectors and tax credits, CP&L should make no-net-cost loans available to any property owner who installs a solar heating system with adequate storage suitable for storage air conditioning with direct load control.

The loan repayment rates depend on the energy displaced. The typical system would annually deliver 12,000 kWH of usable heat for space and hot water heating. For homes with electric water heaters the first year value of this heat at present energy prices is $699 for electric

resistance space heat, $563 for oil heat, $516 for LP gas, $459 for heat pump heat, and $427 for natural gas heat. All of these savings are large enough to repay a no-net-cost loan. However, it might be desirable to speed up repayment by increasing the payment size as the price of displaced energy escalates. This repayment method would have to be used with homes having natural gas, heat and water heat since the first year $300 value of the heat delivered at present gas prices is less than the loan interest. Escalating prices should permit reasonable repayment times even in the all natural gase case.

If half the suitably roofed homes added active solar systems with storage air conditioning by 1995 then these will represent about 10% of the residential air conditioning load.

In addition there are a substantial number of home renovations annually which involve adding living space and new roof. In one sample of 20 small, single family homes on large lots, half of them added roof and living space over a 25 year period. The observed average rate of 2% per year is probably not representative of the CP&L system as a whole which includes attached homes, rental units, large homes and many with limited yard space. Even if the observed rate is a factor of three too high there would still be about 7% of the units in 1995 which now exist and have had roof added between now and then. If half of these are suitable for solar energy then another 3% of the residential air conditioning load would be converted to off-peak storage.

Storage Bin Application - Non Solar:

Time-of-day rates make storage bin cooling attractive even when they cannot be used for solar energy. When a conventional air conditioner wears out or needs major repair the consumer may choose storage cooling. A 14,000 btu/hr EER = 10 air conditioner and a storage bin cost about $1,800. A 28,000 btu/hr EER = 10 air conditioner to do the same job cost $1,300. The net cost of adding storage is thus $500 since the installation costs are about the same for either cooling unit. The conventional worn out unit being replaced is assumed to have EER = 7 and with present residential electric rates would cost $233.24 per year to operate 1,000 hours. The storage unit taking advantage of TOD rates would operate 2,000 hours for $107.55 including demand charges for about 100 hours of on-peak use each month. The difference in operating costs easily repays a no-net-cost loan for the $500 difference in cost between the two options.

Thus storage bins in conjunction with TOD rates are seen to be applicable to most centrally air conditioned houses even if they are not suitable for solar heat. Central air conditioning is about 64% of the residential weather sensitive load during the cooling season. Since the residential load is about 42% of the coincident peak the total potential for weather related peak reduction by treating centrally air conditioned residences is large. Of the total housing stock in 1995, 22% has been estimated as active solar new homes, 10% as active solar retrofits on existing roof and 3% as active solar retrofits with new roof. The 22 + 10 + 3 = 35% of total homes represent 0.42 x 0.35 = 15% of the total weather sensitive peak. The remaining 65% of homes not

active solar have 0.65 x 0.64 x 0.42 = 17% of the system weather sensitive peak due to centrally air conditioned homes. If two-thirds of these units take advantage of storage bin cooling then the system weather sensitive peak would be reduced another 11%.

The total expected reduction in 1995 weather sensitive system peak thru storage bin air conditioning of centrally air conditioned homes is 11 + 15 = 26%. This is 26% of the total weather sensitive peak. Since only 42% of that peak is residential the reduction is 26/42 = 62% of the residential weather sensitive peak. Thus if all this storage and load control is installed the summer residential load would actually peak at night on the hottest summer day.

Storage Bin Application - Commercial and Industrial:

Small commercial loads are essentially the same as residences and thus the same analysis should apply. Consider for example a 10 kW, 100,000 btu/hr unit running 1,000 hours per year. It would have an annual energy bill ranging between $563 and $800 depending on what other loads entered into the demand billed during the non-cooling months. Under Small General Service TOD rates it would cost $675 per year. However, with a 2,400 $ft^3$ storage bin its whole load could be shifted off peak and the annual energy bill would be $286. The $277 to $500 annual bill reduction would easily pay back a $2,000 no-net-cost loan to pay for the storage bin. The no-net-cost loan is especially important here because businesses typically expect to invest their limited capital at a much higher rate than that available in the long term bond market.

In the above it has been assumed that the same 10 kW machine would be used in either the normal or storage system. In fact a small unit would do the job in nearly all cases and save some capital investment to further increase the attraction to storage cooling.

Larger cooling loads using chilled water distribution systems can store cool directly in a large unpressurized water tank if care is taken in designing flow paths and baffling to preserve storage tank stratification. In some cases such as supermarkets which need very low humidity, air conditioner evaporator temperatures are normally low. In these situations it may be feasible to switch to machinery with evaporator temperatures low enough to store cool by making ice and greatly reduce the size of the storage unit. There seem to be no reasons why 60% of the commercial and industrial air conditioning cannot be converted to storage if no-net-cost loans are made available.

Air Conditioner Efficiency Improvement:

By 1995 every air conditioner made before 1975 will be more than 20 years old and probably scrapped. Upgrading the efficiency at the time of replacement is very easy as explained in the example in the No-Net-Cost Loan section. A consumer would be very foolish to choose a cheaper model with high operating costs when a high efficiency and probably sturdier model has the same short term costs and lower long term costs. It is quite likely that the lower efficiency models would be driven from the local market by lack of demand.

Heading Season Weather Sensitive Peak Load:

Low grade heat for winter space heating is easy to obtain from many sources and easily stored. Thru 1995 it should be rather easy to bring down the growth in winter weather sensitive peaks to match the summer peaks. Any storage bin air conditioner can also be an off-peak heating system simply by adding strip heaters and controls to the air conditioning unit. Resistance heat can be switched to some other source such as natural gas, LP gas, or oil. In some cases with electric furnaces and heat pump backup heaters the switch over can consist of simply adding an air-water heatexchanger with hot water derived from a new fuel fired water heater and circulating pump. This scheme is often convenient because it allows the flue pipe to be some distance from the air handler. The new water heater also eliminates the water heating electrical load. To the extent that solar heating is installed fuel and electrical energy resources become available to reduce the growth in winter peak demand. These actions to reduce winter weather sensitive peaks are readily financed thru no-net-cost loans because fuels and off-peak electricity are all substantially less expensive than on-peak electricity.

Mild Weather Peak Load Reduction:

There is at least one large steady residential load that can be further reduced below the values expected by CP&L's load management and conservation program. The planned water heater load control is to reach only 25% saturation by 1995 with an average peak load reduction of 0.4 kW per unit controlled. These targets can be improved upon considerably. The 0.4 kW per heater figure can be raised to 0.8 kW each by increasing the off-time to eight to twelve hours. Control can be extended to low population density regions by using $10 quartz crystal controlled time clocks similar to those most people wear on their wrists. With a lithium battery the clocks would need attention only once every ten years. The twelve hour off-time would require upgrading the size and insulation of water heaters when they are replaced due to age. By 1995 most of them will be. If a 0.4 kW load reduction is worth $24 per year than a 0.8 kW load reduction is worth at least $48 per year. It is actually worth more since it has the same effect as controlling twice as much load for the same control cost. Upgrading the size of a water heater costs about $2 per gallon of capacity. Adding 50 to 80 gallons to the new tank is thus easily financed by a no-net-cost loan which would be quickly repaid by the $48 annual payment. At least half the customers probably have room and would make the switch to the larger tank. The 1995 peak load reduction would then be 4 x 69 MW = 0.28 GW nearly independent of weather.

