BNL 50863

Lh. 575

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ENERGY DEMAND ANALYSIS IN THE WORKSHOP ON ALTERNATIVE ENERGY STRATEGIES

Steven C. Carhart

April 1978

ECONOMIC ANALYSIS DIVISION
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

UNDER CONTRACT NO. EY-76-C-02-0016 WITH THE
UNITED STATES DEPARTMENT OF ENERGY

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Printed in the United States of America

Available from

National Technical Information Service

U.S. Department of Commerce

5285 Port Royal Road

Springfield, VA 22161

Price: Printed Copy \$4.00; Microfiche \$3.00

July 1978

260 copies

ABSTRACT

The Workshop on Alternative Energy Strategies, conducted from 1974 through 1977, was an international study group formed to develop consistent national energy alternatives within a common analytical framework and global assumptions. A major component of this activity was the demand program, which involved preparation of highly disaggregated demand estimates based upon estimates of energy consuming activities and energy requirements per unit of activity reported on a consistent basis for North America, Europe, and Japan. Comparison of the results of these studies reveals that North America requires more energy per unit of activity in many consumption categories, that major improvements in efficiency will move North America close to current European and Japanese efficiencies, and that further improvements in European and Japanese efficiencies may be anticipated as well. When contrasted with expected availabilities of fuels, major shortfalls of oil relative to projected demands emerge in the eighties and nineties. Some approaches to investment in efficiency improvements which will offset these difficulties are discussed.

Introduction

The Workshop on Alternative Energy Strategies represented a unique experiment in international collaboration directed at a common global problem, specifically the growing shortages of energy in the forms and at the prices to which we have become accustomed, and the problem of managing a transition to an energy system consistent with emerging resource availabilities.

WAES was unique in its organization. As conceived by Professor Carroll Wilson of M.I.T., the Project Director, WAES brought together senior decision makers from government, industry, and academia for a non-official, ad hoc study. Each senior member (participant in WAES nomenclature) designated one or more members of his staff or personnel from a co-operating organization in his country to work essentially full time on WAES as his associate. The study began in the Fall of 1974 and concluded in the Spring of 1977 with the publication of its final report, Energy: Global Prospects 1985-2000. In addition to this overview report, WAES is publishing three technical volumes giving the details of the analysis. The first of these, published late last year is Energy Demand Studies: Major Consuming Countries. This presents, in full detail, the national demand studies performed by the WAES national teams.

These demand studies were performed within an overall framework indicated in Figure 1. The WAES analysis differs from most other studies in that it was performed by national teams from each country using a common methodology.

Separate supply and demand studies were performed for a range of scenario case assumptions. For all cases, certain global assumptions were made concerning economic growth, oil price, and national policy

Figure 1. WAES methodology is based on projections based on common assumptions.

response. For the period 1985-2000, additional input parameters included additions to world oil reserves, the principal replacement fuel for oil, and possible political ceilings on OPEC oil production. These are summarized in Figure 2.

For each global case, each national team would begin from the global assumptions and estimate what appropriate national parameters would be in those circumstances. Thus, for a given rate of growth in GWP, an individual country might be higher or lower according to the judgement of the national team.

For these parameters, national energy demand and supply estimates were developed as shown in Figure 1. These were then integrated at the national level. The fuel deficits were assumed to be covered by imports and unused domestic supply was assumed to be available for export. Global exports and imports were balanced to test for adequacy of supply. We will discuss this in more detail later, but first let us look closely at demand analysis.

WAES Demand Studies

The demand projections performed in WAES have several distinctive features. First, they were performed by national teams with special knowledge of the national situations in the various WAES countries. The individuals involved are listed in an appendix. Second, the analyses were performed using a common methodology and framework.

The first principle of this methodology was to separate projections of the mix of energy consuming activities from the intensity of each activity. Separate estimates were made for sixty-nine sectors of activity levels and energy intensities, for both the base year of 1972 and for the year 1985 under the various scenario assumptions. Thus, for each sector,

	Factors That Influence Future Economy	Variables
1977-1985	World economic growth rate*: high (6%) or low (3.5%)	High Low
	Oil price: rising (\$17.25) constant (\$11.50) or falling (\$7.66)	17.25 11.50 7.66
	National policy response: vigorous or restrained	Vig Res
1985-2000	World economic growth rate: high (5%) or low (3%)	High Low
	Energy price: rising (\$17.25) or constant (\$11.50)	17.25 11.50
	Gross additions to oil reserves: 20 BB/YR or 10 BB/YR	20 10
	OPEC oil ceiling: 45 MBD or 40 MBD	45 40
	Principal replacement fuel: coal or nuclear	Coal Nuc

		A	B	C	D	E
1977-1985	Growth rate	High	Low	High	Low	High
	Oil price	17.25	17.25	11.50	11.50	7.66
	National policy	Vig	Vig	Vig	Res	Res

1985-2000	Growth rate	High	High	Low	Low	Low
	Energy price	17.25	17.25	17.25	11.50	11.50
	Reserve additions	20	20	20	10	10
	OPEC ceiling	45	45	45	40	40
	Replacement fuels	Coal	Nuc	Coal	Coal	Nuc
		C-1	C-2	D-3	D-7	D-8

* The period from 1973 to the end of 1975 is assumed to correspond to actual world economic conditions, with recovery to 1973 levels by the end of 1976 postulated.

