Energy Conservation Policy in Developing Countries: The Case for Market Solutions

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ABSTRACT

Interest in energy conservation, although to some degree cyclical, has been stimulated during the last twenty years by the rising cost of energy in a wide range of developing and developed countries, especially following the oil price shocks of 1973-1974 and 1979-1980; by environmental concerns, notably due to the impact of increasing energy consumption on global warming, pollution, forests and natural habitats; and by national security considerations, as domestic energy supplies continue to be vulnerable to political events in the Middle East. An active debate has ensued, in which it is alleged that the existence of a variety of market failures, imperfections and distortions justifies government intervention in energy markets to promote expenditures on energy conservation.

It is the purpose of this paper to evaluate the validity and relevance of that debate to developing countries, in terms of demand-side management, mainly where the public sector exerts control over a significant portion of energy supply; and where that supply is sold predominantly in markets subject to consumers acting competitively. The central tenet of the paper is that confusion in the debate can only be avoided if a careful distinction is maintained between arguments related to the proper functioning of energy markets, on the one hand; and externalities, on the other.

On the basis of a review of the literature on the sources of possible market failures and the proposed remedies, much of which was inspired by circumstances in the U.S.A., the paper finds that evidence of significant market failures sufficient to justify government intervention in energy markets is not convincing; and that the proposed remedies in any case are inappropriate. The paper concludes that, while environmental externalities may provide grounds for carefully-targeted public sector intervention in energy markets, the national security argument is hard to sustain in developing countries; and market imperfections and distortions generally do not justify non-price intervention, with the possible exception of information provision and support for basic research and development.

ENERGY CONSERVATION POLICY IN DEVELOPING COUNTRIES: THE CASE FOR MARKET SOLUTIONS

I. Introduction

1. This paper examines the debate surrounding the public policy arguments for Government intervention in the energy market to promote commercial energy conservation. While much of the literature reviewed was inspired by circumstances in the U.S.A., we are concerned particularly with its application in developing countries, where the public sector exerts control over a significant portion of energy supply; and where that supply is sold predominantly in markets subject to private-sector consumers acting competitively. The major economies of Latin America would fit this description, notably Argentina, Mexico, Chile and Brazil.

2. Since Government intervention in the energy sector is typically justified in terms of market imperfections and externalities, these are first summarized (Section II). We then review (in Section III) how a competitive market would ensure that energy conservation measures are implemented optimally, relative to increases in energy supply, as part of a least-cost solution. Section IV analyzes how imperfections may impede the workings of the competitive market, leaving aside externalities. Section V considers empirical literature on consumers' discount rates, which purports to measure the degree to which the existence of market imperfections interferes with the decision-taking process of the competitive market; and Section VI discusses the principal measures which are proposed in practice to ameliorate them, *viz.* information provision, improved financing of energy conservation investments, appliance efficiency standards, and building codes. The empirical evidence on the effectiveness of energy conservation measures is reviewed (Section VII) before we return, in Section VIII, to the issue of externalities. Finally, in Section IX, we conclude that, while environmental externalities may provide grounds for carefully-targeted public sector intervention in energy markets, market imperfections generally do not justify non-price intervention, with the possible exception of information provision and support for basic energy research and development (R & D).

II. Market Imperfections

3. The existence of market distortions, barriers or imperfections has been alleged to establish a case for the public sector to intervene in the energy market.[1/] The goal of such intervention is to foster energy conservation beyond the level which would be determined by market forces alone. These imperfections can be classified in a variety of ways, but the main types identified in the

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1/ See, for example, E. Hirst, W. Fulkerson, R. Carlsmith and T. Wilbanks, "Improving Energy Efficiency: the Effectiveness of Government Action", *Energy Policy*, June 1982: "Government programmes are justified on the basis of the market barriers listed above and also on the basis of social benefits not fully captured by private interests"; and L. Schipper, J.M. Hollander, M. Levine and P.P. Craig, "The National Energy Conservation Policy Act: An Evaluation", *Natural Resources Journal*, Vol 19, October 1979: "The need for government participation is illustrated by the abundant set of market failures that deter conservation of energy in buildings". A more qualified and accurate statement is provided by A.C. Fisher and M.H. Rothkopf, "Market Failure and Energy Policy", *Energy Policy*, August 1989: "To the extent that markets fail, government intervention may improve the efficiency of the allocation of resources - though it is, of course, not guaranteed to do so".

literature can be categorized in terms of: those which distort the price signals or else place constraints on the consumer's ability to respond, even if the price signals are correct; and those which stem from deficiencies in the basic process underlying energy conservation decisions. However, the empirical evidence is unsatisfactory on the relative importance of these imperfections and the actions best suited to deal with them.

(i) Distorted Price Signals and Responses

4. If energy prices are below the full economic costs, including environmental costs and the national security costs of depending on imports, the pricing signals will be distorted. There may also be distortions between energy production costs and prices, compared with energy conservation costs, for example due to subsidies on certain forms of energy production and macroeconomic distortions, e.g., taxes and duties on the import of energy-efficient equipment. A more subtle distortion in energy pricing signals can be traced to the high transaction costs of efficient energy pricing, arising from metering and other requirements of load management.

5. Whereas the pricing signals in the energy market may be correct, there could be constraints which limit the extent to which consumers are able to respond efficiently to those signals. Imperfections in the capital market (along with inadequate internal cash generation in firms) may limit the availability of finance; currency restrictions may curtail the supply of foreign exchange to implement energy conservation measures; and there may be quotas or an outright ban on the import of certain energy-efficient equipment or devices to measure energy efficiency, which is not produced locally.

(ii) Deficient Decision-Taking Processes

6. Various deficiencies have been identified in the way that energy consumers take decisions, leading to inertia or under-investment in energy conservation. Consumers could be slow in responding to changes in energy prices, especially where energy represents a small proportion of total costs; they may face imperfect information about the benefits and costs of energy conservation (partly because the private sector may be unable to capture fully the benefits of research and development on generic energy conservation technologies and therefore unwilling to carry it out); they may lack the methodology to evaluate that information (i.e., to handle the inter-temporal comparisons or trade-offs which must be made between additional capital costs and reductions in energy costs); they may not know how to design, initiate and implement energy conservation programs (notably due to a specific lack of expertise in energy management at the plant level); and they may be ignorant about the sources of energy conservation finance and the procedures for securing it.

7. Writers have frequently identified institutional and regulatory barriers to efficient decision-taking in the energy market, notably the divorce between those who take decisions about the design and construction of energy-using facilities (architects, builders etc.) and those who will pay the

operating costs (owners and managers) or between the owners of a building and those who will occupy and use it. Furthermore, firms which consume energy may not be motivated by profit maximization; managers may not pursue energy efficiency or may attach a low priority to it, due to the role of non-profit incentives in managerial decision-taking;[2/] and there could be a widespread use of cost-plus pricing, particularly in the public sector, under which companies routinely try to pass higher energy costs on to consumers.

(iii) Empirical Evidence

8. Direct empirical evidence of the impact of these market imperfections is unsatisfactory, especially in the second category. The literature describes their existence, and there is a body of circumstantial evidence for particular cases, but their relative importance and the actions best suited to overcome them have not been demonstrated.[3/] The argument hinges predominantly on indirect evidence, from econometric studies, that consumers reveal discount rates far in excess of the cost of capital in their energy-conservation decisions; and engineering evidence of a significant difference between the energy consumption that could be achieved theoretically from more efficient and known technologies and actual consumption.[4/] This theoretical difference amounts typically to at least 10-20% of total energy consumption in most countries: an even higher figure is sometimes quoted.[5/] For Brazil, a 1987 study estimated that the additional electricity savings available from implementing technologies in six major end-use areas "that are technically and economically feasible and, in many cases, already available in Brazil" could amount to 20% by 2000 and that "additional savings may be

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2/ For example, there may be more prestige attached to the implementation of large-scale investment projects rather than more mundane and low-prestige energy conservation measures or managers may be more preoccupied with short-term problems.

3/ This position was taken by C. Blumstein, B. Krieg, L. Schipper and C. York, in "Overcoming Social and Institutional Barriers to Energy Conservation", *Energy*, Vol. 5, No. 4, April 1980; and more recently, nearly a decade later, by R.S. Carlsmith, W.U. Chandler, J.E. McMahon and D.J. Santini, *Energy Efficiency: How Far Can We Go*, ORNL Report TM-11441, January 1990.

4/ A good example is E. Hirst *et. al.*, "Improving Energy Efficiency: the Effectiveness of Government Action", *op. cit.*. From the fact that energy audits of 48 hospitals in four States in 1981 proposed energy conservation measures that would cut energy use by 20%, they infer that Government information programs could resolve the issue; and that the high potential rates of return to investment in conservation measures in new houses, to improve thermal performance, shown by a study in Kansas City, "suggest that the new housing market is not economically efficient" and there is "an important role for government programmes".

5/ E. Hirst *et. al.*, *ibid.*, cite a 1978 study at the Mellon Institute, which estimated the hypothetical savings from a "least-cost" energy strategy in 1978 of 25% of total energy actually consumed in that year. H. Geller, J. Harris, M. Levine and A. Rosenfeld suggested in 1987 that the U.S.A. could have reduced its total energy bill by 25%, simply by adopting available technologies which are economically justified. See "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the U.S. Economy", *Annual Review of Energy*, Vol. 12, 1987.

possible in other areas such as water heating and air conditioning."[6] A more comprehensive review of energy savings potential in a sample of 25 developing countries by the Joint UNDP/World Bank/Bilateral Aid Energy Sector Management Assistance Program (ESMAP) suggested that an average of 20% of total end-use energy could be saved from the existing capital stock.[7] By showing that the cost of conservation measures is considerably below the value of the energy savings and the cost of supply alternatives, the advocates of Government intervention conclude that action by the public sector can remove the institutional obstacles and market imperfections which prevent these gains from being realized, or else introduce additional distortions in order to offset those caused by market imperfections.[8]

III. Energy Conservation and Least-Cost Supply

9. In order to evaluate the question of market imperfections and public sector intervention more carefully, it is instructive to remind ourselves how a perfectly competitive market would take care of energy conservation as part of the least-cost solution.[9] Throughout the discussion, we assume for convenience the absence of externalities, which are treated separately and in detail in Section VIII.

6/ H.S. Geller, J. Goldemberg, J.R. Moreira, R. Hukai, C. Scarpinella and M. Yoshizawa, "Electricity Conservation in Brazil: Potential and Progress", *Energy*, Vol. 13, No. 6, 1988.

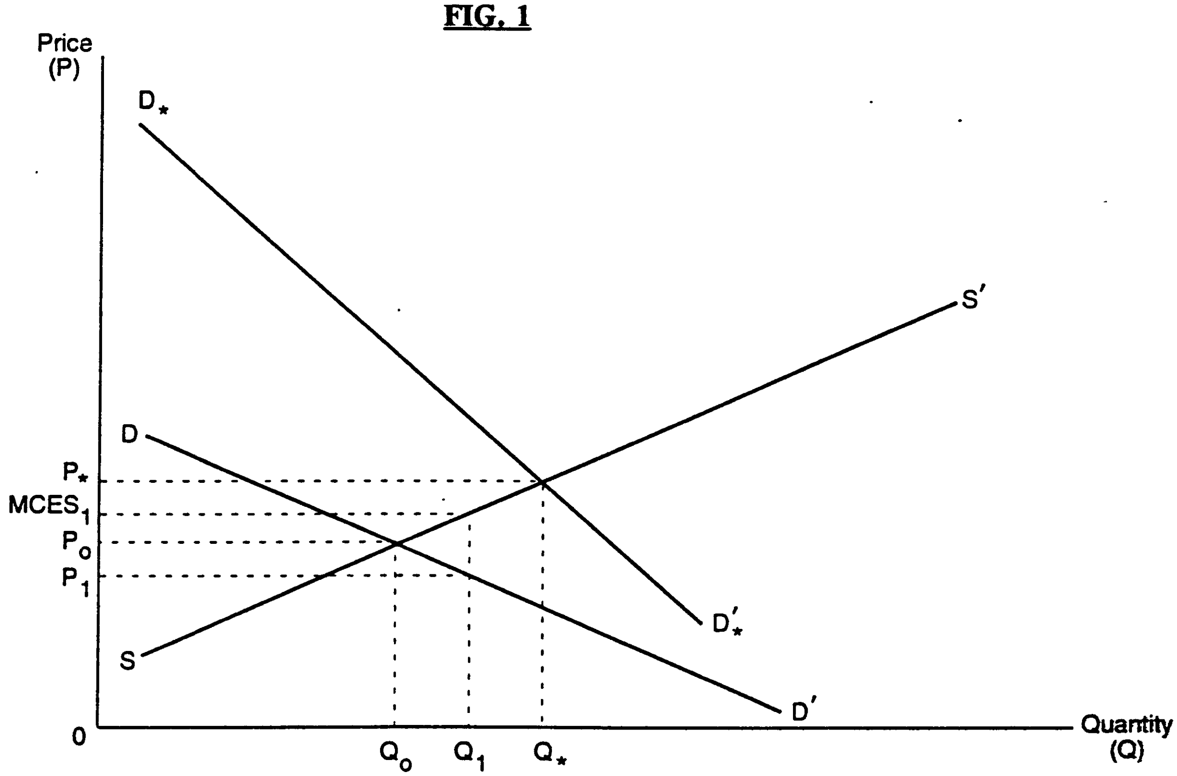
7/ "Energy Efficiency Strategy for Developing Countries: the Role of ESMAP", Background Paper for Discussion at ESMAP's Annual Meeting, World Bank, 1989.