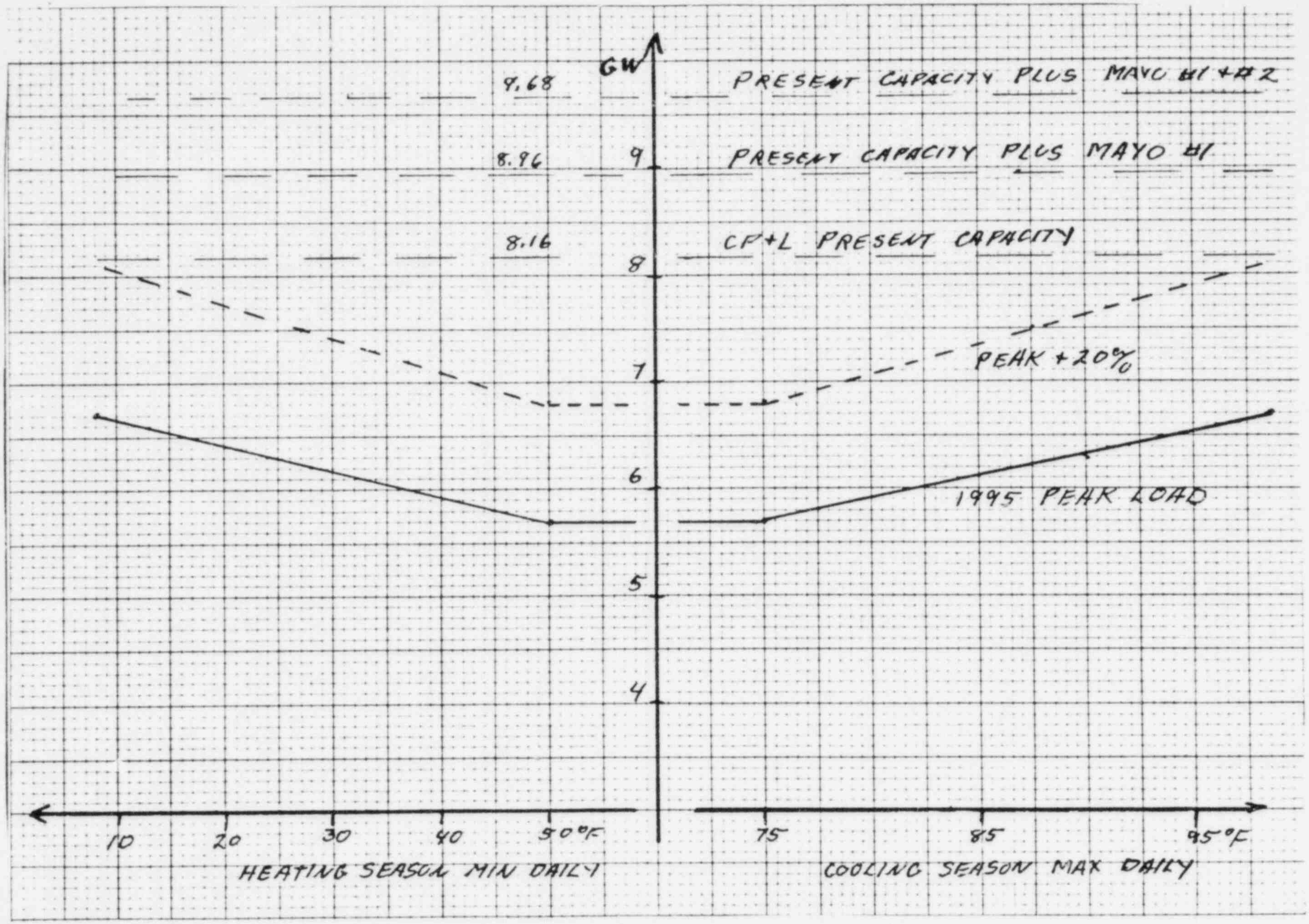



Figure 4 CP&L 1995 system peak loads and generating capacity with additional conservation and load managment and without Shearon Harris units 1 and 2.

Summary:

Figure 4 summarizes the results of these analyses. With a suitably designed and promoted conservation and load management program the growth in weather sensitive peak loads can be substantially reduced. Under these conditions the 1995 peak load would be 6.7 GW which is well within the present generating capacity of the system at 8.163 GW.

The crucial elements of the program are information, no-net-cost loans, and load shifting thru storage. The cost to the ratepayers of the specific elements in the program is essentially zero.

Conclusion:

Since a no cost program can make the present CP&L generating capacity adequate thru 1995 no further construction or new generating plant operation is needed for the forseeable future. However, since Mayo unit 1 is nearly complete it probably should be finished. The excess capacity from Mayo unit 1 will provide some margin for error in case it takes longer than expected for customers to respond to the load management program. The capacity of Mayo unit 2 and Shearon Harris units 1 and 2 is unnecessary. There is a no-net-cost method to meet the needs that these plants were originally intended to serve. The only cost associated with cancelling Shearon Harris units 1 and 2 is the modest cost of the coal fuel they would have displaced. Should it happen that load management works much more poorly than planned then Mayo unit 2 could be finished and if necessary some quick peaking capacity could be purchased. All of these solutions have a lower cost and therefore consume fewer resources than completing and operating Shearon Harris units 1 and/or 2.

# SOLAR-AIR SYSTEMS GIVE COMFORT AND CASH

Dr. G. George Reeves, Energy Control Systems
3324 Octavia St., Raleigh, N. C. 27606

Owning a low-cost solar energy system is a little like owning a small oil well - it delivers energy and tax sheltered money. For a typical new home a Solar-Air system from Energy Control Systems will cost initially about $1000 more than a heat pump and electric water heater. But, it will save more than half the electric bills for heat, hot water and air conditioning. The extra $1000 initial cost can be simply added to the mortgage. This adds a few dollars per month to the mortgage payment but for every one dollar added to the mortgage payment six dollars are taken off the monthly electric bill. Thus you always have more spending money if you have a Solar-Air home. In addition, mortgage interest is tax deductible and money saved on electric bills is tax exempt cash! With Solar-Air you will be warmer in winter, cooler in summer and have more cash in your pocket.

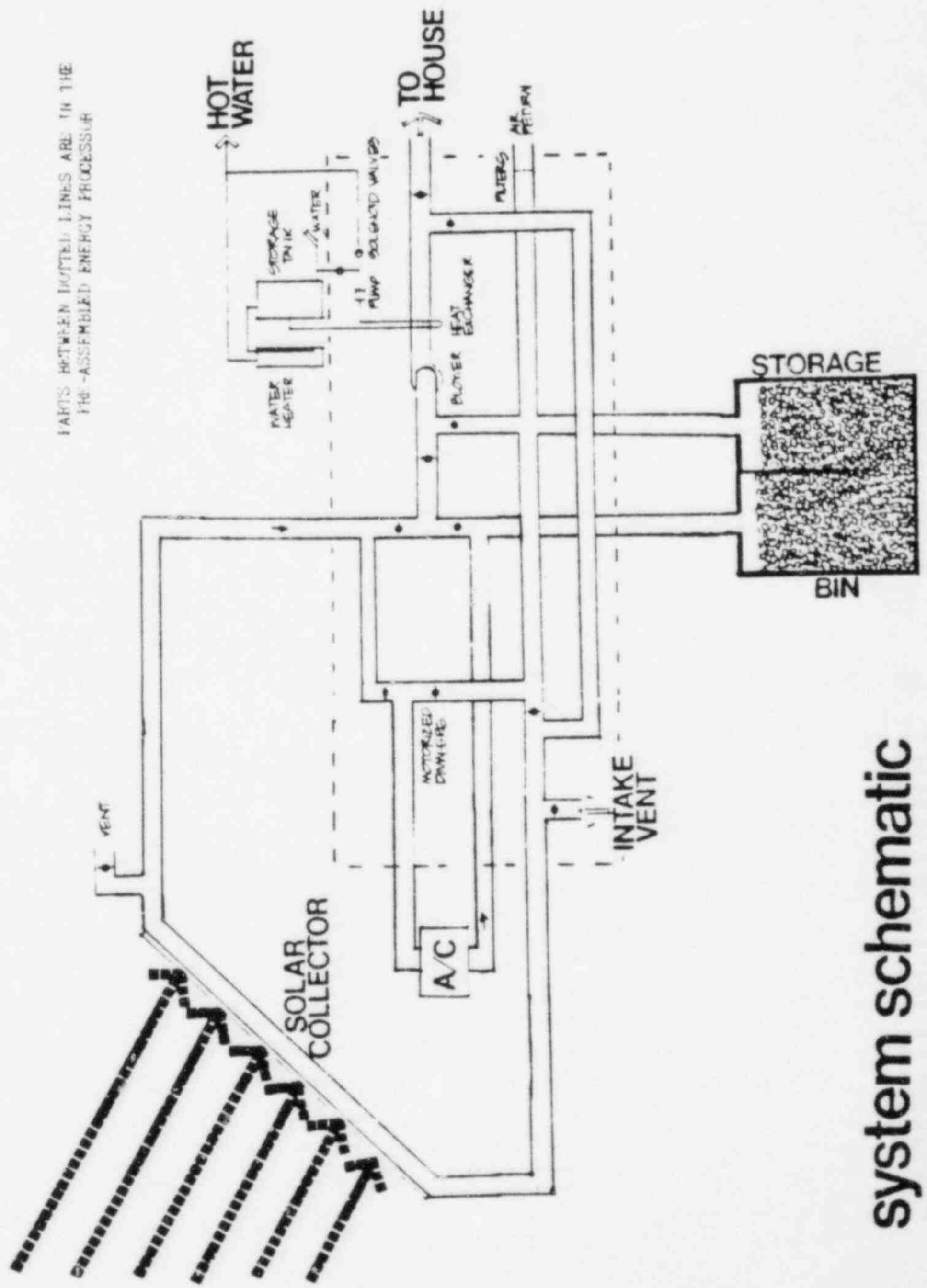
The Solar-Air System:

A typical system for heat; hot water and air conditioning has a sun collector, storage, back up heater, chiller and control system. The Solar-Air collector normally provides much of the South roof area and is tilted 45° to catch the winter sun. The sun passes thru two layers of clear material and is absorbed by and warms a black surface. Air blown thru the Solar-Air panels is heated by the warm black surface. Air is best for a solar heating system in this part of the country since most people want air conditioning and air collectors can be simple, economical and avoid plumbing, corrosion, and leakage problems. Solar heated air can heat the house directly, heat water in an air - water heat exchanger, or heat a storage bin. The storage bin is usually about 1/2 to 2/3 of a cubic foot of rocks for each square foot of collector. The house can be heated at night or on cloudy days by circulating room air thru the hot storage bin and back into the room. A conventional hot water storage tank saves solar heated water for use at night. If there are several cloudy days in a row the stored energy will be used up and some other (back up) heat source is needed. Gas or oil water heaters and wood stoves are quite satisfactory back up heat sources.

The system also assists in summer air conditioning by using the collector and storage bin. In summer the bin can store cool rather than heat. The collector can be used at night to cool air which then goes thru a chiller and thru the storage bin. The chiller is much like a window air conditioner. By running the chiller at night with the collector cooled air the cooling efficiency is substantially increased. The stored cool can be used to cool the house on the next warm day by circulating room air thru the storage bin. Since the storage bin lets the chiller run both night and day in very hot weather, the btu capacity of the cooling unit can be about half as large as a conventional central air contitioner. An automatic Energy Processor[1] containing blower, pump, heat exhanger and motorized valves manages all the required energy flows in response to sunlight, system temperatures and thermostat setting.

A typical, well insulated 1800 square foot new home will need about 400 square feet of collector to provide about 60% of the winter heat and hot water energy: 90% of late spring, summer and early fall hot water; and a 40% reduction in summer cooling costs when compared to a similarly insulated heat pump home. The solar energy system will reduce the first year energy bill by about 10,000 kWH worth $500. In future years the dollar savings would increase due to inflation in energy costs. The Public Staff of the N. C.

Appendix I




system schematic

Utilities Commision projects an electricity cost inflation rate of about 7% per year thru 1990. With a 7% inflation rate the solar system saving in energy bills would total $47,305 over 30 years.

Solar-Air System Costs - - New House:

The costs of the various parts of a typical Solar-Air system are shown in the table below.

| | | | |
|---|---|---|---|
| 416 square foot collector | $ 2496 | Solar energy system price | $ 8500 |
| Collector insulation and ducting | 236 | Less cost saving on items omitted | - 4000 |
| Rafter heat shields | 278 | Less N.C. tax rebate | - 1000 |
| Storage bin | 400 | Less U.S. tax rebate | - 2528 |
| Storage tank (120 gal) | 260 | | |
| Gas fired water heater | 280 | Net cost of adding solar | $ 972 |
| Chiller (14,000 Btu/hr) | 400 | | |
| Energy Processor | 1650 | | |
| Installation of collector, system, room ducting and contractors profit | 2500 | | |
| | $ 8500 | | |

The sales price of a solar energy system installed to heat, cool and make hot water for a typical new home would thus be about $ 8500. This does not mean that the solar system has increased the cost of the home by anywhere near this amount. In the first place the Solar-Air system replaces a heat pump,electric water heater and 400 square feet of conventional roof that together would have cost about $ 4000. These money saving features mean that installing a Solar-Air system increases the direct cost of a new house by only $ 8500 - 4000 = $ 4500. To help you pay this $ 4500 the state of North Carolina will send you checks totaling $ 1000 as N. C. income tax rebates under present law. The U. S. government will send you income tax rebate checks totaling an additional $ 2528. The money refunded comes from N. C. and U. S. income taxes withheld from your pay. Thus the tax rebates pay $ 3528 of the $ 4500 leaving you with a net cost of only $ 972 to be added to the mortgage. Put more simply the $ 972 added to the mortgage saves $ 47,305 in electric bills over a 30 year period.

Cash Spending Money Effects - - New House:

Since the $ 972 Solar-Air system always saves more from the electric bill than it adds to the mortgage payment, there is always more spending money with solar. The table below shows how much extra spending money there is for several years during the life of a 30 year mortgage. The dollar value of the solar energy goes up each year because energy costs are assumed to inflate 7% per year. The

| year from start of mortgage | annual value of solar energy delivered per year | monthyl solar loan payment costs | extra solar spending money per year | accumulated solar savings in the bank |
|---|---|---|---|---|
| 1 | $ 500 | $ 7.15 | $ 414 | $ 440 |
| 5 | 655 | 7.27 | 568 | 2918 |
| 10 | 919 | 7.35 | 831 | 8256 |
| 20 | 1808 | 8.01 | 1712 | 32576 |
| 30 | 3551 | 10.06 | 3436 | 95222 |

mortgage interest rate has been taken at 12% and the long term savings account interest at 9%. The right hand column in the table shows how much money would accumulate in the savings account if the extra solar spending money is saved each year. The money saved accumulates to total $ 95,222 by the time the mortgage is paid off! For computations in the table income tax rates for $ 11,400 annual taxable family income has been used. The exact values of the numbers in the table change slightly for different interest, inflation and tax rates,but the overall result is essentially the same. If you live in a state without solar tax credits then the result is still attractive. Leaving out the N. C. tax rebate increases the initial mortgage payment to $ 14.51 per month and causes the final 30 year accumulated savings to be $ 86,906 instead of $ 95,222.

Solar-Air System Cash - - Existing House:

An existing house usually already has a heating and cooling system and a roof so that some of the Solar-Air money saving features in new homes are not applicable. However, a Solar-Air Collector is roof that can be either added on top of existing roof or used to create a new carport, garage or room addition. The structure of many existing homes is so massive that the storage bin is not needed. The surplus solar heat in the daytime can simply be used to warm the home a few degrees. The live-in storage saves about $1000 in cost. Without a bin a Solar-Air system with 416 square feet of collector would cost about $6000 total installed price. Tax credits of $2400 Federal and $1000 State would reduce the amount to be financed by the homeowner to $6000- 2400-1000- $2600. This simple Solar-Air system would use the existing heating, cooling and hot water equipment for backup. The $2600 to be financed can be more than repaid by the $500 per year energy bill saving. For example if the $2600 is financed with a 10 year home improvement loan at 16% interest the cash effects would be as shown in the following table:

| year from start of loan | annual value of solar energy delivered per year | monthly solar loan payment costs | extra solar spending money per year | accumulated solar savings in the bank |
|---|---|---|---|---|
| 1 | $ 500 | $ 34.92 | $ 81 | $ 86 |
| 5 | 655 | 37.88 | 200 | 822 |
| 10 | 919 | 44.83 | 381 | 2942 |
| 20 | 1807 | 0 | 1807 | 24073 |
| 30 | 3557 | 0 | 3557 | 81046 |

The exact values of the numbers in the table depend on interest and inflation rates but for any reasonable values the overall result is essentially the same. If for example the loan interest rate is 18% instead of 16% then the accumulated cash savings is $79,641 instead of $81,046. If there are no state tax credits in your state then the amount financed changes to $3600 and the accumulated cash saving becomes $75,504 instead of $81,046.