National economic studies done under these assumptions, when summed, actually result in global rates of 5.2 and 3.4% to 1985 and 4.0 and 2.8% from 1985 to 2000.

We assume that the scenario variables are approximately independent of each other, within a certain range of values. Any combination of values may, then, be possible and no combination is automatically excluded from consideration.

Figure 2. WAES global case assumptions.

energy demand was estimated according to the equation:

Delivered energy = Activity level x energy/unit activity.

With the overall global scenario of growth, price, and government policy, each national team developed an appropriate national economic and demographic projection which was used to estimate WAES activity levels. Energy intensities were developed for the same scenario variables, taking into account what types of conservation technologies are justified by the case prices and how fast they might be introduced under the case assumptions concerning prices and government policies.

From these estimates of activity levels and energy intensities, demand totals were built up as shown in Figure 3. The exact categories used in this disaggregation are shown in an appendix.

This general approach was motivated to a large degree by the well known fact that there exists among developed countries a range of about a factor of two in their energy/output relationships, as shown in Figure 4. We wanted to know the underlying causes of these differences; how they might change over time; and to what degree the energy saving techniques of one country might be transferred to others. We developed this approach of disaggregation involving separation of activity projections and energy per unit activity projections to facilitate such investigations. Full results of the WAES demand studies upon which this paper is based are reported in reference (1).

The first major differences between countries can be seen in the 1972 sector breakdowns shown in Table 1.

A few major conclusions can be drawn from these aggregated totals. Transportation is clearly a far more important factor in energy consumption in North America than in either Europe or Japan. This is due to a combination

Total National Energy Use is Found by Summing the Energy Use Column of the 69 Line Items.

Figure 3. WAES energy demand analysis.

Figure 4. WAES countries, energy/capita and GNP/capita 1972.

Table 1

1972 Sector Breakdowns, percent

Country	Industry	Transport	Comm/Public	Residential	FAMC	Feedstocks
Canada	28.4	26.7	16.5	22.5	(1)	6.0
Denmark	20.7	21.7	12.3	34.9	10.2	0.0
Finland	43.5	14.1	10.0	27.4	4.9	(2)
France	37.9	23.1	(3)	38.9	(4)	(5)
W. Germany	32.4	18.2	9.5	25.2	4.9	9.6
Italy	39.2	18.2	7.1	23.0	2.5	9.9
Japan	49.0	21.0	8.5	8.4	4.6	8.5
Mexico	41.2	37.1	8.1	13.5	(6)	(6)
Netherlands	22.0	31.3	7.6	21.9	6.7	10.8
Norway	43.3	20.8	6.7	19.3	6.4	3.5
Sweden	37.7	17.8	13.0	25.3	2.7	3.4
United Kingdom	36.7	18.9	5.6	23.1	6.1	9.4
United States	27.0	32.0	7.8	21.4	3.8	7.9

(Processing losses excluded. Fossil fuel/electricity mix varies between countries.)

1. Not specified.
2. Included in Industrial.
3. Included in Residential.
4. Fishing and agriculture included in Residential. Mining and construction included in Industrial.
5. Included in Industrial.
6. Included in Commercial and Public.

of greater distances; less efficient transportation technologies; and a less efficient mix of transportation modes. More detailed statements can be made based on the disaggregated data.

Second, industrial use of energy is of far greater relative importance in Europe and Japan. This is perhaps due more to North American transport inefficiency than any characteristics of energy use in industry overseas, since many industries abroad are more efficient than their American counterparts.

Countries with warmer climates such as Italy and Mexico can be seen to use relatively little energy in their buildings as might be expected. Japan's low consumption in buildings can be attributed in large measure to the lower space available per person due to high population densities. Northerly industrial countries with lower population densities have greater requirements for buildings, though these vary within this group due to different standards of comfort, area per person, structural standards, and HVAC equipment.

However, these structural characteristics are likely to change. The growth in different sectors is anticipated to be very different. Table 2 summarizes these trends for case C, which assumes constant real prices and the implementation of vigorous conservation policies in all countries.