8/ Aside from the U.S. literature, for developing countries see J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H. Williams, *Energy for a Sustainable World*, Wiley Eastern Limited, 1988; M. Munasinghe, "Third World Energy Policies, Demand Management and Conservation", *Energy Policy*, March 1983; M. Munasinghe and G. Schramm, *Energy Economics, Demand Management and Conservation Policy* (1983); H. Kohli and E. Segura, "Industrial Energy Conservation in Developing Countries", *Finance and Development*, December 1983; and J.R. Gamba, D.A. Caplin and J.J. Mulckhuyse, *Industrial Energy Rationalization in Developing Countries* (World Bank 1986).

9/ Detailed expositions of the argument in the context of the U.S. electricity industry have been given by P. Joskow, Testimony Before the Subcommittee on Energy and Power, House Committee on Energy and Commerce, Congress of the United States, March 31, 1988; and L.E. Ruff, "Least-Cost Planning and Demand-Side Management: Six Common Fallacies and One Simple Truth", *Public Utilities Fortnightly*, April 28, 1988.

10. Fig. 1 portrays a simplified model of the energy market: initially, we presume that the curve

FIG. 1



SS', representing the marginal cost of energy supply (MCES) is upward sloping (or highly elastic in the case of imports) over the relevant range of supply; and that the demand curve is shown by DD'. For any quantity under SS', the program of lowest investment and operating costs for the energy sector has been selected. Similarly, for any quantity under the curve DD', consumers have optimized investment in energy conservation, i.e., to the point where the incremental investment in energy conservation (ΔI_{EC}) equals the present value of the stream of incremental expected energy savings produced by that investment. More precisely, the optimum condition for energy conservation investment is:

$$\Delta I_{EC} = \sum_{t=1}^{t=N} \frac{P_t \Delta Q_{ECt}}{(1+r)^t} \quad (1)$$

where r is the discount rate applied to energy consumption investments and P_t and ΔQ_{ECt} are (respectively) the energy price and the expected additional (physical) energy savings in year t attributable to the incremental investment in energy conservation ΔI_{EC}. The values of r, P_t and Q_t will vary across consumers.

11. Fig. 1 treats prices and quantities as constant annual amounts. With $P_t = P$, $\Delta Q_{ECt} = \Delta Q_{EC}$ for all t, equation (1) reduces to:

$$\Delta I_{EC} = a_{\overline{n}|r} P \Delta Q_{EC} \tag{2}$$

where $a_{\overline{n}|r}$ is the factor for the present value of an annuity for n years at an interest rate r, i.e.,

$$a_{\overline{n}|r} = \frac{1-(1+r)^{-n}}{r} \tag{3}$$

Defining the marginal cost of energy conservation (MCEC) as the annual equivalent of ΔI_{EC} per unit of additional energy saved, then

$$MCEC \equiv c_{\overline{n}|r} \frac{\Delta I_{EC}}{\Delta Q_{EC}} = P \tag{4}$$

since $c_{\overline{n}|r}$, the capital recovery factor, is the inverse of $a_{\overline{n}|r}$.

12. Assuming diminishing returns to energy conservation investment, $\Delta I_{EC}/\Delta Q_{EC}$ will increase as the level of energy conservation investment goes up. It follows that less energy conservation will take place as we move down the demand curve DD' in Fig. 1: as P falls, with a given discount rate r, MCEC is reduced by reducing conservation investment, to maintain the marginal optimizing condition. As a reference, curve $D_*D'_*$ in Fig. 1 represents the corresponding demand curve with no energy conservation investment; and the horizontal gap between DD' and $D_*D'_*$ therefore measures the amount of energy conservation taking place. Similarly, an increase in r raises MCEC *via* the capital recovery factor $c_{\overline{n}|r}$; and consumers respond by cutting energy conservation investment at all prices to reduce $\Delta I_{EC}/\Delta Q_{EC}$ to the point where equality between MCEC and P is restored. It follows that the curve DD' in Fig. 1 moves to the right for increases in r; and, with the MCES curve SS', price and supply increase, while energy conservation decreases.[10/]

13. In the case of Fig. 1, the market ensures an optimal allocation of resources at the equilibrium price P_0 and quantity Q_0: energy is supplied at least cost, with MCES=MCEC=P_0, compared with the higher price P_* and supply Q_* with zero energy conservation. No intervention is necessary to encourage investment in energy conservation measures. The case of a falling MCES, e.g., through

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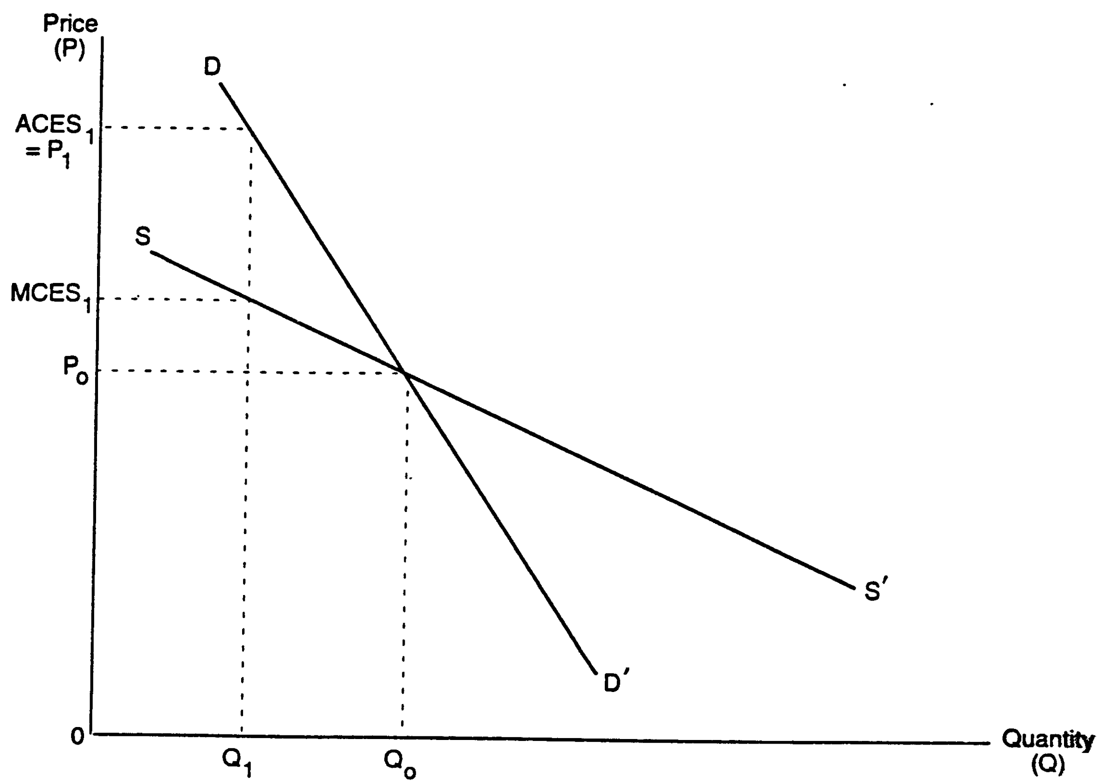
10/ Mathematically, we define: the relationship $Q_s = f(I)$ between annual physical energy savings Q_s and energy conservation investment I, with its inverse $I = g(Q_s)$; and MCEC as $c_{\overline{n}|r}\delta I/\delta Q_s = c_{\overline{n}|r}g'(Q_s) > 0$, with $g''(Q_s) > 0$ (diminishing returns). For $Q_s = 0$, we define demand $Q = \phi(P)$. With a given discount rate r and price P, energy conservation Q_s will be pursued to minimize annual energy expenditures $E = P(Q-Q_s) + c_{\overline{n}|r}g(Q_s)$, i.e. until $\delta E/\delta Q_s = -P + c_{\overline{n}|r}g'(Q_s) = 0$, giving our optimizing condition P = MCEC in equation (4). Q_s increases with P to maintain the optimizing condition: $dQ_s/dP = 1/[c_{\overline{n}|r}g''(Q_s)] > 0$, as $g''(Q_s) > 0$. With a given energy price P and an increase in r, Q_s decreases with r as MCEC is adjusted to maintain the optimizing condition: $dQ_s/dr = -(\delta MCEC/\delta r)/(\delta MCEC/\delta Q_s) < 0$, since $\delta c_{\overline{n}|r}/\delta r > 0$, $g'(Q_s) > 0$ and $g''(Q_s) > 0$.

economies of scale, and a downward-sloping SS' is in Fig. 2. Again, the equilibrium price and quantity are at P_0 and Q_0 respectively.[11]

14. In contrast to the perfectly competitive market, the advocates of Government intervention to promote energy conservation argue that, in practice, the distortions in price signals and consumers' responses, combined with deficiencies in decision-taking (as described in Section II), will prevent least-cost energy supply and optimal investment in energy conservation from being attained. Hence, while the importance of market forces is acknowledged, it is postulated that outside action is necessary to overcome the inertia caused by these imperfections and induce additional conservation beyond the (constrained) market solution.[12] We now turn to these arguments, with the exception of externalities, which we reserve for Section VIII.

FIG. 2



11/ Fig. 2 assumes that the demand curve intersects SS' from above, to ensure Marshallian stability.

12/ A typical statement is in J. Goldemberg *et. al.*, *Energy for a Sustainable World, op. cit.*, p. 328: "Given its advantages, the market should be relied upon as an instrument for implementing end-use oriented energy strategies, wherever possible. And policies which impede the efficient functioning of the market, e.g. price controls, average cost pricing, and producer subsidies, should be eliminated. However, and this is crucial, the public sector has to intervene in the energy market to eliminate market distortions, to lower consumer discount rates, and to deal with the problems of poverty, externalities, the need for research and development, and scarcity of needed information - problems that the market is intrinsically incapable of dealing with adequately".

IV. The Effect of Imperfections, Barriers and Distortions on the Energy Market

(i) Distorted Price Signals and Responses

15. Evidently, if $P < MCES$, there will be cost-effective measures which are not being implemented, but that is precisely why economists recommend MC pricing. The situation in Fig. 1, where the curve of energy supply SS' is upward sloping, is typical for the major sources of commercial energy, such as petroleum products, coal and natural gas.[13/] While Fig. 2 may have been appropriate for electricity supply in the past, the era of declining long-run marginal costs, when the industry enjoyed substantial economies of scale, is over in most developing and developed countries. We do not, therefore, regard Fig. 2 as a realistic representation of the contemporary energy market.

16. Suppose that price is set at $P_1 < P_0$ in Fig. 1. There is empirical evidence that this situation is widespread in developing countries, at least for electricity supply: it may result because, with rising MCES, the average cost of energy supply (ACES) is likely to be less than MCES and excess profits would be generated; or simply from a desire to subsidize energy prices ($P < ACES$).[14/] Then quantity Q_1 will be supplied, with $MCES_1 > P_1$. Since energy conservation will be pursued only to the point where $MCEC = P_1 < MCES_1$, energy conservation will be more economic at the margin than energy supply. However, the argument that marginal-cost pricing does not exist in practice is insufficient where the Government has a direct influence on energy prices. From an economic point of view, it is better public policy for the Government to use its influence to ensure that energy prices reflect economic costs, before intervening in the market to create further distortions, since it has direct control over at least some energy pricing (e.g., electricity) in most developing countries. Non-price intervention should not be justified on the grounds that it may be politically easier, although it frequently is; and if excess profits would be generated ($ACES < MCES$), this can be viewed as an additional benefit in most developing countries, creating an opportunity for the Government to supplement a generally inadequate fiscal base by levying taxes and yielding a valuable new source of revenue.[15/]

17. With the downward-sloping MCES curve SS' in Fig. 2, ACES > MCES. At the point (P_0, Q_0), financial losses would be incurred if MCES pricing were pursued. Although we do not regard a falling SS' as a realistic representation of MCES (para. 15), implementation of ACES pricing on financial grounds would drive investment in energy conservation beyond the optimal level. For example, suppose price were set at $P_1 = ACES_1 > P_0$; then $MCEC_1 = P_1 = ACES_1 > MCES_1$ and energy consumption would be sub-optimal at Q_1 rather than Q_0.