Summary:

The clear message in these numbers is that you can use a Solar-Air system and the bank's money to heat and cool your house and make hot water. The energy bill saving will repay the bank loan and leave a lot of cash available for other things. If the house is sold the Solar-Air system will add to its sales appeal and value.

Many people find these solar energy cash savings incredible. However, in an average week about $10 worth of solar energy hits a typical roof and is wasted and lost. A Solar-Air system simply captures this energy and makes it useful. Owning a non-solar roof in 1981 is equivalent to setting fire to a $10 bill every Friday. Next year a non-solar roof will cost even more due to energy cost inflation.

With a Solar-Air system you can be warmer in winter, cooler in summer, save much money, conserve non-renewable resources and be less effected by the uncertainties in future energy prices and supplies. 8/81

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STATE OF NORTH CAROLINA

COUNTY OF WAKE

Today Dr. G. George Reeves appeared before me and affirms that the attached analysis and information is true and correct to the best of his knowledge and belief and was prepared by him for Wells Eddleman.

Dr G George Reeves this 11th day of February 1983
Dr. G. George Reeves

Muriel W. Moore
Notary Public

# COSTS AND SAVINGS FROM CONSERVATION AND LOAD MANAGEMENT SUBSTITUTIONS FOR CP&L GENERATION

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February 10, 1983

Introduction:

The purpose of the analysis is to quantify the costs and benefits of the specific conservation and load management measures treated in the author's "Conservation and Load Management Substitutions for CP&L Generation" report of July 14, 1982. The following assumptions will be used throughout this analysis:

1. All dollar values are expressed in 1982 dollars
2. All costs and energy prices inflate at the same rate as overall inflation rate
3. Existing electric rates reflect true costs
4. Costs and savings (benefits) are computed at the consumer bill
5. Each measure is implemented in 13 even increments from 1983 through 1995.

High EER Air Conditioners:

A 14,000 btu per hour air conditioner with EER = 10 uses 933 watts less and costs \$180 more initially than a common EER = 6 unit. Thus it costs the consumer 180/0.933 = 193 per kW of load reduction. The estimated 1995 system load reduction was 0.8 GW on the maximum summer day reducing the maximum weather sensitive peak from 3.3 GW to 2.5 GW. The annual power demand increment would be 0.8/13 =.0615 GW = 61.5 MW. The yearly consumer cost of this 61.5 MW is estimated at $\$193 \times 61.5 \times 10^3 = \$11.88 \times 10^6$. The additional energy saved each year is estimated at $61.5 \times 10^3 \times 1000 = 61.5 \times 10^6$ kWH for the typical 1000 hours of air conditioner use per year. The value of the

energy saved is about 5.8 cents per kWH on residential bills and from 5.1 to 7.8 cents per kWH on small general service bills. The lower 5.1 figure applies if the customer's air conditioning load is a small fraction of his total demand charges. The 7.8 figure applies if the airconditioning demand is the majority of his total demand. The 5.8 cents per kWH number has been used for all air conditioning loads. The cost after 1995 assumes that each year 5% of the high EER air conditioners need replacement.

| Year | $\times 10^6$ Cost | $\times 10^6$ Saving |
|---|---|---|
| 1983 | 11.88 | 3.57 |
| 1984 | 11.88 | 7.14 |
| 1985 | 11.88 | 10.71 |
| 1986 | 11.88 | 14.28 |
| 1987 | 11.88 | 17.85 |
| 1988 | 11.88 | 21.42 |
| 1989 | 11.88 | 24.98 |
| 1990 | 11.88 | 28.55 |
| 1991 | 11.88 | 32.12 |
| 1992 | 11.88 | 35.29 |
| 1993 | 11.88 | 39.26 |
| 1994 | 11.88 | 42.83 |
| 1995 | 11.88 | 46.40 |
| any year after 1995 | 7.72 | 46.40 |

Table I. High EER Air conditioners Costs and Savings

Active Solar New Homes

It was estimated that with reasonable enecouragement 22% of the 770,000 residences expected in CP&L's service area in 1995 will be solar homes constructed during the next 13 years at an average rate of 13150 per year. Each home solar heating system has an estimated net, after credits cost to the consumer of $1,000. The estimated energy saving per year is $500 per home after allowing for maintenance.

| Year | Cost $\times 10^6$ | Saving $\times 10^6$ |
|---|---|---|
| 1983 | 13.15 | 6.57 |
| 1984 | 13.15 | 13.15 |
| 1985 | 13.15 | 19.72 |
| 1986 | 13.15 | 26.30 |
| 1987 | 13.15 | 32.87 |
| 1988 | 13.15 | 39.45 |
| 1989 | 13.15 | 46.02 |
| 1990 | 13.15 | 52.60 |
| 1991 | 13.15 | 59.17 |
| 1992 | 13.15 | 65.75 |
| 1993 | 13.15 | 72.32 |
| 1994 | 13.15 | 78.90 |
| 1995 | 13.15 | 85.47 |
| any year after 1995 | 0 | 85.47 |

Table II Active Solar New Homes Costs and Savings

Active Solar Retrofits:

It was estimated that 13% of the CP&L service area residences in 1995 or 100,100 units will have active solar energy systems retrofited by 1995. Spread over 13 years, 7,700 residences per year would be retrofitted at a net consumer cost of $3,500 each. It has been assumed that the market penetration for each type of conventional heating is the same for the converted homes as it was for CP&L as a whole in 1981. The weighted average annual energy bill reduction is thus $554 per unit. This understates the actual system wide cost saving because there will be a tendency for more expensive conventional systems to be converted.

| Year | $\times 10^6$ Cost | $\times 10^6$ Saving |
|---|---|---|
| 1983 | 26.95 | 4.27 |
| 1984 | 26.95 | 8.53 |
| 1985 | 26.95 | 12.80 |
| 1986 | 26.95 | 17.06 |
| 1987 | 26.95 | 21.33 |
| 1988 | 26.95 | 25.59 |
| 1989 | 26.95 | 29.86 |
| 1990 | 26.95 | 34.13 |
| 1991 | 26.95 | 38.39 |
| 1992 | 26.95 | 42.66 |
| 1993 | 26.95 | 46.92 |
| 1994 | 26.95 | 51.19 |
| 1995 | 26.95 | 55.46 |
| any year after 1995 | 0 | 55.46 |

Table III. Active Solar Retrofit Costs and Savings

Residential Storage Bin Air Conditioning Without Solar:

From the above estimates 35% of the 1995 residences in CP&L's service area are anticipated to be active solar assisted. Assuming 1981 central air conditioning market penetration applies in 1995 then 64% of the remaining non-solar units would have central air conditioning. Assuming that 2/3 of these take advatage of storage air conditioning by 1995 there would be

$$2/3 \times 0.65 \times 0.64 \times 770000 = 213,547$$

such residences. The net cost of converting to storage bin air conditioning at the time of present system wearout is the difference between the cost of an EER = 10 full size air conditioner and a storage bin. Taking 28000 btu/hr as a typical residential conventional cooling system, the net cost difference is $140 per unit. The annual saving per unit through time-of-day rates and mostly off-peak running should be $55.72 per unit. This is the additional saving beyond what would occur with a conventional EER = 10 unit

| Year | $\times 10^6$ Cost | $\times 10^6$ Saving |
|---|---|---|
| 1983 | 2.30 | 0.92 |
| 1984 | 2.30 | 1.83 |
| 1985 | 2.30 | 2.75 |
| 1986 | 2.30 | 3.66 |
| 1987 | 2.30 | 4.58 |
| 1988 | 2.30 | 5.49 |
| 1989 | 2.30 | 6.41 |
| 1990 | 2.30 | 7.32 |
| 1991 | 2.30 | 8.24 |
| 1992 | 2.30 | 9.15 |
| 1993 | 2.30 | 10.07 |
| 1994 | 2.30 | 10.99 |
| 1995 | 2.30 | 11.90 |
| any year after 1995 | 0 | 11.90 |