A few tentative conclusions can be drawn from these relative growth rates. For most countries, industrial energy growth rates approximate the overall total growth rate. Opportunities for improved efficiency in this sector are evidently typical of the economies as a whole. Transportation growth rates for most countries are generally above average, suggesting limited opportunities for improvement. The major exception to this is the United States, for which the transportation growth rate is well below the average. This largely reflects the major improvements which can

Table 2
Sector Growth Rates for Delivered Energy
1972 - 1985, Case C

Country	Industry	Transport	Comm/Public	Residential	FAMC	Feedstocks	Total
Canada	2.8	3.2	3.8	1.2	(1)	8.3	3.2
Denmark	2.1	3.6	1.4	0.5	3.3	-	2.0
Finland	4.3	4.9	3.2	1.5	1.5	(2)	3.5
France	2.7	3.5	(3)	2.3	(4)	(5)	2.7
W. Germany	2.3	1.8	2.9	1.3	1.8	3.7	2.2
Italy	3.6	-0.4	2.6	2.8	6.5	6.6	3.2
Japan	5.6	6.9	6.1	5.3	2.7	3.7	5.7
Mexico	7.4	7.2	11.9	8.5	5.5	8.8	7.7
Netherlands	5.7	1.5	1.6	2.9	3.2	8.1	3.9
Norway	3.1	5.1	3.8	0.8	1.8	5.8	3.3
Sweden	3.5	2.5	1.1	-0.2	7.3	9.3	2.8
United Kingdom	1.3	1.9	0.6	1.4	0.4	3.7	1.6
United States	3.2	0.8	1.9	-0.1	2.2	5.4	1.9

(processing losses excluded)

1. Not specified.
2. Included in Industrial.
3. Included in Residential.
4. Fishing and agriculture included in Residential. Mining and construction included in Industrial.
5. Included in Industrial.

be made in U.S. automobile efficiencies. Commercial and Public trends are varied; these reflect a combination of varied growth rates in this sector as well as different climatic conditions and opportunities for improving building construction. Residential growth rates are generally below the averages; this situation reflects the fact that population in the developed countries is growing a good deal more slowly than GNP, and the fact that major improvements are possible in many residential buildings.

Although the relative importance of these different sectors is important, a far more important phenomenon is at work: a general reduction in the amount of energy required for increments of GNP. This can be expressed in terms of the energy coefficient, or the ratio of percentage growth in primary energy consumption (including processing losses) to percentage growth in GNP. This is true despite a gradual increase in electricity as a fraction of delivered energy in most countries.

As we have seen earlier, the *average* energy/GNP relationship varies by about a factor of two among industrialized countries. However, further conclusions emerge from the detailed WAES projections: 1. In response to post-1973 oil price increases, the energy co-efficient associated with future growth will be less than pre-embargo figures; and 2. further increases in energy prices and strengthening of government conservation policies may be expected to further reduce the energy coefficient. Regional averages for the period 1965-72 with world oil prices in the vicinity of \$3.00 per barrel ranged as high as 1.05. Three WAES cases show the effects of these higher prices and conservation policies. Cases A, C, and E shown in Table 3 are all high GWP growth cases. Case E, as noted in Figure 2, assumes that world oil prices fall from recent levels

Table 3

Elasticity of Primary Energy Consumption With Respect to GNP

WAES Cases, 1975-1985

	A	C	E
Canada	.472	.524	.735
Denmark	.551	.729	1.086
Finland	.479	.692	.889
France	.410	.563	.895
W. Germany	.597	.659	.737
Italy	.378	.613	1.122
Japan	.848	.878	.944
Mexico	1.262	1.120	1.213
Netherlands	0.873	1.016	1.271
Norway	1.321	1.357	1.467
Sweden	.747	.898	1.215
United Kingdom	.657	.735	.781
United States	.458	.562	.894

All figures based on primary resource requirements, including processing losses.

Table 4

1972 Automobile Efficiencies
MJ/KM

CANADA	5.48
DENMARK	3.13
W. GERMANY	3.39
ITALY	3.21
JAPAN	3.82
MEXICO	8.67
NETHERLANDS	3.24
NORWAY	3.25
SWEDEN	3.20
UNITED KINGDOM	3.33
UNITED STATES	5.55

of \$11.50 (1975 dollars) to \$7.66 by 1985 and minimum conservation policies are followed. Case C, with constant real prices at \$11.50 (1975 dollars) and vigorous conservation policies, shows much lower energy coefficients. Case A, with prices rising to \$17.25/barrel in 1975 dollars and vigorous conservation policies, results in even lower coefficients.

It is essential to emphasize that these coefficients are not projected on an aggregate basis, but instead are the results of assessments of the rate at which conservation technologies can be implemented in each of the sixty-nine WAES demand categories for the economic growth, price, and policy assumptions of each WAES case. Individual opportunities for transfers of conservation technologies can be identified through comparison of energy/output relationships at the detailed level.