13/ For tradeables, notably petroleum products, SS' is highly elastic and yields the same results as the upward-sloping curve in Fig. 1.

14/ See "Review of Electricity Tariffs in Developing Countries during the 1980s", Industry and Energy Department Working Paper, Energy Series Paper No. 32, World Bank, November 1990; and "Energy Efficiency Strategy for Developing Countries", World Bank, *op. cit.*.

15/ Or off-setting tax reductions can be made, if there is a constraint on increasing total tax receipts.

18. A more sophisticated version of the energy model in Fig. 1 recognizes that energy supplied at different times of the day, week and year has a different value and cost, so that different demand and supply curves are needed, leading to different equilibrium prices and quantities for different time-periods. The differential pricing of certain types of energy (notably electricity and gas) and the related concept of load management, e.g., using interruptible supplies and time-of-day metering, involves transaction costs, which may be significant. The issue of cost effectiveness must be addressed, particularly with some (but by no means all) residential customers. If proper metering is not employed, consumers may make choices about appliance use and energy conservation on the basis of energy prices which do not reflect economic costs. However, a variety of approaches are available to handle the problem, such as offering optional metered tariffs, where the individual consumer pays for the meter and weighs the cost of metering against the benefits.[16/] The example of the 'chuveiro', from Brazil, is a case where special metering is unlikely to be cost-effective. The 'chuveiro' is a relatively inexpensive shower fitting, which heats the water electrically as it is used, contributing significantly to the evening system peak. About 20 million are estimated to be in use in Brazil.[17/] However, rather than, say, regulating the design and manufacture of the device, a tax could be included in the purchase price to reflect its contribution to system capacity costs.[18/]

19. In the context of developing countries, a particular variation is heard on the argument that energy prices and costs give inadequate signals to consumers or consumers may not be able to respond appropriately to those signals, due to macroeconomic distortions, notably in trade policy. Thus, the foreign exchange required to purchase energy-efficient items may be restricted;[19/] there may be taxes or controls on the import of energy-efficient equipment and devices to measure energy efficiency; or some forms of energy supply may be subsidized, either directly by the Government or indirectly, by failing to capture the high economic cost of the foreign exchange implicit in capital-intensive supply solutions. It is then proposed that taxes and subsidies (which could be tax deductions or other tax incentives, such as accelerated depreciation for energy-efficient investments) are needed to offset distortions.

20. On the demand side of the energy market, macroeconomic distortions have a range of impacts on DD' in Fig. 1. A tax on energy conservation equipment (*ad valorem* or unit) will raise MCEC

16/ See P.L. Joskow, "Public Utility Regulatory Policy Act of 1978: Electric Utility Rate Reform", *Natural Resources Journal*, Vol. 19, No. 3, October 1979. Setting a tariff to reflect the weighted average cost of peak and off-peak use does not really address the issue, since the allocation of conserved electricity between peak and off-peak hours at the margin may differ from the average allocation used to calculate the weights.

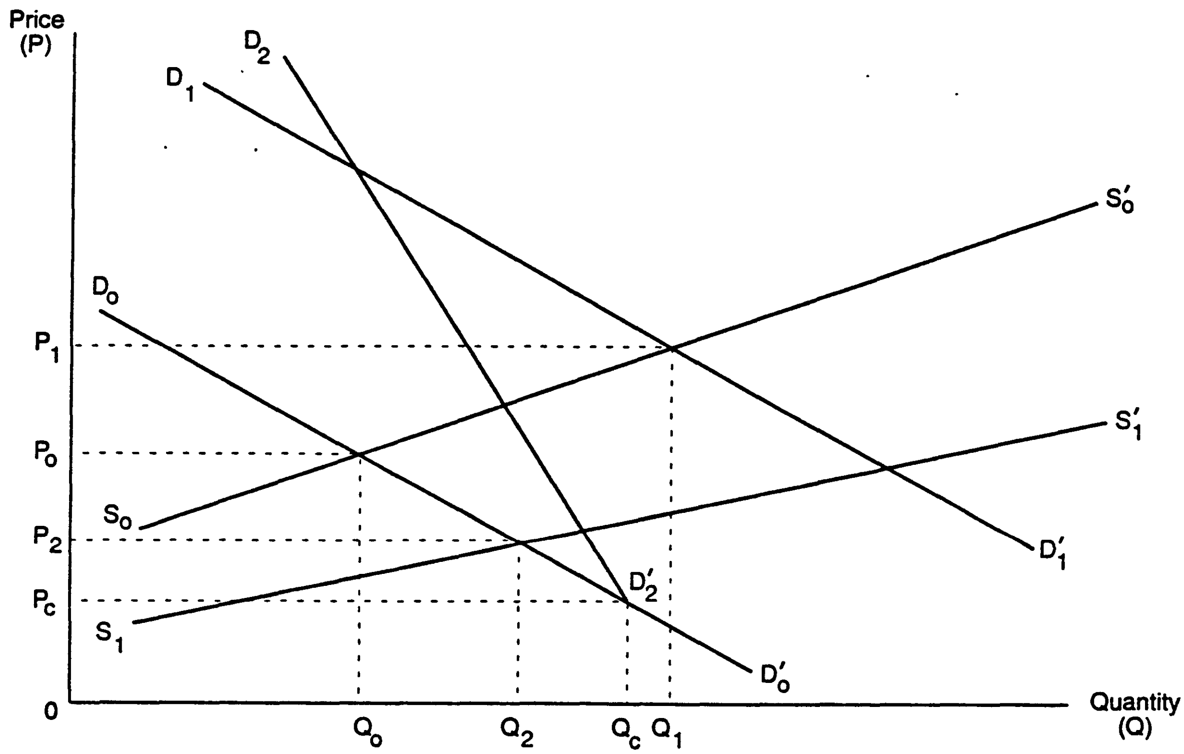
17/ "Testes Revelam Problemas com o Chuveiro Elêtrico", *São Paulo Energia*, Ano VII, No. 63, April 1990.

18/ The transaction costs of the tax need to be compared with the cost of regulations. There is also an issue concerning the recipient of the tax proceeds. While the tax may not significantly affect the use of the 'chuveiro' and hence the cost of supply, the consumer will bear and be forced to recognize the costs imposed on the system and an incentive provided to produce a more efficient shower fitting. Of course, we do not address here regulations designed to improve the safety rather than the energy efficiency of the 'chuveiro'.

19/ Presumably, it would also be restricted for energy-producing items, e.g. imported capital for electricity generating plant.

throughout DD'. At each energy price, investment in energy conservation will decline, to reduce MCEC: DD', in effect, shifts to the right, say from $D_0D'_0$ to $D_1D'_1$ in Fig. 3.[20] The equilibrium price and supply increase from P_0 to P_1 and from Q_0 to Q_1 respectively, with less investment in energy conservation than before. Limitations on the availability of energy efficiency devices, either directly (through quotas and physical controls) or indirectly (through a lack of financing sources, including foreign exchange) are more complex. If they are effective, then (by definition) at some energy demand $Q_c > Q_0$ on $D_0D'_0$ in Fig. 3, the demand for energy conservation devices is curtailed (equivalent to an artificially high MCEC at the curtailment point); and the price elasticity of demand for energy falls with respect to price increases above P_c. Hence, for prices above P_c, the demand curve in effect again shifts to the right, say to $D_2D'_0$, with qualitatively similar impacts on energy price, supply and conservation.[21]

FIG. 3



20/ Mathematically, an additional term τQ_s (a unit tax) or $\tau c_{n]r}I$ (an *ad valorem* tax) is added to E in footnote 10, so that the condition becomes $P = c_{n]r}g'(Q_s) + \tau$ or $P = c_{n]r}g'(Q_s)(1 + \tau)$ respectively.

21/ Mathematically, referring to footnote 10, a constraint I_c on energy conservation investment sets an upper limit $f(I_c)$ on energy savings and determines energy demand $Q = \phi(P) - f(I_c)$ for $Q > Q_c$, $P > P_c$. The optimizing condition becomes $P = g'(Q_s)(1 + \lambda)$, where the Lagrangean λ is the shadow value of the (constrained) energy conservation investment. Market forces would tend to establish a premium value for the constrained investment equal to λ.

21. Special treatment for energy conservation measures amounts to an attempt to shift $D_1D'_1$ or the relevant section of $D_2D'_0$ in Fig. 3 to the left but represents an inefficient way to find the optimum energy price and supply. Apart from the difficulties in implementing a program of special treatment and predicting its consequences, taxes, limited foreign exchange availability and import restrictions are general distortions and are not best tackled through the energy sector by manipulating the demand curve for energy: there is no presupposition that special treatment for energy conservation has greater net welfare benefits than, say, making more foreign exchange available or subsidizing other constrained activities outside the energy sector. Broader Government action is more appropriate on trade and exchange rate policy.

22. On the supply side of the energy market, developed as well as developing countries have subsidized energy production;[22/] and analytically, such subsidies will shift the MCES curve to the right, say from $S_0S'_0$ to $S_1S'_1$ in Fig. 3, by artificially depressing the real MCES, leading to a lower equilibrium price P_2 relative to the optimum P_0, an increased supply $Q_2 > Q_0$ and again under-investment in energy conservation. However, demand-oriented measures, based on special programs for energy conservation, are theoretically questionable in dealing with supply distortions. In effect, they try to shift $D_0D'_0$ to the left to offset the rightward shift in $S_0S'_0$. The remedy is to discontinue all subsidies, not to subsidize energy conservation measures.[23/]

(ii) <u>Deficient Decision-taking Processes</u>

23. It is sometimes claimed that consumers respond (at best) only slowly to price signals and meanwhile costs will be incurred by the economy, due to the dynamics of price adjustment in the real world, which are not recognized in Fig. 1.[24/] For example, a given increase in real income may shift the demand curve outward from $D_0D'_0$ to $D_1D'_1$ in Fig. 3 in the short run, but as more energy conservation takes place in response to price increases, the curve will settle somewhere between $D_0D'_0$ and $D_1D'_1$. Producers supposedly, for some period of time, overestimate demand and during the response lag, resources will be misallocated between production and conservation.

24. While there is nothing intrinsically different about energy, as lags occur in the adoption of other products, it is not usually argued that Government intervention is required. An interesting

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22/ For example, Brazil has subsidized nuclear power and ethanol. Widespread subsidies to U.S. energy development, for nuclear and hydroelectric power, coal, oil and gas were described by R.H. Bezdek and B.W. Cone, "Federal Incentives for Energy Development", *Energy*, Vol. 5, No. 5, May 1980.

23/ At the level of individual project analysis, foreign exchange limitations can still be addressed by evaluating supply alternatives with shadow exchange rates, reflecting (*inter alia*) the rate of return on foreign exchange in the private sector used for energy conservation.

24/ See, for example, L. Schipper *et. al.*, "The National Energy Conservation Policy Act: An Evaluation", *op. cit.*: "When *neither* expensive new energy sources *nor* spontaneous changes in demand patterns come about quickly enough to satisfy political goals (such as the reduction of oil imports), it is necessary for government to stimulate investments in conservation and supplies or to remove barriers that prevent a 'spontaneous' response of the marketplace". Also L. Schipper, "Another Look at Energy Conservation", *American Economic Association (Papers and Proceedings)*, May 1979.

approach has been elaborated by Shama, in which a parallel is drawn between the adoption of conservation devices and the diffusion of innovations.[25] Shama argues that the slow adoption of some energy conservation measures is rational, if the innovations analytical framework is adopted. The relative advantages of conservation devices must be demonstrated, compared with well-tried and established supply alternatives; they must be perceived as compatible with existing life-styles or a decision taken to change life-style; and they are more complex than generally supposed, requiring an understanding of basic energy economics. The conclusion is that these factors should determine the type of marketing which is necessary, for example using small-scale trials to reduce consumer risk or targeting the segment of the population which is ready to take up the innovation (e.g., the "early adopter").[26] Price is less important in encouraging adoption at some stages than at others. Rather than intervening in the market, authorities might do well to examine more carefully and publicize the successful marketing strategies which were pursued for select innovations, e.g., in the communications industry. Removal of barriers to competition and restraints on trade would also be appropriate, to encourage the supply of cost-effective technologies.