Table IV. Costs and Savings for Non-Solar Residential Storage Air Conditioning

Non Residential Storage Air Conditioning:

The weather sensitive coincident summer peak with EER = 10 air conditioners in 1995 would be 2.5 GW. The non-residential fraction of this 2.5 GW has been estimated at 58%. Converting 60% of the non-residential 58% would shift 870 MW of coincident summer peak load to off-peak. Non-residential consumers would pay about $200 per kW shifted and annually save $38.90 per kW under time-of-day small general service rates. Allowing 13 years for the change would mean converting 870/13 = 66.92 MW per year.

| Year | $\times 10^6$ Cost | $\times 10^6$ Saving |
|---|---|---|
| 1983 | 13.38 | 2.60 |
| 1984 | 13.38 | 5.21 |
| 1985 | 13.38 | 7.81 |
| 1986 | 13.38 | 10.41 |
| 1987 | 13.38 | 13.02 |
| 1988 | 13.38 | 15.62 |
| 1989 | 13.38 | 18.22 |
| 1990 | 13.38 | 20.83 |
| 1991 | 13.38 | 23.43 |
| 1992 | 13.38 | 26.03 |
| 1993 | 13.38 | 28.64 |
| 1994 | 13.38 | 31.24 |
| 1995 | 13.38 | 33.84 |
| any year after 1995 | 0 | 33.84 |

Table V. Non-Residential Storage Air Conditioning Costs and Savings

Water Heater Control:

It is estimated 345,000 customers can be converted to effective off-peak only water heating at a consumer cost of $130 each, saving 0.8 kW each and reducing each customer's bill $48 per year. The continuing $3.45 x $10^6$ annual cost assumes an average 13 year life for the larger storage tanks.

| Year | x $10^6$ Cost | x $10^6$ Saving |
|---|---|---|
| 1983 | 3.45 | 1.27 |
| 1984 | 3.45 | 2.55 |
| 1985 | 3.45 | 3.82 |
| 1986 | 3.45 | 5.10 |
| 1987 | 3.45 | 6.37 |
| 1988 | 3.45 | 7.64 |
| 1989 | 3.45 | 8.92 |
| 1990 | 3.45 | 10.19 |
| 1991 | 3.45 | 11.46 |
| 1992 | 3.45 | 12.74 |
| 1993 | 3.45 | 14.01 |
| 1994 | 3.45 | 15.29 |
| 1995 | 3.45 | 16.56 |
| any year after 1995 | 3.45 | 16.56 |

Table VI. Water Heater Load Control Costs and Savings

Summary:

Table VII shows the total consumer costs and savings for the six measures discussed here. Notice that the annual costs are quite small after 1995 because properly built storage bins should have a very long trouble free life. Active air-collector solar heating should last as long as the attached building with proper maintenance which has been included in the net saving calculations.

| Year | $\times 10^6$ Cost | $\times 10^6$ Saving |
|---|---|---|
| 1983 | 71.11 | 19.20 |
| 1984 | 71.11 | 38.39 |
| 1985 | 71.11 | 57.59 |
| 1986 | 71.11 | 76.78 |
| 1987 | 71.11 | 85.98 |
| 1988 | 71.11 | 115.18 |
| 1989 | 71.11 | 134.37 |
| 1990 | 71.11 | 153.57 |
| 1991 | 71.11 | 172.76 |
| 1992 | 71.11 | 191.96 |
| 1993 | 71.11 | 211.11 |
| 1994 | 71.11 | 230.35 |
| 1995 | 71.11 | 249.55 |
| any year after 1995 | 11.17 | 249.55 |

Table VII.

The net long term savings 245.55-11.17 = 234.38 million dollars per year is considerably larger than the $88 million annual fuel cost saving if Shearon Harris units 1 and 2 are built and operated at 70% of capacity to save coal.

Additional Savings:

In addition to the savings estimated here there are others which are related but not specifically included. Any electric heating customers who add storage bins for cooling will probably also take advantage of time-of-day rates and shift their heating off-peak. Many heat pump customers may choose to install a fuel fired water heater and a heat exchanger for heat pump backup and save on both their heating and water bills. Thus there are additional savings beyond those in Table VII.

2

STATE OF NORTH CAROLINA

COUNTY OF WAKE

Today Dr. G. George Reeves appeared before me and affirms that the attached analysis and information is true and correct to the best of his knowledge and belief and was prepared by him for Wells Eddleman.

Dr G George Reeves ~~this~~ 28th day of June 1983
Dr. G. George Reeves

Notary Public
Muriel W. Moore
1321 Chaney Rd.
Raleigh, North Carolina

ADDITIONAL 1995 CP&L CONSERVATION ENERGY

Dr. G. George Reeves

3324 Octavia St.

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June 25, 1983

Introduction:

Another useful way to quantify the costs and benefits of conservation measures is to compute the cost per kWH saved. This way is particularly useful to consumers because it lets them rank competing conservation measures and also avoid those which cost more than the energy they save.

A conservation measure has an annual extra maintenance cost (M) and an annual capital cost (CC) determined by the intial cost (I), the useful life (n), and a discount rate (d)

$$CC = I \frac{d}{1-(1+d)^{-n}}$$

where n is in years, d is the effective annual, after tax, after inflation interest rate that consumers pay or receive on safe, long-term borrowing or saving. When the inflation rate is steady long enough for the capital markets to adjust d = .03. Consumers pay their bills with after tax, inflated dollars. Thus the appropriate consumer discount rate is the after tax and inflation interest rate on long term borrowing and saving. For example for 1% inflation, mortgages cost 6% and savings yield 5%. With 30% marginal state and federal income taxes the after-tax numbers are 0.7 x 6 = 4.2% and 0.7 x 5 = 3.5%. One percent inflation reduces the real after-tax interest rates to 3.2% and 2.5% respectively. Steady 5% inflation should produce 12% mortgage interest rates and 10.5% long term savings interest for

real after tax and inflation rates of 3.4% and 2.4% respectively. When inflation is changing fast interest rates lag and overshoot leading to transients in the value of d which average out over the years.

The total cost of conserved energy (CCE) for some conservation measure is:

$$(CCE) = \frac{1}{\Delta E}\left[M + I\,\frac{d}{1-(1+d)^{-n}}\right]$$

where $\Delta E$ is the number of kWH saved annually.

High EER Air Conditioners:

A 14,000 btu per hour air conditioner with EER= 10 uses 933 watts less and costs $180 more than an EER=6 unit.[1] For the typical 1000 hours annual use 933 kWH would be saved. The more efficient unit should have no extra maintenance costs (M=0). For a 20 year life[2] the cost of each of the conserved 933 kWH is thus

$$(CCE) = \frac{1}{933}\left[0 + 180\,\frac{.03}{1-(1.03)^{-20}}\right] = 1.30\ ¢/\text{kWH}$$

The total 0.8 GW load reduction by 1995 due to high efficiency units[3] implies a total energy use reduction of 800 GWH in 1995.

Active Solar New Homes:

A typical new home active solar heat and hot water system costs $4500 before tax credits $1972 after 40% U.S. credits and $972 after U.S. and N.C. credits (Appendix I). The system would save 10,000 kWH

per year compared to a typical good heat pump equiped home. Additional maintenance costs are about $40 per year. A properly maintained air system should have a life of 40 years or more; thus take n= 40. For low costs active solar air without tax credits:

$$(CCE) = \frac{1}{10,000}\left[40 + 4500\ (.03984)\right] = 2.19\ ¢/kWH$$

With U.S. tax credits only:

$$(CCE) = \frac{1}{10,000}\left[40 + 1972\ (.03984)\right] = 1.19\ ¢/kWH$$

With both U.S. and N.C. tax credits:

$$(CCE) = \frac{1}{10,000}\left[40 + 972\ (.03984)\right] = 0.79\ ¢/kWH$$

The total 1995 energy saving anticipated from new active solar homes in CP&L's territory is $0.68 \times (169,400 \times (10,000) = 1152 \times 10^9$ kWH or 1152 GWH. The 0.68 factor is the fraction of new homes that would have heat pumps. It assumes that new homes without solar use wood, natural gas or heat pumps and that the distribution among these three stays as it was in the 1982 saturation survey.