For example, Table 4 shows the 1972 efficiencies of automobiles from WAES countries. The United States, Canada and Mexico have automobile fleets which use approximately twice the energy per kilometer as is used in Europe and Japan. This is probably attributable for the most part to the higher energy prices in Europe and Japan (which often include high levels of tax) and the purchase taxes on automobiles common in these countries. The taxes typically rise steeply with weight, displacement, or horsepower.

The importance of prices in shaping the energy consuming technologies in developed countries is highlighted in Figure 6. Gasoline prices in Europe and Japan are approximately twice prevailing levels in North America, due in large part to taxes. Italy, which has the most efficient cars of any major country, has gasoline prices three times as high as those in North America.

Figure 6. Selected energy prices comparison
- mid- to late-1975.

Not only do we find more efficient automobiles in Europe and Japan than we find in North America, we also find a greater emphasis on transport modes which are more efficient, mainly buses and railroads, as shown in Table 5.

Japan and most European countries also show less emphasis on energy-intensive air travel than one finds in North America. Unlike automotive technology which may be fairly readily transferred, these modal mixes are probably of limited relevance to current U.S. problems in view of the greater distances typical in this country. However, there may be lessons of considerable regional importance. The Japanese railroad system - which uses some of the world's most advanced railroad technology in the densely populated Tokyo-Osaka corridor - may offer some ideas for redevelopment of railroads in the U.S. Northeast corridor despite its recent financial difficulties.

Interpretation of energy efficiency data proved to be more difficult in the industrial sector. The only unit of output which could be consistently applied to all sectors was value added. Thus, data were reported in terms of energy per unit of value added. Many teams reported in addition energy per ton or other physical measure appropriate to each industry. Use of monetary measures of output naturally raises questions of conversion between countries. Since the Smithsonian agreement permitting floating exchange rates had been in effect for some time prior to 1972, all data are reported in terms of energy per 1972 dollar. This is based on the assumption that the floating market exchange rates provide a reasonable basis for calculating the relative value of output in different countries. The results of these calculations are summarized in Table 6.

In most categories, we find a wide range of energy/value added figures. These can be attributed to a range of factors; product mix; production technology; age of plant; plant utilization rates; or other factors. Since

Table 5

1972 Passenger - Km Per Capita

	AUTO	BUS	RAIL	AIR	TOTAL
CANADA	9761	553	147	995	11456
DENMARK	6718	1480	597	840	9635
WEST GERMANY	6772	1011	642	315	8710
ITALY	4274	899	692	35	5900
JAPAN	2166	1064	2955	125	6310
MEXICO	653 ⁽¹⁾	760	76	126	1615
NETHERLANDS	6257	666	650	--	7573
NORWAY	4233 ⁽¹⁾	979	531	232	5975
SWEDEN	7438 ⁽¹⁾	853	561	1083	9935
UNITED KINGDOM	5674 ⁽¹⁾	--	232	396	6302
UNITED STATES	14347 ⁽²⁾	374	66	1293	16080

No entry indicates data unavailable.

(1) Assumes 1.7 average load factor.

(2) Based on 1.9 average load factor reported in DOT Nationwide Personal Transportation Survey.

Table 6

1972 Industrial Energy Intensities
MJ/1972 \$ Value Added

	IRON & STEEL	NON- FERROUS	PAPER	CHEM- ICALS	MINERAL PROD.	FOOD PROD.	TRANS- PORT EQUIP.	MISC.
CANADA	94	126	171	96	129	30	16	--
DENMARK	149	89	21	32	146	32	19	16
WEST GERMANY	216	66	109	36	87	17	11	9
ITALY	199	105	45	241	205	34	16	11
JAPAN	287	114	128	176	143	19	5	50
NETHERLANDS	234	--	98	121	--	27	--	17
NORWAY	356	326	90	113	149	46	12	--
SWEDEN	119	94	418	28	91	21	13	17
UNITED KINGDOM	200	47	26	73	190	26	16	21
UNITED STATES	243	118	125	98	114	30	11	13

Notes: No entry indicates data unavailable.

All conversions made at 1972 U.N. exchange rates.

these figures are reported on the basis of two-digit ISIC categories, the activities within any individual category are so heterogeneous that any comparisons must be made with great care.

Preliminary investigations into some of the figures showing wide divergence from median values in each industry gave some indication of how investigation might proceed. The low energy/output relationship in West Germany for mineral products is probably due in part to the widespread use of the dry process for cement manufacture in that country. The relatively high energy requirement for energy in the Italian chemical industry appears to stem in part from the fact that the industry has a high fraction of its production devoted to basic chemicals (rather than highly refined chemicals such as pharmaceuticals) which are produced in older plants. The low energy requirements in the Swedish steel industry are probably due in part to the production of highly processed, specialized alloys rather than more basic materials. Other key factors affecting these figures include the degree to which scrap is used for metal production; the labor intensity of various processes; and the mix of products within a two-digit sector in different countries. Further investigation is needed which will look in more detail below the two-digit level of aggregation in order to identify specific production approaches which may be transferable between nations. The data available at the two-digit level are useful primarily as a screening device for suggesting areas for more detailed study.