25. Imperfect information; ignorance surrounding the way in which to evaluate, design, initiate, finance and implement energy conservation programs; and an institutional separation of the designers, constructors, owners and operators of buildings have all been identified as distortions in the decision-taking process regarding energy consumption, causing the energy demand curve in Fig. 1 to lie between D.D'. and DD'. MCES and MCEC would not then be brought into line through the price mechanism; and, evidently, the market solution would entail a higher energy price and supply than P_0 and Q_0 respectively.

26. Firms consuming energy as an intermediate product may exhibit patterns of behavior which are not motivated by profit maximization. For example, they may give low priority to energy conservation and try to pass on higher energy costs to final consumers through cost-plus pricing.[27] In terms of Fig. 1, the effect is complex to interpret, but one possibility is to reduce the price elasticity of energy demand with respect to an increase in the prevailing energy price: the effect of an energy price increase on energy demand and supply would then be less than otherwise, leaving unexploited investment opportunities in energy conservation.[28] Notice, however, that the magnitude is hard to predict: cost-plus pricing raises the price of the final product by the full amount of the incremental cost of the energy component, reducing demand for the final product and hence energy consumption. Again, if these patterns are economy-wide, it is not obvious that action in the energy sector alone will lead to a more efficient result, compared with better information and an improved policy framework encouraging greater competition. Where the public sector itself, as an energy consumer, is using deficient pricing rules, it is even more difficult to argue that intervention is necessary: the Government should rectify such distortions through policy action.

25/ A. Shama, "Energy Conservation in U.S. Buildings", *Energy Policy*, June 1983.

26/ The type of adopter depends on the stage which has been reached in developing the innovation.

27/ The behavior is essentially the same as in a firm where energy costs are a small proportion of total costs.

28/ C.f. the discussion of the impact of limitations on the availability of energy conservation devices in para. 20.

27. The possible deficiencies in the decision-taking process identified above, especially in para. 25, have provided a fertile ground for the debate over non-price measures to promote energy conservation. First, the most extensive and rigorous empirical work on market imperfections has been devoted to the calculation of discount rates revealed by consumers in their decisions about appliance choice. Second, the most popular energy conservation measures are directed at ameliorating these particular distortions, notably through: information programs; attempts to increase the funding available for energy conservation (e.g., through demand-side bidding); and energy efficiency standards for appliances and buildings. We discuss these subjects in detail in Sections V and VI.

V. Market Imperfections and Consumer Discount Rates

28. Empirical testing of the energy consumption model underlying Fig. 1 has concentrated on comparing the cost of capital with consumers' implicit discount rates, the latter calculated from quantitative studies of decisions about appliance choice. The hypothesis is that, where preferences reveal discount rates substantially in excess of the relevant cost of capital, there is *prima facie* evidence of deficiencies in the decision-taking process and of market imperfections.

29. An appliance choice model requires a restatement of equation (1) in para. 10, to allow for selection between mutually exclusive alternatives, with different investment outlays (first costs) and lifetime energy running costs. The incremental streams for investment and energy savings are then defined as differences in investment and operating costs for the (mutually exclusive) alternatives under comparison, which provide the same energy service. Comparing appliances A and B, the consumer selects A if its "life-cycle" cost is less than that of B, i.e., if:

$$(I_A - I_B) + \sum_{t=1}^{t=N} \frac{P_t(Q_{At} - Q_{Bt})}{(1+r)^t} < 0 \qquad (5)$$

Here, I_A and I_B are the initial outlays and Q_{At} and Q_{Bt} the energy consumed in year t for appliances A and B respectively; while r is the discount rate. For example, A may have a higher investment outlay ($I_A > I_B$) but lower annual operating costs than B ($Q_{At} < Q_{Bt}$). As before, the values for the variables are consumer-specific, due, *inter alia*, to differences in expectations and transaction costs. Facing given expectations about energy prices and appliance investment and operating costs, an increase in r will reduce the present value of A's energy savings stream (Q_{At} - Q_{Bt}) and make condition (5) less likely to hold: first costs become relatively more important in the calculation. Higher discount rates may represent, for example, increased uncertainty about future energy prices and the physical savings to be expected from conservation investment or the higher cost of credit.

30. The classic empirical work on consumers' discount rates appeared in an article written by Hausman, based on an econometric model using the type of decision-taking process embodied in

condition (5).[29] The model found that, in the purchase of room air conditioners, consumers revealed discount rates of 15%-25%. It is important to notice, however, that the discount rates were a function of income: low-income consumers exhibited much higher discount rates than high-income consumers, which is entirely consistent with economic analysis. Findings by Dubin and McFadden, for the choice of space and water heating, are consistent with Hausman: an implied discount rate of 20% at the sample mean income, varying inversely with the level of income.[30]

31. The results of these and more than 20 other studies of consumer discount rates in appliance choice were reviewed by Train in 1985.[31] While the results varied widely, they were generally consistent with those of Hausman and of Dubin and McFadden, being located within a range of 10% to 30%, except for refrigerators, where discount rates in excess of 40% were typical. Fourteen of the studies reviewed by Train estimated the influence of income, finding (like Dubin and McFadden) that in all cases the discount rates fell as income increased; three contained evidence on the effect of ownership status, with lower discount rates for consumers who own their homes rather than renting them; and two provided some limited evidence that discount rates increase with the age of the household head.

32. Work by Hartman and Doane on weatherization investments over 1982-1983, published after Train's survey, also included an allowance for occupancy status, age of the head of household and income. Most of the estimated implicit discount rates were high, although income was again an important factor, with the average household revealing a discount rate of 27%. Renters and (unlike the studies surveyed by Train) young heads of household showed much higher rates (45%-160%) than owners and older householders (0%-90%).[32] More recent investigations, by Ruderman *et. al.*, similarly found high discount rates.[33]

33. Although high implicit discount rates are consistent with certain types of market imperfection, they do not constitute proof that market intervention is necessary. Indeed, bearing in mind the inevitable uncertainties surrounding econometric estimates, we do not find the weight of empirical

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29/ J.A. Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables", *Bell Journal of Economics*, Vol. 10, No. 1, Spring 1979.

30/ J.A. Dubin and D.L. McFadden, "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption", *Econometrica*, Vol. 52, No. 2, March 1984.

31/ K. Train, "Discount Rates in Consumers' Energy-Related Decisions: A Review of the Literature", *Energy*, Vol. 10, No. 12, 1985.

32/ R.S. Hartman and M.J. Doane, "Household Discount Rates Revisited", *Energy Journal*, Vol. 7, No. 1, January 1986.

33/ H. Ruderman, M.D. Levine, J.E. McMahon, "The Behavior of the Market for Energy Efficiency in Residential Appliances, including Heating and Cooling Equipment", *Energy Journal*, Vol. 8, No. 1, January 1987. The study covered 1972-1981 data for gas and oil central space heating, room and central air conditioners, electric and gas water heaters, refrigerators and freezers. The derived discount rates were in the range 40%-825%, except for air conditioners (20%).

evidence on discount rates to be surprising: consumers can be expected to regard the benefits of energy conservation as highly uncertain, partly because future energy prices are uncertain but also because they will vary widely from case to case; conservation investments are much less liquid than many financial assets; consumers may have good reasons for preferring more energy-intensive appliances in their individual circumstances; the estimated energy savings may be wrong; the marginal cost of credit may be high, for example represented by credit cards; or some consumers may not be creditworthy, etc.[34/]

VI. Energy Conservation Measures

34. Advocates of Government intervention have identified a range of measures to reduce the perceived market imperfections. These comprise various programs to provide information, improve financing opportunities for energy conservation investments, introduce appliance efficiency standards and establish codes requiring certain standards of energy efficiency in buildings. We examine these in turn.

(i) Information Provision

35. Programs to improve the provision of information about energy conservation are targeted at reducing the perceived costs and raising the perceived benefits of energy conservation measures. In essence, they reduce the transaction costs associated with making the energy investment decision and, at the conceptual level, they are readily interpreted in relation to equation (1) in para. 10. Operating on the left-hand side, better information about the availability of energy conservation measures and the associated investment costs reduce the perceived value of ΔI_{EC}. Consumers will invest more in energy conservation at any given energy price, to restore equality with the right-hand side, shifting the demand curve DD' in Fig. 1 to the left. Operating on the right-hand side of equation (1), better and more reliable information about future energy prices and physical energy savings may raise the benefits directly or (by reducing the risk premium included in the discount rate) indirectly. Again, consumers would invest more in energy conservation, reducing the right-hand side, until equality is restored with ΔI_{EC}, and DD' shifts to the left. Thus, by reducing the transaction costs of energy conservation, information programs can lower the equilibrium energy price and quantity supplied.

36. Government intervention in the energy market, to provide basic information, may be justified if there are economies of scale or if property rights are hard to establish. For example, it may not be efficient for large numbers of individual agencies or firms to develop their own information programs and audit methodology, when much is generic. Also, Government can educate or inform mortgage

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34/ Among the attempts to explain the phenomenon of high implicit consumer interest rates, see D.N. Dewees, "Energy Conservation in Home Furnaces", *Energy Policy*, June 1979; R.W. Gates, "Investing in Energy Conservation: are Homeowners Passing up High Yields?", *Energy Policy*, March 1983; H. Chernoff, "Individual Purchase Criteria for Energy-Related Durables: the Misuse of Life Cycle Cost", *Energy Journal*, Vol. 4, No. 4, 1983; H. Ruderman *et. al.*, "The Behavior of the Market for Energy Efficiency in Residential Appliances, including Heating and Cooling Equipment", *op. cit.*; and R. J. Sutherland, "An Analysis of Conservation Features in Commercial Buildings," *Energy Systems and Policy*, 1991 (forthcoming). A. Shama, "Energy Conservation in U.S. Buildings", *op. cit.*, expressed the view that high implicit discount rates may reflect rational behavior if the innovations framework is adopted.

lenders and builders, including speculative builders, about the additional value of energy-efficient homes. Finally, Government initiatives to require the provision of certain types of information and to promote standardization of the form of information provision, through appliance labelling, have been advocated, to increase the efficiency of the market. However, such initiatives impose costs on suppliers and require a central decision by Government on exactly which type of information to provide (for example, to make it broader than energy consumption) and how to display it.

37. A particular category of information which may merit Government support is fundamental research and even limited development in areas where it is difficult to grant property rights. Such support is no different from the general argument for public funding of certain research activities. Basic research on combustion and materials and the environmental consequences of energy production and use, as well as applied research on the testing and demonstration of generic new technologies could fall into this category. However, the role of Government in energy R&D must always be carefully scrutinized: apparent lack of interest or resources on the part of the private sector, the possible past success of Government programs and the long-term nature and sometimes high risk of R&D are not sufficient arguments for Government involvement;[35/] and the cost-effectiveness of energy R&D efforts in contrast with other applications of scarce Government funds should be established.[36/]

38. It is frequently argued that an energy corporation or public utility is well-placed to market conservation services. For example, it has detailed knowledge of the energy demand of its consumers, well-established contacts, technical expertise and some degree of goodwill and credibility. On the other hand, the utility usually has knowledge of only one supply source and limited experience of selling conservation services rather than supplying energy. Interest may or may not exist, depending on the relationship between price and the marginal cost of supply or non-supply and the extent to which excess capacity exists.[37/] While there is no reason why an energy supplier should

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35/ See R.J. Sutherland, "An Analysis of the U.S. Department of Energy's Civilian R&D Budget", *Energy Journal*, Vol. 10, No. 1, January 1989.

36/ Some of the successes of U.S. Government-supported R&D are detailed in H. Geller *et. al.*, "The Role of Federal Research and Development in Advancing Energy Efficiency: a $50 Billion Contribution to the U.S. Economy", *op. cit.*. A strong case for reorienting government R&D efforts more towards end-use energy strategies, including those supported by aid agencies, has been made by J. Goldemberg *et. al.*, *Energy for a Sustainable World*, *op. cit.*.

37/ The conditions under which a U.S. public utility would be interested in energy conservation, i.e. reducing demand rather than increasing supply, are discussed in A.M. Marino and J. Sicilian, "The Incentive for Conservation Investment in Regulated Utilities", *Journal of Environmental Economics and Management*, Vol. 15, No. 2, June 1988. Important possibilities would be $P < MCES$, deferment of lumpy investments and capital rationing.

not be permitted to supply conservation services, provided that it does not take advantage of a monopoly position and it operates profitably, energy service companies may be more suitable.[38]

39. The concept of National Energy Conservation Centers or Energy Extension Services (akin to agricultural extension services) has been proposed for developing countries, to conduct promotional and technology demonstration campaigns, give technical advice, conduct audits or train firms to do their own audits.[39] Such a strategy may be effective where imperfect information makes conservation investments look risky or innovative to consumers unfamiliar with the technology. As in the case of the utility (which might in practice be the same entity), such Centers should charge for the cost of their services wherever feasible.