Active Solar Retrofits:

The estimated 100,000 active solar retrofited homes in CP&L's territory in 1995 would each cost $3500 with U.S. and N.C. credits.[3] Without the N.C. credit the cost would be $4500. Without any tax credits the intial cost per solar unit would be $7500. Do-it-yourself installation would reduce the costs to about $1700, $2700, and $4500 respectively.

A system life of 40 years is assumed and the added maintenance would be about $40 per year as in the new house case. For each of the contractor installed cases the cost of conserved energy is:

(CCE) = 3.39 ¢/kWH (no tax credits)

(CCE) = 2.19 ¢/kWH (U.S. tax credit only)

(CCE) = 1.79 ¢/kWH (U.S. and N.C. credits).

For do-it yourself installations the conserved energy costs are:

(CCE) = 2.19 ¢/kWH (no tax credits)

(CCE) = 1.48 ¢/kWH (U.S. tax credits only)

(CCE) = 1.08 ¢/kWH (U.S. and N.C. credits).

The total system GWH reduction in 1995 depends on how many of these 100,000 homes had electric heat and/or water heaters. Using saturation data and assuming that the 100,000 retrofited homes are similar to the overall population there would be 15,900 heat pumps, 34,100 electric heat and 82,500 electric water heaters. With 4,050 kWH per water heater, 6,000 kWH per heat pump and 8,300 kWH per electric furnace the total 1995 reduction would be 713 GWH.

Solar Water Heaters:

The 500,600 non-solar heated residences in CP&L's area in 1995 are candidates for solar water heaters. A standard 40 $ft^2$, $2000 before tax credit unit can be expected to provide 60% of the annual hot water of a typical residential customer using 60 gallons per day. This would save 2887 kWH per year. U.S. and combined U.S. and N.C. tax credits would reduce the system consumer cost to $1200 and $700 respectively. The system should last at least 20 years with extra

maintenance costs of about \$10 per year.

(CCE) = 5.00 ¢/kWH (no tax credits)

(CCE) = 3.14 ¢/kWH (U.S. credits only)

(CCE) = 1.98 ¢/kWH (U.S. and N.C. credits)

If three-forths of the 1995 non-solar heated homes with electric water heaters have converted to solar water heat then the annual energy saving would be 894 GWH. This estimates 500,600 x 0.825 x 0.75 = 309,746 solar water heaters in CP&L s area in 1995. This ia 4.3 times more units than contemplated by CP&L's load management program.

Window Shading and Unshading:

Window treatments are another example of cost effective solar conservation measures. Few people realize that an ordinary 15 square foot south facing window can capture 20.4 therms or 598 kWH of heat per average heating season in Raleigh. Incident radiation during each heating season would average 193,710 btu per square foot[5] and about 70 % would be delivered through double glazed windows. Also, few people realize how much solar heat is collected by curtained windows during the cooling season.

During the heating season, people presently have about half of their south window area obscured by curtains and outside screens which keep out about 55 % of the potential solar gain. Assumming that the windows are about 30 % shaded by fenestration and trees; the available annual energy from opening curtains fully and storing screens for the heating season is 0.55 x 0.7 x 598 = 230 kWH for a south 15 $ft.^2$ window. The annual cost of hiring someone to do this would probably not average

more than \$2 per window. The cost per kWH is thus 2/230 = 0.87 ¢/kWH assuming resistance heat is replaced.

The 1995 system wide saving from this measure can be estimated by assuming that each of the 250,000 non-solar, electrically heated homes has 50 $ft^2$ of south window. The estimated 1995 annual saving is 192 GWH. The estimate may be somewhat high because it neglects the fact that some of the energy displaced would have come from heat pumps; but on the other hand it may be somewhat low because it neglects the electric backup heat saving in active solar homes.

During the cooling season heavy white curtains or drapes reflect only about half of the solar heat that penetrates. Typical numbers are 60% transmission thru outside insect screening, 70% transmission thru double glass and 50% transmission thru inside drapes. Thus an unshaded window with the drapes closed transmitts 0.6 x 0.7 x 0.5 = 0.21 of the incident solar energy to the home interior. The average annual incident solar energy on 200 $ft^2$ of Raleigh window during June, July and August is 14 million btu if the windows are equally divided among N, S, E and W wall areas. 21% of this energy or 2.94 million btu would get into the home. At EER=10, an airconditioner would need 294 kWH to remove this heat gain. For the 74% of the homes with air conditioning, assuming it is used an average of 60 days per summer and that windows are 70% shaded by trees and buildings: the annual 1995 energy would be 78 GWH to remove this solar summer gain.

The simplest way to reduce this gain is to grow morning glory on wire mesh in front of the windows. For ground floor 15 $ft^2$ windows it

would cost about $2 and if the home occupant rolls up and saves the mesh each year it should last 20 years. Upper floor windows would also need window boxes and cost about $10 each. An average unshaded 15 $ft^2$ window would have its solar gain reduced by 221 x $10^3$ btu saving 14.7 kWH for 60 days use per year. The cost of conserved energy is:

(CCE)= 0.91 ¢/kWH (ground floor)

(CCE)= 4.57 ¢/kWH (upper floor)

Lighting:

If there are an average of two, 100W incandescent lamps per home that burn 2000 hours per year, then another 185 GWH can be saved on 1995 residential lighting. A 32W fluorescent lamp produces more light than a 100W incandescent bulb.[6] Considering ballast losses about 60W is saved for each incandescent bulb replaced. Replacement costs are between $15 and $30 per bulb depending on whether or not a screw in fluorescent substitute can be used in an existing fixture. Bulb cost is about the same per hour since fluorescent bulbs cost about 5 to 10 times as much as incandescent but last more than 10 times as long. Taking fixture and ballast life at 20 years the cost of conserved energy is:

(CCE)= 0.84 ¢/kWH (same fixture)

(CCE)= 1.67 ¢/kWH (new fixture)

Motors:

More efficient fractional horsepower motors are now available at only a slight increase in price.[7] Any motors with substantial annual use should be the high efficiency kind. For example, consider ¼hp blower motors which run about 3000 hours per year. The high efficiency

motor uses 62W less and has a retail list price \$23.37 more. At 3000 hours per year and a 10 year life the cost of conserved energy is:

(CCE)= 1.47 ¢/kWH.

Nearly all such motors now in the system will probably need replacing by 1995. Some homes have more than one; dual heat pump homes have four. It is thus likely that by 1995 there will be an average of one per residence. The 1995 system energy saving would be 143 GWH.

Bath Water Space Heat:

Some energy saving measures cost nothing in money or comfort. It is simply a matter of making a slight change in the way things are done. Bath water space heat is an example of this. A bath or shower with 15 gallons of hot water has 3.3 kWH of energy which normally flows immediately down the drain. However, in the heating season the water can be allowed to to stand in the tub until it cools to room temperature. This removes about 2.2 kWH from the waste water and transfers it to the space to be heated. By simply opening the drain later 2.2 kWH of free space heat is obtained. This is easily done for the last bath of the day or for any bath followed by a few hour interval until the next use. If an average of one bath per day for the 180 day heating season for 385,000 homes with electric heat or backup heat follow this procedure, then 152 GWH would be saved.

Television:

There are some energy savings that will occur with no consumer effort or expense. Television receivers are an example. By 1995 nearly all the

present 300W, 864 kWH per year televisions will be replaced by current 100W, 288 kWH units. Newer more efficient sets do not cost more, the overall technology has simply changed for the better. As old TV's wear out and are replaced, energy is saved at no cost to anyone. Actually, only the larger sets use 100W now with many 19" units using only about 2/3 as much energy. However, 100W is probably a good number to use for the future to account for the tendency to use auxiliary equipment such as computers, games, and VCR's with TV. These auxiliary units typically need from a few watts to a few tens of watts.

Taking the present average annual TV energy per household to be 864 kWH, we can expect a 444 GWH reduction in annual energy use for television.