The final sector to be examined in detail is the residential sector, shown in Table 7. Space heating is the dominant component of these figures, and this accounts for the low requirements of warm countries such

figures, and this accounts for the low requirements of warm countries such as Mexico and Italy, though other factors such as living space per person are also involved.

The main lesson of this table is the low requirements of countries such as Norway and Sweden compared with the U.S. and Canada, despite their having a colder climate on average. These differences arise from a set of building standards and lending practices which lead to much tighter construction and higher levels of insulation. Higher prices for heating oil also contribute to this phenomenon. With prices and building code requirements rising in the U.S., the Scandinavian experience suggests that - given time to turn over the building stock - major improvements are possible in this sector.

Table 7
1972 Energy Per Dwelling (10^9 J)

CANADA	196
DENMARK	122
W. GERMANY	93
ITALY	59
MEXICO	33
NETHERLANDS	139
NORWAY	84
SWEDEN	108
UNITED KINGDOM	77
UNITED STATES	180

Energy Conservation in the Global Context

As we noted earlier, for a given set of global scenario assumptions, each national team developed national supply and demand projections. These are then balanced, taking into account expected fuel mix, including maximum plausible movement away from the fuel form anticipated to be in short supply - oil. The excess of demand for each type of fuel over domestic supply becomes that nation's desired imports. Any excess of domestic supply over demand then becomes potential exports. The supply and balancing procedures are described in various WAES publications (2,3,4) and will be summarized here in relation to their implications for energy conservation.

The availabilities and demands for all WAES countries and non-WAES countries except Comecon and China are combined in the global integrations illustrated schematically in Figure 7. When the cumulative global demands for imports exceed available exports, the case "breaks," or becomes internally inconsistent. In the real world of course, this means that the case assumptions would no longer hold. This means that economic growth would fall, the oil price would increase, or more stringent policies would be required (or some combination of all three).

The most disturbing aspect of the WAES global integrations was that for a wide variety of case assumptions, a common pattern of oil shortfall emerged. This is illustrated for two WAES cases in Figure 8. For other assumptions, the behavior of oil supply and demand is the same but occurs at different times.

The upper line indicates oil demand based on the WAES demand studies and fuel mixes, with appropriate adjustment for anticipated switches from oil. Oil supply is built up from the bottom of the chart, beginning with non-OPEC sources. Most of the growth here stems from the addition of Alaskan North Slope and North Sea output to our supplies.

Figure 7. Supply-demand balance calculations: "unconstrained" integrations.

Figure 8. WOCA oil production for C-1.

The OPEC production figures include maximum anticipated production from OPEC nations with significant populations and the ability to absorb oil revenues in development programs. The balance of OPEC production comes from the "low absorbers" whose small populations and high oil reserves place them in a position of having no use other than overseas investment for their surplus oil revenues. These nations - principally the Arabian Peninsula nations - have the option to place a political limit on their output. This could be motivated by internal political considerations such as conservation of oil reserves for future generations; or it could be part of the political bargaining process related to peace in the Middle East.

The various levels of political limits correspond to different possible political outcomes. The lowest level, 33 million b/d, corresponds to a continuation of current output in Saudi Arabia of around 9 million b/d.

Saudi Arabia's ultimate production is more than twice that amount, but even the maintenance of current levels is open to question.

If no political production ceiling is set, then anticipated demand exceeds available supply in 1996 - even with significant efforts at conservation and fuel switching. However, if political production ceilings are instituted, desired demand exceeds maximum available supply - perhaps as early as 1981.

Of course, these potential "gaps" are artifacts of the WAES methodology and will not occur in reality; supply will equal demand. However, the adjustments which will be needed to equilibrate supply and demand - at growth price, and policy levels different from the case assumptions - may be very painful. These could include much lower economic growth rates; higher energy prices; or the need for severe energy policies.

Thus, even with substantial efforts at efficiency improvement and fuel switching, we can foresee a period of uncertain adequacy of oil supply commencing in the early eighties. The exact timing and effects of this period of tightness depend on the sequence of events leading to it - be they simple prorationing of OPEC production; an internal Saudi decision; or a cutoff as part of another Middle East conflict.