(ii) Financing Energy Conservation Investments

40. A wedge may be driven between the two sides of equation (1) in para. 10, if imperfections in the capital market limit consumers' access to capital. Also, high labor mobility, or the various types of owner/renter problem discussed in para. 55, may lead to an emphasis on first-costs rather than operating costs, equivalent to high implicit discount rates in equation (1), as discussed earlier. In these situations, financing opportunities can be designed and geared to individual circumstances, without resorting to subsidies (e.g., on interest rates) or other special actions favoring the energy market. Subsidies inevitably have an opportunity cost, in terms of the reduced availability of capital to non-energy uses.

41. Various types of shared savings contracts are possible to deal with the problem of consumer finance for energy conservation. Essentially, an energy service company (which could be the public utility itself) agrees to install the energy conservation measure at its own expense, while the consumer contracts to reimburse the company at regular intervals, say monthly, from the estimated energy savings. If these savings are as large as claimed, there should be ample scope for both the consumer and the company to make a profit. Appliance rental and lease options are similar ways to deal with the perceived aversion to high first-cost, as well as the problem of those who move frequently. The public utility or a private rental/lease company finances the initial appliance cost and hires or leases the appliance on, say, a monthly basis.

42. A particular form of shared savings contract has been proposed by Cicchetti and Hogan, who point out that it is possible to "unbundle" energy supply, such that the energy conservation services

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38/ The issue of supplying energy conservation services in the U.S. context is discussed by D. Norland and J. Wolf, "Utility Conservation Programs: Opportunities and Strategies", *Public Utilities Fortnightly*, August 8, 1985; I.M. Stelzer, "What Role Can Utilities Play in Energy Conservation Programs", *Energy Journal*, Vol. 3, No. 1, January 1982; and M.C. Whittaker, "Conservation and Unregulated Utility Profits: Redefining the Conservation Market", *Public Utilities Fortnightly*, July 7, 1988. A good discussion of the comparative advantages of technology-oriented energy service companies is in R.H. Williams, "Innovative Approaches to Marketing Electric Efficiency", in T.B. Johansson, B. Bodlund and R.H. Williams, *Electricity: Efficient End-Use and New Generation Technologies and their Planning Implications*, Lund, Sweden, 1989.

39/ J.R. Gamba *et. al.*, "Industrial Energy Rationalization in Developing Countries", *op. cit.*; and J. Goldemberg *et. al.*, *Energy for a Sustainable World*, *op. cit.*.

which are sold to the utility are distinguished from the energy services retained by the customer.[40/] The "unbundling" makes it possible to differentiate the costs of investing in energy conservation (demand-side alternatives) from the benefits of enjoying the same level of services, at a lower level of energy consumption. The former reduce the quantity of energy which the utility needs to supply and the costs would therefore be reimbursed by the utility. The latter, in contrast, are enjoyed by the consumer, who (under the Cicchetti-Hogan scheme) continues to pay the supplier for an equivalent amount of energy supplied. In effect, the consumer pays for the energy which is conserved (not consumed), while the supplier pays for the cost of the investment which was necessary to obtain that conservation.

43. There are serious practical problems involved with the Cicchetti-Hogan approach, e.g., because the energy service relates not to real energy but to estimates of energy not supplied and the scope for misrepresentation on the part of the energy service company will be clear;[41/] but Joskow has demonstrated that, from an analytical point of view, the "unbundling" approach is entirely consistent with the standard competitive model, as described in Fig. 1, because the consumer pays the full cost of the conservation service[42/] and the utility is merely acting as an intermediary between the conservation supplier and the energy consumer. However, Joskow correctly underlines two critical components in the approach: first, the utility pays no more than the equivalent MCES for the conservation project; and second, the consumer who benefits from the conservation project continues to pay the utility for the energy which would have been consumed without the project. Joskow then concludes that the scope for shared savings is limited to the difference between MCES and P, which of course is zero in the properly-functioning competitive model.

44. In terms of the basic energy conservation model underlying Fig. 1, the maximum payment π which the energy supplier can make to the conservation supplier is MCES. Under the Cicchetti-Hogan scheme, the maximum savings to be shared between the conservation supplier and the consumer (who could be the same person) are correspondingly π-MCEC = MCES-MCEC = MCES-P. Evidently, at the equilibrium P_0,Q_0 in Fig. 1, there is no incentive for this type of shared savings contract, as MCES=P. Nevertheless, Joskow suggests that the energy supplier has a useful role to play by, in effect, acting as a broker between the energy consumer and the energy conservation supplier, e.g., providing a convenient way to amortize the investment cost of the conservation measure, through the monthly energy bill;[43/] and to some extent ameliorating informational barriers by giving its "seal of approval" to the conservation measure. He also suggests that the energy

40/ C.J. Cicchetti and W. Hogan, "Including Unbundled Demand-side Options in Electric Utility Bidding Programs", *Public Utilities Fortnightly*, June 8, 1989.

41/ C.J. Cicchetti and W. Hogan, *ibid.*. Some of the practical problems are discussed further in M.R. Hoover, J.S. Garces and R.S. Ridge, "Demand Side Bidding: A Practical View", *Public Utilities Fortnightly*, June 21, 1990.

42/ P.L. Joskow, "Understanding the 'Unbundled' Utility Conservation Bidding Proposal", *Public Utilities Fortnightly*, January 4, 1990. See also L. Ruff, "Environmental Protection through Energy Conservation: a Free Lunch at Last?", *Energy and the Environment in the 21st Century*, M.I.T. Press, Cambridge, MA, 1990.

43/ In effect, being the vehicle to amortize the investment shown in equation (4).

supplier "can offer subsidies to correct pricing distortions", if marginal cost pricing does not exist, up to a limit of MCES-P, although we have argued that it is better public policy to attack pricing distortions directly rather than resort to subsidies or other market interventions.

45. Evidently, not all forms of shared savings contracts and rental/lease agreements meet the test of covering costs. Where the Government or public utility is involved, there is the danger that some subsidy will be made for the rented appliance or energy conservation service.[44] A particular case in point is a version of the shared savings contract which has recently appeared in the literature and generated a lively debate in the context of the U.S. electricity industry. It focusses on the proposition that it is more economic to conserve energy than to produce it; and the perceived need, in consequence, to include energy conservation alternatives along with supply alternatives in an "all-source" bidding program, to find the least-cost way to supply future electricity demands. One of the strongest proponents of buying "negawatts" on an equal footing with kilowatts has been Lovins.[45] The argument is deceptively simple: since the public utility would pay for extra kilowatts of capacity, why should it not be willing to pay an equivalent amount to reduce consumption, i.e., to buy "negawatts"?. "After all, a kilowatt-hour saved is just like a kilowatt-hour generated, only cheaper, and can be resold to someone else, so they should be treated alike."[46] The payment could be made directly to consumers or to energy service companies on their behalf, to cover some or all of the investments necessary to implement energy conservation measures. In effect, the utility would be paying the consumer to invest in, for example, more efficient appliances, higher thermal efficiency and autogeneration.[47]

46. At first sight, the Lovins proposal appears similar to the Cicchetti-Hogan scheme. However, the problem with the "negawatt" auction is that it eliminates the second of the two critical components identified by Joskow (see para. 43). Turning to our basic energy conservation model: while the payment for a supply-side alternative covers its cost (MCES), the cost of an economical energy conservation measure (MCEC) is already compensated through the reduction in the customer's bill on the kilowatthour savings (P). If the payment for the energy conservation measure is $\pi = MCES$ and there is no off-set in the consumer's bill, the subsidy received by the energy conservation supplier and

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44/ Some interesting examples from U.S. utilities in Pennsylvania and New Jersey are given by M.A. Brown and D.L. White, "Stimulating Energy Conservation by Sharing the Savings: a Community-based Approach", *Environment and Planning A*, Vol. 20, 1988. These shared savings contracts are three-way agreements, involving the public utility, an energy service company and the consumer. They are unfortunately not transparent with regard to the distribution of benefits and costs.

45/ See A.B. Lovins, "Saving Gigabucks with Negawatts", *Public Utilities Fortnightly*, March 21, 1985.

46/ A.B. Lovins, *ibid*, p. 24.

47/ The flexibility benefits of demand-side alternatives are also emphasized in the literature, from a system planning perspective, because they can be adjusted in small increments. See E. Hirst, "Flexibility Benefits of Demand-Side Programs in Electric Utility Planning", *Energy Journal*, Vol. 11, No. 1, January 1990; and A.B. Lovins, "Saving Gigabucks with Negawatts", *op. cit.*. However, there is nothing special about such programs: marginal cost pricing, for example through interruptible loads, and small-scale supply options, such as gas turbines, have the same feature.

energy consumer jointly becomes (in contrast to para. 44) π+P-MCEC=MCES+P-MCEC=2P-MCEC: there is a windfall gain, which would encourage inefficient energy conservation measures.[48/] Furthermore, if the payments for energy conservation measures are directed only or mainly at one form of energy (such as electricity), which is likely to be the case, consumers' inter-fuel substitution decisions will be distorted.

47. Special credit programs are sometimes proposed for low-income consumers on the grounds that they have insufficient access to financial markets. Yet there is no obvious reason why such arrangements should be made for energy markets as opposed to other markets. The financial market is normally assumed to assess adequately the credit-worthiness of borrowers and charge appropriate interest rates to reflect the risk of default. Similarly, direct income support for poorer consumers, for example through tax credits, free audits and grants, as has been provided under U.S. legislation, is hard to justify, without evidence that they increase the welfare of poor consumers more than other types of intervention.

48. The argument is sometimes heard that the market interest rate, which appears in equation (1) in para. 10, exceeds the social rate of discount, causing a bias towards first-cost. If true, it requires action throughout the economy, not confined within the context of energy conservation. It is not a solution to treat the decisions of individual consumers, concerning the disposition of their own incomes in energy markets, as if they were public investment decisions, by making calculations on their behalf at discount rates determined by central planners.[49/]

(iii) Appliance Efficiency Standards

49. In terms of condition (5) in para. 29, appliance efficiency standards shift decisions away from certain appliances with lower investment costs and higher operating costs by, in effect, attaching a very high or infinite value to the investment cost of the appliances excluded under the regulations. As pointed out by Hausman and Joskow, the ensuing reduction in consumer choice can be presumed to

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48/ The point is well-put by C.J. Cicchetti and W. Hogan, "Including Unbundled Demand-Side Options in Electric Utility Bidding Programs", *op. cit.*: "In the case in which the utility pays the customer to make the conservation investment .... the utility buys the 'supply' of conservation, but the customer receives the energy service produced by that investment free! The incentive given the customer is wrong. He is paid twice: once by giving him the dollars for the conservation device, again by providing a free service. This misplaced incentive could result in inefficient over-investment in conservation". In practice, the value of the subsidy depends not only upon the relationship between MCES, MCEC and P: it also reflects the way in which a utility's payments for conservation investments translate into a higher average revenue requirement, through the inclusion of the cost of those investments in the rate base. With P=MCES, inefficient energy conservation measures will raise the average revenue requirement and hence P but the consumer's bill will still fall so that he is indeed compensated twice for his expenditure on the (subsidized) energy conservation measure. For a numerical example, see L.E. Ruff, "Environmental Protection through Energy Conservation: a Free Lunch at Last?", *op. cit.*, pp. 21-22.

49/ It is not inconsistent to use a discount rate for public investment decisions which is different from the ones used in the private sector.

decrease welfare.[50] For example, there are welfare losses due to consumers being forced to incur higher investment outlays to "enjoy" lower annual energy costs, even assuming that the engineering calculations turn out to be more correct than those which have implicitly been made by consumers. Referring to condition (5), mandatory standards preclude consumers with values of r above a critical value from maximizing their welfare.[51] Second, appliances may be removed from the market which have features perceived to be desirable by consumers, but which are not understood by the central planners. The assumption underlying the "life-cycle" cost comparisons in condition (5) is that A and B provide an equivalent quality of energy service. In reality, additional terms are needed to attach monetary values to differences in the services provided by A and B. Third, standards by definition must cover wide areas, although conditions of climate, energy prices, tastes and habits can vary widely, thereby underlining the consumer-specific nature of the P_t, Q_{At} and Q_{Bt} in condition (5).[52] Even on a voluntary basis, appliance efficiency standards may serve to limit competition among existing manufacturers and restrain new entrants; and to the extent that standards are directed at specific types of appliance using specific types of energy, they are liable to distort inter-fuel substitution. In any case, the gains from higher efficiency will be eroded to some extent by the "rebound" or "feedback" effect, discussed in paras. 60-62; and it is not clear why consumer choice of a refrigerator or furnace is less rational than other durables.