Summary:

The summary table lists the measures discussed here with their costs and the GWH made available by them in 1995. The GWH column is the extra energy made available beyond that planned by CP&L's load management program. The measures are all cost effective since they cost less than the present price of electricity. In fact, they all cost less per kWH than the future expenditures for any of the Shearon Harris' units. Unit 1 has the lowest future expenditures at $825 million in 1984, 1985, and 1986 construction costs and future fuel, operations, maintenance, repair, and decommissioning charges. At 60 % capacity factor and a 20 % annual capital charge, future construction cost is 3.49 ¢/kWH. All other future charges would have to total less than 1.08 ¢/kWH to be equal to the least attractive present

## SUMMARY TABLE

| Measure | | ¢/kWH CCE | 1995 GWH | New 1995 GWH |
|---|---|---|---|---|
| High EER | | 1.30 | 800 | 707 |
| New Active Solar | No Credits | 2.19 | 1152 | 1152 |
| | U.S. Only | 1.19 | | |
| | U.S. and N.C. | .79 | | |
| Retrofit Active Solar | No Credit | 3.39 | | |
| | U.S. Only | 2.19 | | |
| | U.S. and N.C. | 1.79 | | |
| Do-it-yourself Retrofit Active Solar | No Credit | 2.19 | 713 | 713 |
| | U.S. Only | 1.48 | | |
| | U.S. and N.C. | 1.08 | | |
| Solar Water Heaters | No Credit | 5.00 | 894 | 686 |
| | U.S. Only | 3.14 | | |
| | U.S. and N.C. | 1.98 | | |
| Winter Windows | | .87 | 192 | 192 |
| Summer Windows | Upper | 4.57 | 78 | 78 |
| | Ground | .91 | | |
| Lighting | Same Fixture | 0.84 | 185 | 185 |
| | New Fixture | 1.67 | | |
| Motors | | 1.47 | 143 | 143 |
| Bath Water Space Heat | | .00 | 152 | 152 |
| TV | | .00 | 444 | 444 |
| | | | | 4452 |

conservation measure at 4.57 ¢/kWH on the list. The next most expensive present measure is solar water heat without any state tax credit at 3.14 ¢/kWH. It costs less than the remaining unit 1 construction costs. Thus, even if all construction costs on unit 1 before 1984 were magically forgiven and erased, it would still be more expensive per kWH than the listed conservation measures. It is also of interest that the listed measures total to 4452 new GWH made available which would be the output of unit 1 at 56% capacity factor.

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# SOLAR-AIR SYSTEMS GIVE COMFORT AND CASH

Dr. G. George Reeves, Energy Control Systems
3324 Octavia St., Raleigh, N. C. 27606

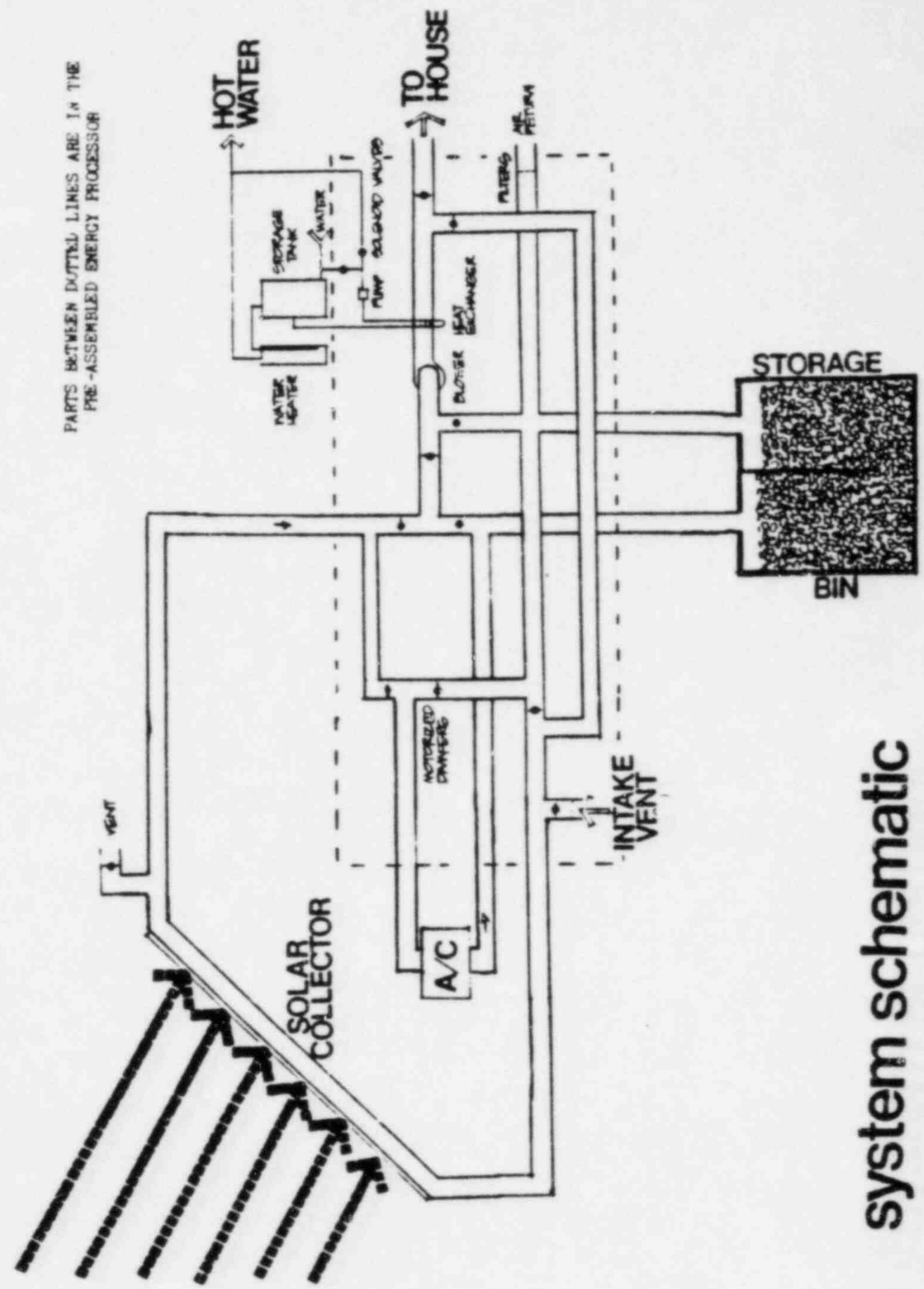
Owning a low-cost solar energy system is a little like owning a small oil well - it delivers energy and tax sheltered money. For a typical new home a Solar-Air system from Energy Control Systems will cost initially about $1000 more than a heat pump and electric water heater. But, it will save more than half the electric bills for heat, hot water and air conditioning. The extra $1000 initial cost can be simply added to the mortgage. This adds a few dollars per month to the mortgage payment but for every one dollar added to the mortgage payment six dollars are taken off the monthly electric bill. Thus you always have more spending money if you have a Solar-Air home. In addition, mortgage interest is tax deductible and money saved on electric bills is tax exempt cash! With Solar-Air you will be warmer in winter, cooler in summer and have more cash in your pocket.

## The Solar-Air System:

A typical system for heat; hot water and air conditioning has a sun collector, storage, back up heater, chiller and control system. The Solar-Air collector normally provides much of the South roof area and is tilted 45° to catch the winter sun. The sun passes thru two layers of clear material and is absorbed by and warms a black surface. Air blown thru the Solar-Air panels is heated by the warm black surface. Air is best for a solar heating system in this part of the country since most people want air conditioning and air collectors can be simple, economical and avoid plumbing, corrosion, and leakage problems. Solar heated air can heat the house directly, heat water in an air - water heat exchanger, or heat a storage bin. The storage bin is usually about 1/2 to 2/3 of a cubic foot of rocks for each square foot of collector. The house can be heated at night or on cloudy days by circulating room air thru the hot storage bin and back into the room. A conventional hot water storage tank saves solar heated water for use at night. If there are several cloudy days in a row the stored energy will be used up and some other (back up) heat source is needed. Gas or oil water heaters and wood stoves are quite satisfactory back up heat sources.