Demand Study Conclusions

Based on the results of the WAES demand studies, several conclusions can be drawn. These are interpretations solely of this author, as deadlines and other priorities did not permit WAES as a body to undertake detailed comparative analysis of these studies. I believe the principal conclusions we may draw are the following:

1. Significant scope exists for reducing the energy/GNP relationship of the U.S. approaching those of Europe and Japan. Some structural differences will remain such as the mix of transportation activities, but most major energy intensity reducing technologies should be transferable.

2. Significant scope exists for efficiency improvements in Europe and Japan, though not as great as in the U.S. This is due to a more efficient current capital stock in Europe and Japan, particularly automobiles and buildings.

3. Even with the substantial improvement in efficiency and fuel switching, when oil demand is compared to likely supplies, we appear to be entering a period of limited oil availability.

4. The major limiting factor in equilibrating supply and demand is the lead times associated with large scale supply additions or implementation of conservation technologies.

Toward a Soft Landing

We have seen that despite appreciable implementation of conservation technologies, the world stands on the brink of a period in which the availability of oil supplies to meet desired demand will be uncertain and subject to political limitations which could be imposed by a small number of critical oil producers.

Based on the WAES analysis, the imposition of such a cutoff would result in an inconsistent case; this means that in order to equilibrate supply and demand, one or more of the following conditions would prevail:

1. World economic growth would drop below the reference case levels;
2. Oil prices would rise substantially in real terms; and
3. Governments would be forced to adopt energy policies more stringent than the maximum judged politically feasible by the WAES national teams.

These conditions could quite likely be accompanied by severe inflation, unemployment, and disruption of normal economic activity. Such considerations would be severe if the limitations on oil availability were imposed suddenly or involved actual reductions from current output; they would be less severe if they involved simple leveling off of OPEC output.

What is the role of conservation in this environment?

Conservation must be pursued as part of a total program for transition from oil based, rapid energy growth to a sustainable energy economy based on maximum efficiency and declining oil availability. If we are to avoid potentially massive disruptions of industrial economies, we must engineer a soft landing from the oil based, high growth energy patterns of the past.

The key to achieving this transition is acceleration of the rate of turnover of the energy consuming capital stock in order to replace it with

more efficient equipment. The WAES scenarios include a substantial amount of this in response to existing energy prices and vigorous government conservation policies. However, in response to the tight world oil situation anticipated in the eighties, conservation programs of the following sort need to be considered:

1. Methods to speed up the turnover of the automobile stock, replacing the existing fleet with economically justified, higher efficiency vehicles. The tax/rebate proposal of the administration is the right general approach, but strengthening of its provisions should be examined.

2. Incentives to improve energy performance of buildings. These have been well received by Congress and should be in place soon.

3. Direct government action to improve buildings where incentives are not applicable. This includes those such as public buildings; low income housing; and rental units.

4. Increased investment tax credits for industry. While it is probably inefficient to offer special incentives for energy conserving equipment relative to other equipment, industrial investment - particularly in energy intensive basic industries - has been stagnant in this country, and investment in energy conservation has been hurt as a consequence.

5. Completion of a program to develop backstop technologies for oil. These would be alternative technologies such as syncrude from coal and oil shale which may not be economically competitive at present but which would - if available in large quantities - serve to establish an upper limit on the long run price of oil. Federal pricing regulation could then be directed toward managing a smooth transition to such a long run equilibrium price. This will serve to provide a major incentive to accelerate implementation of conservation technologies.

6. Intensive studies of more radical low energy growth futures. It is well established that known conservation technologies can reduce the intermediate term energy coefficient to 0.5 or so; we need to move further toward exploring possible structural changes in the economy, highly advanced conservation technologies now in the RD & D phase, or other measures which might enable us to estimate very long term minimum energy requirements for specific activities. If lower energy consumption would have a cost in terms of certain GNP components, we need to know this also. The Energy Policy Project Zero Energy Growth scenarios and the forthcoming National Academy of Sciences Committee on Nuclear and Alternative Energy Strategies report offer useful beginnings in this direction.

These are not recommendations adopted by WAES as a group, but rather conclusions this author has reached as a result of participation in WAES. Further research is needed to identify preferred approaches to accelerating turnover of the energy conserving capital stock. In particular, further investigation is required to assess whether programs of this sort would require unrealistic increases in investment and whether there would be any significant economic costs arising from premature retirement of existing capital.

Acknowledgements

This paper summarizes and discusses results of research performed by many persons within WAES, and I am indebted to all of them. However, I especially wish to thank Professor Carroll Wilson of M.I.T., who conceived WAES and invited me to participate as a consultant on the organization of these demand studies; Professor Ben Elbek of the Niels Bohr Institute who prepared internal working papers analyzing these demand studies which

suggested some approaches to this topic; and Paul S. Basile of the WAES staff who edited the national studies for publication. The diagrams in this paper were prepared by WAES consulting artists. Carmen Zopf ably typed repeated drafts, simultaneously meeting deadlines and maintaining her good humor. The interpretations of the results which I have made and any remaining errors are my responsibility alone and are not the responsibility of the WAES group.