50. An interesting example of the introduction of appliance efficiency standards has occurred in the U.S.A. The National Appliance Energy Conservation Act (NAECA) was passed in 1987 to provide for the establishment of energy efficiency standards for twelve consumer appliances.[53] These

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50/ J.A. Hausman and P.L. Joskow, "Evaluating the Costs and Benefits of Appliance Efficiency Standards", *American Economic Association (Papers and Proceedings)*, Vol. 72, No. 2, May 1982.

51/ These welfare losses include income distribution effects, as the higher first-cost of more energy-efficient appliances will impose a larger burden on lower-income consumers, who in any case tend to have higher discount rates (see paras. 30, 31, 32). It is not sufficient to argue that the higher first-cost will be repaid in energy savings: lower-income consumers have limited access to capital and the funds may yield higher benefits to them spent in other ways. Writers frequently overlook this point (c.f. P. Rollin and J. Beyea, "US Appliance Efficiency Standards", *Energy Policy*, October 1985).

52/ For example, an individual's tolerance to heat or use of specific rooms may lead to only occasional use of certain room air conditioners; and with a move to peak load pricing, less efficient appliances may be appropriate outside peak hours, because the costs during those hours are lower than average. Appliance standards cannot accommodate this type of economic effect. See J.A. Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables", *op. cit.*; and J.A. Hausman and P.L. Joskow, "Evaluating the Costs and Benefits of Appliance Efficiency Standards", *op. cit.*. On the peak load pricing effect, see J. Hausman and J. Trimble, "Appliance Purchase and Usage Adaptation to a Permanent Time-of-day Electricity Rate Schedule", *Journal of Econometrics*, Vol. 26, 1984. The view that having a smaller permitted selection of appliances may actually raise consumer welfare, because it reduces the consumers' transaction costs when making the selection, should not be overlooked but runs counter to the basic economic principles of consumer choice in free markets.

53/ Refrigerators and freezers, room air conditioners, central air-conditioners and heat pumps, water heaters, furnaces, dishwashers, clothes washers, clothes dryers, direct heating equipment, kitchen ranges and ovens, pool heaters, and television sets. An Amendment to NAECA, passed in 1988, added fluorescent lamp ballasts.

standards are to preempt State standards and are being introduced under a phased program, according to product, in 1988, 1990, 1992 and 1993.

51. DOE was required to justify the standards, *inter alia*, using cost-benefit analysis, which meant that DOE had to insert its own judgement in place of the market with regard to the variables in condition (5), including: the technical performance of these appliances; how consumers will change their utilization in response to higher efficiencies (the rebound effect); the discount rate; and future energy prices. With regard to the discount rate in particular, DOE made an administrative decision on the trade-off between estimated capital costs and future operating costs. A single figure of 7% in real terms was employed; and although intended to capture the diversity of after-tax borrowing and lending rates facing individual consumers, it is for all practical purposes arbitrary. On the supply side, DOE also substituted its judgement for the market in determining the impact of the standards on competition and the availability of appliances.

52. In general, U.S. appliance manufacturers supported the legislation, since it would replace "a growing patchwork of differing State regulations" with uniform national standards, which would greatly facilitate their production and marketing efforts.[54/] The Administration had opposed an essentially identical earlier version of the 1987 legislation, on the grounds that it intruded "unduly on the free market" and limited "the freedom of choice available to consumers who would be denied the opportunity to purchase lower-cost appliances";[55/] and further opposed the NAECA Amendment of 1988, in the belief "that Federal intervention in the marketplace is generally ill-advised and that Federal regulation more often than not results in a loss of efficiency in the affected industry."[56/] The debate surrounding NAECA also recognized the possibility of distortions in choices of inter-fuel substitution arising out of the legislation, since there was fear that switching might occur from small gas furnaces to electric resistance heating if standards for the former made them uncompetitive and, eventually, unavailable.[57/]

53. The corporate average fuel economy (CAFE) standards in the U.S.A. are another interesting and also highly controversial example. Apart from doubts existing over their effectiveness in achieving their objective of improving vehicle fuel efficiency (see Section VII), the CAFE standards have had impacts on vehicle manufacturers' business decisions -- sometimes called "CAFE gaming" -- which go beyond fuel efficiency. The artificial segmentation of the automobile market -- under the rules which were established for imports and domestic cars, and for light trucks and passenger vehicles -- have distorted manufacturers' decisions regarding the mix of vehicle types, the location of

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54/ Senate Report (Energy and Natural Resources Committee) No. 100-6, January 30, 1987, accompanying the NAECA of 1987, p. 4.

55/ *Ibid.*

56/ Senate Report (Energy and Natural Resources Committee) No. 100-345, May 13, 1988, accompanying the NAECA Amendments of 1988, p.6.

57/ Senate Report No. 100-6, *op. cit.*.

production and the sources of components.[58] Furthermore, it seems probable that the standards penalize consumers who would choose vehicle safety over fuel efficiency; and encourage those who favor larger cars to drive them for a longer period of time, although their fuel efficiency decreases as they get older.

(iv) Building Codes

54. Mandatory building standards or codes are conceptually equivalent to appliance standards, although the argument put to justify them is sometimes different.[59] "Excessive" emphasis on first-cost relative to operating costs in buildings is sometimes attributed to the fact that decisions affecting energy efficiency are often taken by architects and builders at the design stage, although they will not pay the energy operating costs. Builders also purchase domestic appliances, such as air-conditioning systems, furnaces and space heating equipment in new homes independently of the future homeowners. A Canadian study estimated that 48% of the annual energy consumption of all equipment purchased in 1978 for residential use was on an "imposed choice" basis. Furthermore, the building's owners are not necessarily the occupiers. More than half the year-round housing units in New York State are renter-occupied and rental units make up over one-third of the U.S. residential housing stock.[60] These institutional factors are cited to justify building codes and ordinances.

55. Residential energy consumption in rental markets may indeed raise special problems, as it will depend on the way that energy costs are allocated between owners and tenants, and there is empirical evidence that ownership status affects the implementation of energy conservation measures.[61] Rental units can be metered individually for electricity consumption or there may be a master meter, with the owner responsible for payment. In the former case, there is no direct incentive for the owner to install energy conservation devices; and individual renters have only limited ability, beyond behavioral changes, to affect energy consumption, as they are unlikely to invest in energy conservation devices without long-term tenure. Where a master meter is provided, there is no incentive for individual renters to conserve, as all energy costs are absorbed and averaged in overall rents, so that the effective marginal price is zero. Hence, households in multifamily dwellings with central systems (e.g., for water and space heating and for air-conditioning) treat conservation as a collective consumption good.[62] While the role of energy costs in the rental market is complex,

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58/ The distortions are well described in an article in *Fortune*, June 17, 1991.

59/ "Model Conservation Standards" are sometimes advocated as an alternative to mandatory standards, to be adopted on a voluntary basis. Where financial incentives are offered to achieve such voluntarism, they amount to subsidies and inefficiency may result. For example, payments to builders to offset the capital costs of less energy-intensive buildings will encourage over-design and produce windfall gains.

60/ J. Laquatra, "Energy Efficiency in Rental Housing", *Energy Policy*, December 1987.

61/ See K. Train, "Discount Rates in Consumers' Energy-Related Decisions", *op. cit.*; and R.S. Hartman and M.J. Doane, "Household Discount Rates Revisited", *op. cit.*.

62/ E.T Fujii and J. Mak, "A Model of Household Electricity Conservation Behavior", *Land Economics*, Vol. 60, No. 4, November 1984.

individual metering of housing units would appear to resolve many issues of energy conservation. In the final analysis, the level of rents (where there is master metering) and the level of energy bills for individual rental units will affect the demand for those units; and competition between property owners should therefore encourage investment in conservation devices, if they are economically justified. Of course, the need for prices to reflect accurately the economic costs of supply at the master or individual meters must again be underlined. The potential impact of information campaigns should not be underestimated: if retrofit benefits exist, and renters and owners are made aware, it is not difficult to find ways to act jointly to realize the benefits to their mutual advantage.

56. More generally, even in the non-rental residential market, it is sometimes claimed that owner-occupiers as a group choose energy-inefficient buildings, just as they buy appliances which are inefficient. The same arguments which were proposed against appliance efficiency standards in the last section can be levelled against building codes and ordinances in the non-rental residential market, but there is also empirical evidence that home buyers are willing to pay higher market prices for energy-efficient homes, i.e., they capitalize the energy savings in the sales price, so that a rate of return can be earned on residential investment in energy-conservation.[63/] Competition among builders can be made more effective by informing them and extending the concept of labelling to new homes.[64/]

57. In the non-residential market, it has not been explained why business investment in buildings should be less rational than in other sectors. If there is widespread failure to give sufficient attention to energy conservation, much more needs to be known about the reasons, as a basis for tackling them in a more comprehensive fashion. With regard to the builder/owner/occupier dilemma, Sutherland's recent study of energy conservation features in commercial buildings, based on a 1986 nationwide survey conducted by the Energy Information Administration of the DOE, concluded that there is no significant difference between the number of conservation features installed by owners of commercial buildings compared with renters, "which implies that conservation strategies are not impeded by the renting or leasing of buildings."[65/]

63/ M.J. Horowitz and H. Haeri, "Economic Efficiency *v* Energy Efficiency: Do Model Conservation Standards Make Good Sense?", *Energy Economics*, April 1990, estimated a real rate of return of 8% on the resale of energy efficient homes. M. Longstreth, A.R. Coveney and J.S. Bowers, "Conservation Characteristics Among Determinants of Residential Property Value", *Journal of Consumer Research*, Vol. 11, June 1984, demonstrate that basic energy conservation measures to improve a home's thermal integrity, e.g. adding wall and ceiling insulation, increase resale value. K. Train, *op. cit.*, reports an ORNL study (R. Johnson, "Housing Market Capitalization of Energy-Saving Durable Good Investment", Report ORNL/CON-74, 1981) which calculated an implicit discount rate of about 4% applied to energy efficiency in the purchase of homes.

64/ Recognizing that labelling involves transaction costs, as mentioned in para. 36.

65/ R.J. Sutherland, "An Analysis of Conservation Features in Commercial Buildings", *op. cit.*

VII. The Effectiveness of Energy Conservation Measures

58. Quite apart from the conceptual problems in justifying Government intervention in the energy market, evidence on the effectiveness of energy conservation measures is not conclusive. Researchers at the Oak Ridge National Laboratory (ORNL) cite significant savings from a program of free residential audits and interest-free residential weatherization programs for the Tennessee Valley Authority, amounting to 2.5 GWh and 1000 MW for 1987. They refer also to ORNL studies of the CAFE standards, which attributed savings of 230,000 barrels per day to CAFE by 1980; and the Department of Energy conservation programs in effect in 1980, to which savings of 3 million barrels per day by 2000 were imputed, over and above what the market would yield.[66/] More recently, ORNL stated that an additional improvement in energy efficiency of 14% could be achieved by 2010 through cost-effective conservation measures, compared with the gains that could be achieved through the market alone;[67/] and studies by the staff at the Lawrence Berkeley Laboratory of the impact of the appliance standards in NAECA of 1987 and the 1988 Amendment, yield impressive results.[68/] Also in a recent study, Greene compared the effects of CAFE and fuel prices in terms of a manufacturer decision-taking model, utilizing a penalty function to reflect the impact of deviations from CAFE standards and market equilibrium demand on automobile manufacturers' costs. Greene concluded that CAFE standards did have a significant impact on fuel efficiency in new cars.[69/]

59. These results seem impressive. However, other studies have concluded that the expected and realized energy savings attributable to energy conservation programs may be over-estimated; or market solutions might give similar results. Some of these studies are reviewed in paras. 60-64. Section VII then concludes (para. 65) with some observations on the measurement problems faced by all empirical studies on the effectiveness of energy conservation measures.

(i) The Rebound Effect

60. An important reason why both anticipated and realized energy savings may be over-estimated is the "feedback" or "rebound" effect. The basic energy conservation model in equation (1) in para. 10 and condition (5) in para. 29 operates as if the expected additional physical energy savings in year t -- ΔQ_{ECt} or $(Q_{At} - Q_{Bt})$ -- are independent of the energy price P_t. In fact, we can expect a "rebound" from carrying out an energy conservation measure. The demand for energy is derived from the demand for the services which it yields and an increase in the efficiency of an energy-utilizing device

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66/ E. Hirst *et. al.*, "Improving Energy Efficiency: the Effectiveness of Government Action", *op. cit.*.