The system also assists in summer air conditioning by using the collector and storage bin. In summer the bin can store cool rather than heat. The collector can be used at night to cool air which then goes thru a chiller and thru the storage bin. The chiller is much like a window air conditioner. By running the chiller at night with the collector cooled air the cooling efficiency is substantially increased. The stored cool can be used to cool the house on the next warm day by circulating room air thru the storage bin. Since the storage bin lets the chiller run both night and day in very hot weather, the btu capacity of the cooling unit can be about half as large as a conventional central air contitioner. An automatic Energy Processor containing blower, pump, heat exhanger and motorized valves manages all the required energy flows in response to sunlight, system temperatures and thermostat setting.

A typical, well insulated 1800 square foot new home will need about 400 square feet of collector to provide about 60% of the winter heat and hot water energy: 90% of late spring, summer and early fall hot water; and a 40% reduction in summer cooling costs when compared to a similarly insulated heat pump home. The solar energy system will reduce the first year energy bill by about 10,000 kWH worth $500. In future years the dollar savings would increase due to inflation in energy costs. The Public Staff of the N. C.




system schematic

Utilities Commision projects an electricity cost inflation rate of about 7% per year thru 1990. With a 7% inflation rate the solar system saving in energy bills would total $47,305 over 30 years.

## Solar-Air System Costs - - New House:

The costs of the various parts of a typical Solar-Air system are shown in the table below.

| | |
|---|---|
| 416 square foot collector | $ 2496 |
| Collector insulation and ducting | 236 |
| Rafter heat shields | 278 |
| Storage bin | 400 |
| Storage tank (120 gal) | 260 |
| Gas fired water heater | 280 |
| Chiller (14,000 Btu/hr) | 400 |
| Energy Processor | 1650 |
| Installation of collector, system, room ducting and contractor's profit | 2500 |
| | $ 8500 |

| | |
|---|---|
| Solar energy system price | $ 8500 |
| Less cost saving on items omitted | - 4000 |
| Less N.C. tax rebate | - 1000 |
| Less U.S. tax rebate | - 2528 |
| Net cost of adding solar | $ 972 |

The sales price of a solar energy system installed to heat, cool and make hot water for a typical new home would thus be about $ 8500. This does not mean that the solar system has increased the cost of the home by anywhere near this amount. In the first place the Solar-Air system replaces a heat pump,electric water heater and 400 square feet of conventional roof that together would have cost about $ 4000. These money saving features mean that installing a Solar-Air system increases the direct cost of a new house by only $ 8500 - 4000 = $ 4500. To help you pay this $ 4500 the state of North Carolina will send you checks totaling $ 1000 as N. C. income tax rebates under present law. The U. S. government will send you income tax rebate checks totaling an additional $ 2528. The money refunded comes from N. C. and U. S. income taxes withheld from your pay. Thus the tax rebates pay $ 3528 of the $ 4500 leaving you with a net cost of only $ 972 to be added to the mortgage. Put more simply the $ 972 added to the mortgage saves $ 47,305 in electric bills over a 30 year period.

## Cash Spending Money Effects - - New House:

Since the $ 972 Solar-Air system always saves more from the electric bill than it adds to the mortgage payment, there is always more spending money with solar. The table below shows how much extra spending money there is for several years during the life of a 30 year mortgage. The dollar value of the solar energy goes up each year because energy costs are assumed to inflate 7% per year. The

| year from start of mortgage | annual value of solar energy delivered per year | monthyl solar loan payment costs | extra solar spending money per year | accumulated solar savings in the bank |
|---|---|---|---|---|
| 1 | $ 500 | $ 7.15 | $ 414 | $ 440 |
| 5 | 655 | 7.27 | 568 | 2918 |
| 10 | 919 | 7.35 | 831 | 8256 |
| 20 | 1808 | 8.01 | 1712 | 32576 |
| 30 | 3551 | 10.06 | 3436 | 95222 |

mortgage interest rate has been taken at 12% and the long term savings account interest at 9%. The right hand column in the table shows how much money would accumulate in the savings account if the extra solar spending money is saved each year. The money saved accumulates to total $ 95,222 by the time the mortgage is paid off! For computations in the table income tax rates for $ 11,400 annual taxable family income has been used. The exact values of the numbers in the table change slightly for different interest, inflation and tax rates,but the overall result is essentially the same. If you live in a state without solar tax credits then the result is still attractive. Leaving out the N. C. tax rebate increases the initial mortgage payment to $ 14.51 per month and causes the final 30 year accumulated savings to be $ 86,906 instead of $ 95,222.

## Solar-Air System Cash - - Existing House:

An existing house usually already has a heating and cooling system and a roof so that some of the Solar-Air money saving features in new homes are not applicable. However, a Solar-Air Collector is roof that can be either added on top of existing roof or used to create a new carport, garage or room addition. The structure of many existing homes is so massive that the storage bin is not needed. The surplus solar heat in the daytime can simply be used to warm the home a few degrees. The live-in storage saves about $1000 in cost. Without a bin a Solar-Air system with 416 square feet of collector would cost about $6000 total installed price. Tax credits of $2400 Federal and $1000 State would reduce the amount to be financed by the homeowner to $6000- 2400-1000= $2600. This simple Solar-Air system would use the existing heating, cooling and hot water equipment for backup. The $2600 to be financed can be more than repaid by the $500 per year energy bill saving. For example if the $2600 is financed with a 10 year home improvement loan at 16% interest the cash effects would be as shown in the following table:

| year from start of loan | annual value of solar energy delivered per year | monthly solar loan payment costs | extra solar spending money per year | accumulated solar savings in the bank |
|---|---|---|---|---|
| 1 | $ 500 | $ 34.92 | $ 81 | $ 86 |
| 5 | 655 | 37.88 | 200 | 822 |
| 10 | 919 | 44.83 | 381 | 2942 |
| 20 | 1807 | 0 | 1807 | 24073 |
| 30 | 3557 | 0 | 3557 | 81046 |

The exact values of the numbers in the table depend on interest and inflation rates but for any reasonable values the overall result is essentially the same. If for example the loan interest rate is 18% instead of 16% then the accumulated cash savings is $79,641 instead of $81,046. If there are no state tax credits in your state then the amount financed changes to $3600 and the accumulated cash saving becomes $75,504 instead of $81,046.

## Summary:

The clear message in these numbers is that you can use a Solar-Air system and the bank's money to heat and cool your house and make hot water. The energy bill saving will repay the bank loan and leave a lot of cash available for other things. If the house is sold the Solar-Air system will add to its sales appeal and value.

Many people find these solar energy cash savings incredible. However, in an average week about $10 worth of solar energy hits a typical roof and is wasted and lost. A Solar-Air system simply captures this energy and makes it useful. Owning a non-solar roof in 1981 is equivalent to setting fire to a $10 bill every Friday. Next year a non-solar roof will cost even more due to energy cost inflation.

With a Solar-Air system you can be warmer in winter, cooler in summer, save much money, conserve non-renewable resources and be less effected by the uncertainties in future energy prices and supplies.

8/81

G. GEORGE REEVES

## Present Position

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## Professional Experience

Research and development in solar heating, photovoltaic solar energy systems, injection lasers, solid state device fabrication processes, optical communications and electronic instruments. Teaching and course development in electronics, digital systems, thyristor circuit design and electromagnetics. Consulting with NASA, RTI and private companies on solid state devices, fabrication processes, digital systems and solar heating. Management of solar energy design and manufacturing.

## Past Positions

1977 - present - President, Energy Control Systems

1971-1977 - Assistant Professor, Electrical Engineering, North Carolina State Universiety

1962-1971 - Instructor, Electrical Engineering, North Carolina State University

1960-1962 - Teaching Assistant, Electrical Engineering, North Carolina State University

## Education

North Carolina State University, Ph.D. in E.E., 1971; North Carolina State University, M.S. in E.E., 1965; Massachusetts Institute of Technology, B.S. in E.E., 1960.

## Memberships

IEEE, Sigma Xi, Methodist

## Publications

"Polar Display Phasor Measurement Device," M.S. Thesis, N. C. State University 1965.

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## Testimony

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