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APPENDIX

WAES Demand Study Worksheets

Workshop on Alternative Energy Strategies

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NATIONAL DEMAND STUDY WORKSHEETS REVISION 3

Date _____

WORKSHEET FOR COUNTRY _____

YEAR _____

ECONOMIC CASE _____

PRICE CASE _____

POLICY OR OTHER ASSUMPTIONS _____

CATEGORY	SUMMARY					TOTAL BY CATEGORY EX PROCESSING LOSSES
	OIL	GAS	COAL	ELECTRICITY	OTHER	
TRANSPORT						
AGRICULTURE, MINING & CONSTRUCTION						
COMMERCIAL						
PUBLIC						
INDUSTRY						
RESIDENTIAL						
TOTAL DELIVERED ENERGY BY FUEL						
PROCESSING LOSSES BY FUEL						
GROSS INPUT BY FUEL						

SPECIFY UNITS USED IN EACH COLUMN

GROSS ENERGY INPUT
(Add across bottom row)

WORKSHEET FOR: COUNTRY _____ YEAR _____ DATE _____
 PRICE CASE _____ POLICY OR OTHER ASSUMPTIONS _____ ECONOMIC CASE _____

CATEGORY: TRANSPORT	(A)	(B)	(C)	(D)	(E)	(F) (10 ¹⁵ BTU)	(G) (10 ¹⁵ BTU)	
	POPULATION/AUTO	DISTANCE/AUTO/YR	LOAD FACTOR	FRACTION U ¹ OR R ²	ENERGY/DISTANCE	FOSSIL FUEL	ELECTRICITY	
URBAN AUTO								(1)
RURAL AUTO								(2)
	ACTIVITY LEVEL	% ELECTRIFIED	LOAD FACTOR	FOSSIL FUEL ACTIVITY LEVEL	ELECTRICITY/ ACTIVITY			
URBAN BUS								(3)
INTERCITY BUS								(4)
RAIL PASSENGERS								(5)
AIR TRAVEL-D ³								(6)
AIR TRAVEL-I ⁴								(7)
SHIP TRAVEL								(8)
RAIL FREIGHT								(9)
AIR FREIGHT-D								(10)
AIR FREIGHT-I								(11)
TRUCK-LOCAL								(12)
TRUCK-INTERCITY								(13)
SHIP FREIGHT-D								(14)
SHIP FREIGHT-I								(15)
MISCELLANEOUS								(16)
SPECIFY UNITS USED IN EACH COLUMN					TOTAL			

1. U=Urban   3. D=Domestic
 2. R=Rural   4. I=International

WORKSHEET FOR: COUNTRY _____ YEAR _____

ECONOMIC CASE _____

PRICE CASE	POLICY OR OTHER ASSUMPTIONS

CATEGORY: AGRICULTURE, FORESTRY, AND FISHING (ISIC MAJOR DIVISION 1)

CATEGORY: AGRICULTURE, FORESTRY, AND FISHING (ISIC MAJOR DIVISION 1)								
	(A) VALUE ADDED	(B) ENERGY VALUE ADDED	(C) AREA HARVESTED	(D) ENERGY/ AREA	(E) PHYSICAL OUTPUT	(F) ENERGY/ OUTPUT	(G) (10 ¹⁵ BTU) FOSSIL FUEL	(H) (10 ¹⁵ BTU) ELECTRICITY
FARM MACHINERY								
GREENHOUSES								
OTHER AGRICULTURAL USE								
FORESTRY (ISIC 12)								
FISHING BOATS (ISIC 13)								
OTHER FISHING USE (ISIC 13)								
Total Fertilizer (tons)	N	P	K	TOTAL				

CATEGORY: MINING	(A) VALUE ADDED	(B) ENERGY/VALUE ADDED	(C) PHYSICAL OUTPUT	(D) ENERGY/PHYSICAL OUTPUT	(10 ¹⁵ BTU) FOSSIL FUEL	(10 ¹⁵ BTU) ELECT.
HANDLING & INTERNAL TRANSPORTATION						(23)
OTHER ENERGY USE						(24)
TOTAL						

CATEGORY: CONSTRUCTION	(A) VALUE ADDED	(B) ENERGY/VALUE ADDED	(C) PHYSICAL OUTPUT	(D) ENERGY/PHYSICAL OUTPUT	(10 ¹⁵ BTU) FOSSIL FUEL	(10 ¹⁵ BTU) ELECT.
HANDLING & INTERNAL TRANSPORTATION						
OTHER ENERGY USE						
SPECIFY UNITS USED IN EACH COLUMN					TOTAL	