67/ R.S. Carlsmith *et. al.*, "Energy Efficiency: How Far Can We Go?", *op. cit.*.

68/ J.E. McMahon, D. Berman, P. Chan, T. Chan, J. Koomey, B. Lebot, M. Levine, S. Stoft and I. Turiel, "Economic and Energy Demand Impacts of U.S. Appliance Efficiency Regulations on Consumers, Manufacturers, and Electric Utilities", *Paper Presented at the Thirteenth Annual International Conference of the International Association for Energy Economics: Integrated Energy Markets and Energy Systems, Lessons and Perspectives*, Copenhagen, Denmark, June 19-21, 1990.

69/ D.L. Greene, "CAFE or Price?: An Analysis of the Effects of Federal Fuel Economy Regulations and Gasoline Price on New Car MPG, 1978-89", *Energy Journal*, Vol. 11, No. 3, July 1990.

is equivalent to a reduction in the price of the energy which it uses. The benefit which occurs as a result of this effective decline in the price of energy can be enjoyed as: an increase in disposable income (i.e., reducing physical energy consumption but maintaining the same level of energy service at lower cost); an increase in the level of energy service (i.e., increasing physical energy consumption and enjoying a higher level of energy service for the same cost); or a combination of both. This holds true not only when the efficiency of a motor vehicle engine or air conditioner is increased. The application of weatherization in a house, for example, has a similar effect to an increase in furnace efficiency. The more elastic the utilization of a given appliance with respect to changes in the price of the energy which it uses, the more significant the "rebound" effect and increases in efficiency could in theory increase total energy consumption. While the "rebound" effect is clearly welfare-increasing -- as in the standard case of a price decrease -- the '"rebound" analysts are emphasizing that quantitative studies which try to predict the results of energy conservation programs should take into account the ensuing adjustment in consumption.

61. A variation of the "rebound" effect has been noted with regard to time-of-day pricing in the electricity sector.[70/] High peak-load prices combined with low off-peak prices will change the pattern of appliance use. If off-peak electricity becomes sufficiently cheap, the consumer might choose a less efficient appliance for use predominantly off-peak; similarly, if use during peak drops sharply, due to higher electricity rates, it may again be more economic to choose a less efficient appliance.

62. The theoretical existence of the "rebound" phenomenon is clear; the issue concerns its numerical importance.[71/] Khazzoom has argued that the "rebound" effect is significant[72/]. For example, he has shown, on the basis of 1969-1980 data in Sacramento, California, that half the energy savings which resulted from the increased efficiency of electrical appliances was lost after four years; in the long run, less than 30% remained. In relation to CAFE standards, he also cites work by Blair, Kaserman and Tepel, to the effect that, in the short run, 30% of the potential reduction in

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70/ J. Hausman and J. Trimble, "Appliance Purchase and Usage Adaptation to a Permanent Time-of-day Electricity Rate Schedule", *op. cit.*.

71/ Some discussions of the theoretical aspects of the "rebound" effect can be found in M. Einhorn, "Economic Implications of Mandated Efficiency Standards for Household Appliances: an Extension", *Energy Journal*, Vol. 3, No. 1, January 1982 and "FEA Efficiency Standards and Energy Usage: Resolving Khazzoom versus Besen and Johnson", *Energy Journal*, Vol. 5, No. 1, January 1984; and F.C. Bold, "Responses to Energy Efficiency Regulations", *Energy Journal*, Vol. 8, No. 2, April 1987.

72/ See, for example, D. Khazzoom, "Economic Implications of Mandated Efficiency in Standards for Household Appliances", *Energy Journal*, Vol. 1, No. 4, October 1980; "The Demand for Insulation - A Study in the Household Demand for Conservation", *Energy Journal*, Vol. 8, No. 3, July 1987; "Energy Savings Resulting from the Adoption of More Efficient Appliances", *Energy Journal*, Vol. 8, No. 4, October 1987; "Energy Savings from More Efficient Appliances", *Energy Journal*, Vol. 10, No. 1, January 1989; and *An Econometric Model Integrating Conservation Measures in the Residential Demand for Electricity*, JAI Press, 1986.

gasoline consumption is offset by increased travel.[73] Dubin, Miedema and Chandran concluded that engineering estimates of reductions in electricity consumption for heating and cooling, caused by improved technologies, could be over-estimated by 8%-12% and 13% respectively.[74] An evaluation of the energy-conservation services provided in Connecticut, under the 1978 National Energy Conservation Policy Act (NECPA), found that estimates of the program savings were statistically insignificant and well below the estimates shown in the audits (2 million BTUs per participant for the former against 16 million for the latter), partly due to households taking some of the gains in the form of increased comfort.[75] The unreliability of engineering estimates, due to the "rebound" effect, has also been indicated in work on weatherization measures in the Pacific Northwest.[76] A particularly cautious view on the effect of energy audits on energy consumption was given by Frankel and Duberg, who maintained that the savings in consumers' energy bills do not match the investment costs required to produce them, as homeowners respond by raising thermostats after implementing the audits' recommendations.[77] Finally, a study of changes in the energy consumption of consumers who have installed energy-conserving devices, by Longstreth and Topliff, throws additional light on the complex issue of consumers' response to energy conservation programs.[78] Using the DOE's Residential Energy Consumption Surveys, it was found that 49% of consumers who installed retrofit measures in 1982 did not reduce energy consumption between 1981 and 1983. These results were attributed partly to consumers increasing their non-heating and non-cooling uses, to compensate for the savings that they enjoyed in their heating and cooling bills. The authors also argued that there were differences between the groups of energy savers and non-savers, in terms of the price changes they faced, house size, household size etc. We shall return to some of these statistical issues shortly.

73/ R. Blair, D. Kaserman and R. Tepel, "The Impact of Improved Mileage on Gasoline Consumption", *Economic Enquiry*, April 1984, cited by D. Khazzoom, "The Demand for Insulation - A Study in the Household Demand for Conservation", *op. cit.*

74/ J.A.Dubin, A.K. Miedema and R.V. Chandran, "Price Effects of Energy-Efficient Technologies: a Study of Residential Demand for Heating and Cooling", *Rand Journal of Economics*, Vol. 17, No. 3, Autumn 1986.

75/ E. Hirst, P.S. Hu, E.F. Taylor and K.M. Thayer, "Connecticut's Residential Conservation Service", *Energy Policy*, February 1985. Another explanation given by the authors was that the audits assumed that conservation measures would be implemented simultaneously and not in isolation.

76/ G.A. Leaf, "The Effectiveness of Weatherization Measures in the Pacific Northwest", *Public Utilities Fortnightly*, April 12, 1984. The failure to implement all the measures assumed in the audit was an additional explanation.

77/ M.L. Frankel and J.A. Duberg, "Energy Audits as an Investment: the Residential Conservation Service Program Analyzed", *Public Utilities Fortnightly*, April 12, 1984. Furthermore, higher energy prices may already have induced homeowners, including those who were not audited, to implement conservation measures (the methodology was based on comparisons between audited and non-audited homeowners); while the engineering estimates of the potential savings could have been too optimistic, even aside from the "rebound" effect.

78/ M. Longstreth and M. Topliff, "Determinants of Energy Savings and Increases after Installing Energy-Conserving Devices", Energy, Vol. 15, No. 6, June 1990.

(ii) Market-Based Instruments

63. The possibility that market solutions can yield the same results as efficiency standards was broached by Mayo and Mathis, who concluded that the CAFE standards had no independent statistically significant impact on the efficiency of the passenger vehicle fleet or the demand for gasoline from 1977 to 1983.[79/] Khazzoom also concluded, on the basis of his work on home insulation in the Sacramento area, that conservation measures were implemented in response to economic incentives (notably energy prices), without the need for Government regulations.[80/] In its comments on the amendment to the NAECA of 1988, the U.S. Administration pointed to the significant gains made by manufacturers of energy appliances in the 1970s, without Federal standards.[81/]

64. In a 1981 study of the cost-effectiveness of energy conservation measures, Hartman produced evidence that market solutions can lead to gains in appliance efficiency which are commensurate with the gains achievable through standards, perhaps as a result of information campaigns and higher prices.[82/] Using the ORNL model, he predicted the effect of DOE efficiency standards for 1980 on average appliance efficiency for space heating (electric, gas and oil), room air-conditioning, water heating (electric, gas and oil), refrigerators, freezers and cookers (electric and gas). The results were compared with estimates for three alternative scenarios: reliance only on market prices; a 100% fuel tax; and information campaigns to reduce perceived market imperfections. He concluded that "only for refrigerators, electric ranges and electric water heaters do the standards generate greater efficiency gains than all 'market' scenarios." A study by Corum and Van Dyke also looked at the effect of alternative policy instruments, this time to achieve a given level of energy efficiency in commercial buildings by the year 2000, *viz.*, mandated building efficiency standards, tax credits and fuel taxes.[83/] It was found that a fuel tax of 15% or a tax credit of 40% could be expected to give the same results as the building efficiency standards required by the 1978 NECPA. Each of these measures has different welfare implications, with building standards reducing consumer choice. On the other hand, econometric testing by Walsh produced no evidence that tax credits had any impact on energy conservation investments, as a result of ignorance about the availability of the credits, failure to understand them, their insufficient size to make a difference and too much paperwork.[84/]

79/ J.W. Mayo and J.E. Mathis, "The Effectiveness of Mandatory Fuel Efficiency Standards in Reducing the Demand for Gasoline", *Applied Economics*, Vol. 20, No. 2, February 1988.

80/ "The Demand for Insulation - A Study in the Household Demand for Conservation", *op. cit.*

81/ Senate Report No. 100-345, *op. cit.*, p. 6.

82/ R.S. Hartman, "An Analysis of Department of Energy Residential Appliance Efficiency Standards", *Energy Journal*, Vol. 2, No. 3, July 1981.

83/ K.R. Corum and J. Van Dyke, "Stimulating Energy Conservation in Buildings", *Energy Policy*, March 1983. The ORNL model was used to simulate the results.

84/ M.J. Walsh, "Energy Tax Credits and Housing Improvement", *Energy Economics*, October 1989.

(iii) Measurement Problems

65. The inconclusive nature of the empirical evidence on the impact of energy conservation measures may not be surprising, in view of the measurement obstacles involved. An excellent discussion of the econometric problems has been provided by Hartman.[85] He points especially to the need to establish appropriate control groups, since often the impact of the measures is estimated by the difference between the energy use of those who took part in a conservation program and those who did not. Self-selection bias arises, because certain types of household have a predisposition towards taking part in the program, for example due to their level of energy consumption, appliance holdings, and family characteristics (notably education, income, number of residents, and age of householder). Non-participants may be "early adopters" who have already started to implement conservation measures. Indeed, Hartman and Doane confirmed the importance of a wide range of factors when they looked at the Residential Conservation Service Programs of the Portland General Electric Company (PGE), following introduction of the 1978 NECPA.[86] Using 1977-1981 data, during which PGE offered audits and zero-interest loan programs for weatherization investments, they found that only a small percentage (8%-36% or 25% for the average household) of the observed reductions in electricity use could be attributed to the programs. An interpretation in terms of the underlying psychology of consumers, rather than econometric specification, is given by Stern, Berry and Hirst.[87] The authors show how the size, type and non-financial features of incentives may have an impact on a conservation measure beyond changing its effective cost. For example, financial incentives may serve to attract attention, in which case increases in size beyond a certain point may have little or no impact; or they may be noticed mainly by those looking for them, so that the effect would be to speed the rate of adoption rather than the level.[88] Different types of financial incentive may be perceived quite differently, although the financial effect may be identical (e.g., manufacturers rebates, grants, subsidized loans, tax rebates, etc.). Finally, a range of features which are part of the financial package are critical: its promotion, simplicity of procedures, reliability of the associated work and trust in its outcome.

VIII. Externalities

66. A crucial assumption underlying the model of the energy market developed in Section III was the absence of externalities (see para. 9), for example caused by traffic congestion, although the impact there may fall more on lost time than on energy efficiency. Evidently, market solutions will not be socially optimal, if external costs in the production or consumption of energy are not reflected in MCES and price. Two externalities are frequently considered: the production and consumption of

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85/ R.S. Hartman, "Energy Conservation Programs: the Analysis and Measurement of their Effects", *Energy Policy*, October 1986.

86/ R.S. Hartman and M.J. Doane, "The Estimation of the Effects of Utility-Sponsored Conservation Programmes", *Applied Economics*, Vol. 18, No. 1, January 1986.