SPECIFY UNITS USED IN EACH COLUMN

AGRICULTURE, MINING & CONSTRUCTION TOTAL

WORKSHEET FOR: COUNTRY _____ YEAR _____

ECONOMIC CASE _____

PRICE CASE _____ POLICY OR OTHER ASSUMPTIONS _____

CATEGORY: COMMERCIAL	(A) FLOOR AREA	(B) HEAT GAIN OR LOSS/AREA	(C) SYSTEM EFFICIENCY	(D) (10 ¹⁵ BTU) FOSSIL FUEL	(E) (10 ¹⁵ BTU) ELECTRICITY	
SPACE HEAT-FOSSIL FUEL						(27)
SPACE HEAT-ELECTRICITY						(28)
AIR COND.-FOSSIL FUEL						(29)
AIR COND.-ELECTRICITY						(30)
		ENERGY/AREA	ELECTRICITY/AREA			
LIGHTING						(31)
MISCELLANEOUS						(32)
PRESENTLY UNKNOWN						(33)

TOTAL

CATEGORY: PUBLIC	FLOOR AREA	HEAT GAIN OR LOSS/AREA	SYSTEM EFFICIENCY	(10 ¹⁵ BTU) FOSSIL FUEL	(10 ¹⁵ BTU) ELECTRICITY	
SPACE HEAT-FOSSIL FUEL						(34)
SPACE HEAT-ELECTRICITY						(35)
AIR COND.-FOSSIL FUEL						(36)
AIR COND.-ELECTRICITY						(37)
		ENERGY/AREA	ELECTRICITY/AREA			
LIGHTING						(38)
MISCELLANEOUS						(39)
PRESENTLY UNKNOWN						(40)

SPECIFY UNITS USED IN EACH COLUMN

TOTAL

WORKSHEET FOR: COUNTRY _____ YEAR _____ ECONOMIC CASE _____

PRICE CASE _____ POLICY OR OTHER ASSUMPTIONS _____

CATEGORY: INDUSTRY	(A) VALUE ADDED	(B) ENERGY/VA	(C) PHYSICAL OUTPUT	(D) ENERGY/OUTPUT	(E) % EXPORTED	(F) FOSSIL FUEL (10 ¹⁵ BTU)	(G) ELECT. (10 ¹⁵ BTU)	(H) FEEDSTOCKS (10 ¹⁵ BTU)	
IRON & STEEL (ISIC 371)									(41)
NON FERROUS METALS (ISIC 372)									(42)
PAPER & ALLIED (ISIC 34)									(43)
CHEMICALS & ALLIED (ISIC 35 minus ISIC 353)									(44)
MINERAL PRODUCTS (ISIC 36)									(45)
FOOD & RELATED (ISIC 31)									(46)
TRANSPORT EQPT. (ISIC 384)									(47)
KEY INDUSTRY, N.E.C.*									(48)
KEY INDUSTRY, N.E.C.*									(49)
MISC. MFG.									(50)

*SPECIFY KEY INDUSTRIES

SPECIFY UNITS USED IN EACH COLUMN

N.E.C.=Not Elsewhere Classified

TOTAL

WORKSHEET FOR: COUNTRY _____ YEAR _____ DATE _____ Page 6 of 6
 PRICE CASE _____ ECONOMIC CASE _____
 POLICY OR OTHER ASSUMPTIONS _____

CATEGORY: RESIDENTIAL POPULATION _____ PERSONS/DWELLING _____ DWELLINGS _____

CENTRAL SPACE HEATING	(A) DWELLINGS (10 ⁶)	(B) HEAT LOSS	(C) SYSTEM EFFICIENCY	(D)	(E) (10 ¹⁵ BTU) FOSSIL FUEL	(F) (10 ¹⁵ BTU) ELECTRICITY	
FOSSIL SINGLE FAMILY ELECT.							(51)
							(52)
FOSSIL TOWN OR ROW HOUSES ELECT.							(53)
							(54)
FOSSIL APARTMENTS ELECT.							(55)
							(56)
	%SATURATION F.F.	%SATURATION ELECT.	ENERGY/UNIT F.F.	ENERGY/UNIT ELECT.			
ROOM HEATING							(57)
AIR COND.-WINDOW							(58)
AIR COND.-CENTRAL							(59)
WATER HEATING							(60)
REFRIGERATORS							(61)
LIGHTING							(62)
COOKING							(63)
DISHWASHERS							(64)
FREEZERS							(65)
T.V.							(66)
KEY APPLIANCES N.E.C.*							(67)
MISC. APPLIANCES							(68)
POTENTIAL APPLIANCES							(69)
SPECIFY UNITS USED IN EACH COLUMN							
*SPECIFY KEY APPLIANCES					TOTAL		

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