87/ P.C. Stern, L.G. Berry and E. Hirst, "Residential Conservation Incentives", *Energy Policy*, April 1985.

88/ As the authors point out, if non-participants are averse to borrowing, zero-interest loans which emphasize the indebtedness aspect of the conservation measure are not likely to be successful.

energy may have deleterious environmental impacts, which impose costs on the global, trans-national, national or local community; and the consumption of imported energy may involve a reduction in national security, due to vulnerability to supply interruptions, again representing a welfare loss to society. In this argument, environment and national security are viewed as collective goods.[89/]

(i) National Security

67. The argument that energy conservation increases national security, by reducing energy imports, requires close scrutiny. First, energy is only one commodity in a complex system of international trade, which would be vulnerable to disruption in a time of crisis. Second, intervention has to be targeted at the specific energy products which are imported at the margin. Generic energy conservation is not selective, affecting indigenous as well as imported energy. A selective tax, e.g., on gasoline, could reduce imports, but may not be as cost-effective as other types of action. A public stockpile or Strategic Petroleum Reserve, fully financed by a levy on imported oil may be a preferred alternative.[90/] Third, past experience shows that a policy of greater self-sufficiency can carry high economic costs, which are particularly hard to justify in the case of developing countries. Brazil's experience is instructive. Following a determined drive for greater independence, energy investment increased from 12% of all investment and 2.5% of GDP in 1973 to nearly 20% of all investment and more than 4% of GDP in the early 1980s.[91/] The nuclear power program has produced virtually no electricity, despite investments of several billion dollars;[92/] and while the alcohol program has been highly successful in displacing gasoline consumption, the program's total investment had reached US$7 billion by the end of 1987.[93/] Furthermore, the costs of greater self-sufficiency were not always transparent: most of the fiscal transfers to the ethanol program failed to appear in the public budget, since they were indirect, represented by the loss of tax revenues through reduced gasoline sales.

(ii) Environment

68. Environmental concerns have provided a strong motivation for energy conservation. Joskow has described how the environmental movement became active in the reform of the electricity tariff structure in the United States in the 1970s, in order to slow down the rate of growth of electricity demand and mitigate "the adverse environmental consequences associated with power plant

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89/ For example, see A.C. Fisher and M.H. Rothkopf, "Market Failure and Energy Policy", *op. cit.*; E. Hirst *et. al.*, "Improving Energy Efficiency: the Effectiveness of Government Action", *op. cit.*; L. Schipper *et. al.*, "The National Energy Policy Conservation Act: An Evaluation", *op. cit.*; and J.H. Gibbons and W.U. Chandler, *Energy: the Conservation Revolution*, Plenum Press, 1981.

90/ See M.A. Adelman, "Coping with Supply Insecurity", *Energy Journal*, Vol. 3, No. 2, 1982.

91/ Based on data from the Ministério das Minas e Energia, Comissão Nacional de Energia, Subgrupo de Referências Básicas, March 1989.

92/ Ministério das Minas e Energia, *Balanço Energético Nacional 1988*, Table 1.3, Brasilia, 1988.

93/ Comissão Executiva Nacional do Álcool (CENAL), *The National Alcohol Program*, May 1988.

construction."[94] More recently, the National Audubon Society developed "a comprehensive strategy to improve US energy efficiency and thereby reduce harmful impacts on wildlife and the general environment due to energy production and consumption."[95] Goldemberg has been particularly eloquent in providing a perspective from the developing countries.[96]

69. Of all the arguments for Government intervention in the energy market, environmental externalities constitute the most convincing and there is scope for making more effective use of economic incentives to reduce adverse environmental externalities. For this reason, it is crucial to distinguish between environmental harm caused by energy consumption, on the one hand, or by production, on the other, so that the remedies can be chosen accordingly.[97]

70. In general, natural gas and petroleum products are of more concern than electricity in terms of consumption; the opposite is true for production, even granted the increasing problems raised by oil spills. Coal has harmful production and consumption effects. Much of the world's air pollution, acid rain and global warming are attributable to the consumption of hydrocarbons, notably carbon monoxide and dioxide, sulfur dioxide and nitrogen oxide. The production of electricity imposes environmental costs, partly because it is a consumer of harmful energy products as intermediate goods; but nuclear plants also pose environmental issues, in use and in the final disposal of radioactive materials. Hydroelectric plants are associated with a range of environmental problems: the risks of catastrophic floods to people and property situated downstream; the flooding of land for reservoirs, which may displace people, create health hazards from water-borne diseases, such as schistosomiasis, and threaten human cultures, the ecological balance, cultural treasures and wildlife; and the impact on people and ecology which occurs during the development of the affected areas as construction proceeds.

71. Since these consumption and production effects vary between energy products and production plants, generalized reductions in energy consumption are not a cost-effective way to deal with them. It would be more efficient to tackle the externality directly, either through the use of market-based incentives (MBIs) or command and control (C&C) measures. MBIs cover economic instruments, such as taxes on emissions, subsidies to abatement measures and tradeable pollution permits. C&C measures are typically embodied in regulations governing activities which inflict environmental

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94/ "Electric Utility Rate Structures in the Unites States: Some Recent Developments", in W. Sichel (ed.), *Public Utility Rate Making in an Energy-Conscious Environment*, 1979. Also: "Environmentalists were interested in reducing the rate of growth in electricity consumption since they anticipated this would reduce the need for more generating facilities and cut the impact of electric power expansion on the environment. Several environmental groups, particularly the Environmental Defense Fund, saw rate reform and especially the use of marginal cost pricing principles and peak-load pricing, as an important instrument for achieving these objectives", in "Public Utility Regulatory Policy Act of 1978: Electric Utility Rate Reform", *op. cit.*.

95/ P. Rollin and J. Beyea, "US Appliance Efficiency Standards", *Energy Policy*, October 1985.

96/ See, for example, J. Goldemberg, "Solving the Energy Problems in Developing Countries", *Energy Journal*, Vol. 11, No. 1, January 1990; and J. Goldemberg *et. al.*, *Energy for a Sustainable World*, *op. cit.*.

97/ C.f. L. Ruff, "Environmental Protection through Energy Conservation: a Free Lunch at Last?", *op. cit.*.

damage. There is a considerable body of theoretical and empirical literature to support the view that MBIs are generally more cost effective than C&C measures, as the former encourage consumers and producers to seek least-cost ways of meeting environmental goals, through adjustments in the level of consumption and production and through inter-fuel substitution.[98/] For example, in the case of pollution, they help to equalize the marginal costs of pollution control across all sources: firms with more expensive pollution control costs will bid up the price of tradeable permits, until (at the margin) permission to pollute costs the same as pollution control or paying a pollution tax. It is extremely difficult to achieve the same result through C&C, because regulation requires a considerable amount of information about the pollution costs of the different emitting sources. Pollution taxes may also be less distortionary than other taxes in meeting a public sector revenue constraint.[99/] As Tietenberg has noted, there has been widespread recognition among leading environmental groups "that the power of the market can be harnessed and channelled toward the achievement of environmental goals, through an economic incentives approach to regulation."[100/] Even when MBIs may be difficult to implement, e.g., because of high monitoring and enforcement costs, it will be more efficient to use indirect instruments, such as the taxation of polluting fuels, rather than energy conservation to handle environmental externalities.

72. To illustrate these issues, it is instructive to look at some of the public policy alternatives in the case of Brazil. Growth in electricity demand in Brazil is expected to be met mainly from hydroelectric power and the potential environmental impacts will vary from the very serious to relatively benign. However, increasing interest is being shown in developing non-hydroelectric alternatives, utilizing bagasse, fuel oil, coal and natural gas. The result will be a complex structure of marginal costs, including environmental costs. Natural gas and bagasse are environmentally the least harmful thermal alternatives. Not all hydroelectric projects will have adverse environmental effects; and those that do can often be mitigated with foresight and appropriate action. Similarly, with coal and fuel oil, the negative environmental effects can be reduced with appropriate technologies, at a cost. Demand-side measures are not good instruments to deal with this situation. Given the high degree of central control in the Brazilian power system, a better approach is to tackle the environmental problems directly in supply-side planning and to internalize the environmental costs wherever possible, so that they can be reflected in marginal cost and price.

73. The production of natural gas and petroleum products in Brazil, on the other hand, has had fewer adverse environmental impacts. To date, the main problems arose from pollution from refineries, which is being tackled directly, again because the system is subject to central control; although, in the future, the possible exploitation of natural gas and oil in the Amazonian region will have to be approached with great caution. Environmental problems are more relevant in the

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98/ See, for example, G. Eskeland and E. Jimenez, "Curbing Pollution in Developing Countries", *Finance and Development*, March 1991; and *Choosing Policy Instruments for Pollution Control - A Review*, Policy, Research and External Affairs Working Paper Series, WPS 624, Country Economics Department, World Bank, March 1991.

99/ C.f. G. Eskeland and E. Jimenez, *op. cit.*.

100/ T.H. Tietenberg, "Economic Instruments for Environmental Regulation", *Oxford Review of Economic Policy*, Vol. 6, No. 1, 1990, p. 17.

consumption of gasoline, diesel and fuel oil. Taxation of these products, based on identifiable environmental costs, would provide an economic basis for inter-fuel substitution, including the development of ethanol, in place of gasoline, and natural gas, to replace fuel oil, gasoline and diesel.

IX. Conclusions

74. Our major conclusion is that, where the public sector exerts control over a significant portion of energy supply and sells it in markets with an active private sector, market imperfections do not provide an adequate justification for the public sector to intervene in the energy market, given the welfare arguments against intervention and the potential for resource misallocation. We have also tried to show that our present understanding of the nature and extent of these imperfections is inadequate to provide a realistic and practical basis for Government non-price intervention to promote energy conservation, and we lack clear-cut evidence that intervention has worked in practice. Far from "clearing away the institutional obstacles and market imperfections which stand in the way of achieving the full range of energy efficiencies which are technically and economically feasible,"[101/] the conservation measures usually advocated would create additional distortions.[102/] While recognizing fully the political obstacles which must be surmounted, the economist is on much sounder ground, *qua* economist, in trying to ensure that an overall competitive framework exists for the economy and that prices in the public sector are based on economic costs, including allowances for environmental costs. However, we acknowledge that the public sector may need to complement these pricing signals with limited and well-conceived action, to ensure an adequate flow of information to the market and to support basic R&D. A wider consumer choice, absent regulations and standards, and more information may raise transaction costs for consumers but are normally regarded as integral elements to the market solution.

75. Externalities create the only major qualification to our conclusion, although not in the sense that they provide a general rationale for the public sector to implement energy conservation measures. Rather, the prices and costs of the specific energy products that create the externalities must be

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101/ J. Goldemberg *et. al.*, *Energy for a Sustainable World*, *op. cit.*, p. 372.

102/ Trying to target our actions precisely enough and choose our delivery mechanisms to bring about the right kind and amount of conservation requires a great deal of additional information about consumer behavior. Some of these questions are pursued further in M.A. Einhorn, "Measuring the Costs and Benefits of Conservation Programs", and D. Norland and J.L. Wolf, "Utility Conservation Programs: A Regulatory and Design Framework", both in *Public Utilities Fortnightly*, July 25, 1985. A good example of the belief that central planners can achieve better results than the market is contained in the evidence submitted by the Northwest Power Planning Council to the Energy and Power Subcommittee, Committee on Energy and Power, U.S. House of Representatives, dated June 10, 1988: "There does not appear to be any significant conceptual difference between soliciting bids for new generation or for conservation. The major concern is that only those measures judged to be cost-effective (on a societal basis) be allowed in a bidder's proposal. To accomplish this, the utility would need a comprehensive least-cost plan, with specific cost-effectiveness criteria for conservation measures available in each of the sectors in its service territory. Other conservation measures that have not been anticipated or included could also be submitted; however, the bidder should be required to include estimates of the total societal cost of these measures and to illustrate that they meet the overall cost-effectiveness criteria". The information requirements to make the approach operational are evidently substantial.

adjusted: through output prices (e.g., with pollution taxes) where externalities are caused by consumption; and through input prices, where they are caused by production. If adjustments in prices are impractical, the externalities may have to be handled directly, through regulations. In the case of developing countries, the revenue implications of our recommendations for energy supply companies should be beneficial, to the extent that marginal cost exceeds average cost;[103/] and while environmental issues are a legitimate public policy concern, using energy policy to increase national security is a vexed question, which must be scrutinized with care, given the typically high costs of greater energy self-sufficiency.

103/ Where economic pricing leads to excess profits, the Government can take advantage of a valuable new source of revenue by levying taxes.