Economics of Energy Conservation in Developing Countries and Analysis of Investment Incentives

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This paper analyzes the economics of energy conservation in developing countries, compares the cost of energy conservation with the cost of enhancing domestic energy supply, and examines the effect of government investment incentive policies on the financial feasibility of energy conservation projects. A representative sample of 21 projects from six Indian industries shows that investing in energy conservation is more economical to a country than investing in domestic energy supply. Moreover, the nature of the conservation effort, i.e. housekeeping improvements, waste heat recovery or process change, is more important in determining the economics of energy conservation than is the type of industry. Analysis of government investment incentives shows that most of them are effective in making uneconomical energy conservation projects financially feasible and that the most effective incentive for the private investor to invest in energy conservation is the removal of fuel subsidies.

1. INTRODUCTION

1.1 Background

A number of studies exist which deal with energy intensity and conservation potential in industrialized countries. These studies have revealed conclusively that from an economic and technological viewpoint, there is substantial scope for using energy more efficiently in all sectors of the national economy. Research by the United Nations has shown that 30 to 50% of the decline in primary energy consumption in the USA and northern Europe during the seventies was due to energy conservation.[1] It has been suggested that with the widespread application of the more efficient technology now available, industrial energy demand in the European Economic Community could decrease by a further 20% by the year 2000.[2]

Similar studies dealing with developing countries are few in number. Industrial energy conservation has been considered to be an inappropriate policy for them to pursue because the industrial sector forms such a small component of developing country economies. However, a recent study by Jankowski showed that industries in most developing countries are more energy intensive than comparable industries in the developed countries.[3] It is clear from his study that there is considerable potential to save energy in the industrial sectors of developing countries. The fact that much of this energy is in the form of imported oil makes energy conservation a very important activity from the point-of-view of reducing the foreign currency requirements of the developing countries.

In order to diversify away from imported oil, many developing countries have embarked on plans to increase the indigenous supply of conventional fuels and to expand their electricity systems. Such strategies require the mobilization of considerable financial resources. Indeed, World Bank lending for energy supply projects has increased over the years and is now around 25% (US $3.25 billion in 1982) of its total lending.[4] In India, almost 23% of the Sixth Plan (1980–85) outlay has been set aside for the power sector.[5] The question is: is increasing supply the most economical solution? A recent study of energy use in the USA manufacturing sector indicated that approximately 25% of the energy used could be

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saved through measures whose capital and life-cycle costs were less than those needed to generate equivalent amounts of energy.[6]

While actions on the supply and demand sides are appropriate, there has been no attempt, to our knowledge, to analyse the relative merits (benefits and costs) of increasing supply versus decreasing demand in developing countries.[7] Indeed there is a dearth of papers on the economics of energy conservation in developing countries. Most papers are too general and either provide aggregate estimates with little or no evidence of the underlying assumptions, or use numbers from developed countries to substantiate their claims that energy conservation in developing countries is economical.[8] Without revealing the details of the analysis, a recent World Bank report contends that short-term measures, which require small investments, in such things as combustion efficiency improvements, insulation and housekeeping measures generally have a payback in 10 to 20 months.[9] Even medium- to long-term measures requiring large investments in such things as retrofitting of existing plants, waste heat recovery, etc. yield paybacks in 2 to 5 years. The World Bank study and others like it claim that energy conservation is economical from the point-of-view of firms and industries. These claims are, however, not backed by detailed and rigorous analysis.

1.2 Objectives of this study

This study has three objectives:

(1) to estimate the economics of energy conservation in developing countries by examining 21 projects in six industries in India;

(2) to compare the costs of energy conservation with the costs of enhancing domestic supply. That is to investigate the extent to which the energy savings which result from the implementation of various energy conservation measures in the industrial sector in India are cost-effective alternatives to investing in the domestic supply of oil and coal;

(3) to analyse the impact of such policies as investment tax credits, low interest loans, fast depreciation and fuel subsidies on the economics of energy conservation from the point-of-view of the private sector firm.

Although the study focuses on India, the results provide some general conclusions that are applicable to most developing countries. A subsidiary objective is to provide an analytic approach to the problem of assessing energy conservation that can be used in other countries. While the methodology is a variation of well-known project evaluation techniques,[10] this paper provides some new insights into their applications in energy analysis.

2. METHODOLOGY

2.1 General issues

A representative sample of 21 energy conservation projects was selected from information that was gathered from: National Productivity Council case studies, consulting reports of a number of firms, and special studies on energy intensive industries.

The selected projects ranged from minor changes in energy management practices in specific firms to industry-wide process changes. Three types of conservation measures were excluded: (1) the substitution of wood or other biomass for primary energy inputs; (2) equipment, techniques and process technologies which are not fully developed or proven; and (3) cogeneration of heat and electricity.

Cogeneration, although one of the most important energy 'conservation' practices, was not included because data on cogeneration projects are virtually non-existent in the public domain in India, although there is cogeneration in the sugar and paper industries. Moreover, conferences held on cogeneration in these industries concentrated on the technology with little reference to economic issues, so that few data useful to this study are available. Furthermore, it is not apparent that cogeneration results in net energy savings overall unless complex calculations are performed on the opportunity cost of the marginal electricity saved. In order to keep the analysis simple, cogeneration has not been included.

The selected projects were used as a basis for evaluating the economics of energy conservation in the industrial sector in India. The main criterion for the selection of the representative sample was that the costs and savings of each project were known.

A benefit-cost model was used to evaluate the cost-effectiveness of each energy conservation and energy supply project. Using benefit–cost estimations, the effect of implementing the selected conservation project was analysed over a 20-year period. Finally, the marginal and average costs of the increase of energy availability through conservation was compared to the marginal and average cost of oil and coal production in India over the same period.

2.2 THE BENEFIT–COST MODEL

A number of technical, economic and financial factors combine to determine the cost-effectiveness of investment in energy conservation technologies. The most widely used methods for evaluating the cost-effectiveness of a project are the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Gross Payback Period (GPB). The latter is the most popular among engineers.[11]

In an energy conservation context, all these methods are used to convert a time series of information on investment, energy savings and energy shadow price inputs into current or real net cash flows or discounted cash flows on a before-tax basis. With input data on energy market prices, capital cost allowance rates (depreciation etc.), other investment incentives and corporate tax rates, after-tax cash flows, may also be computed. In this study the discounted cash-flow (before or after tax) has been used to determine various investment acceptance criteria.

The net cash flow, NCF_t, in an energy conservation context, is given by

$$NCF_t = GCF_t - T_t \tag{1}$$

where GCF = Gross Cash Flow, and T_t = Taxes.

Now,

$$GCF_t = S_t - OM_t - ALP_t \tag{2}$$

and

$$T_t = t_t(S_t - OM_t - ALP_t - D_t) + TC_t \tag{3}$$

where for year t, S_t = value of energy savings, OM_t = operation and maintenance cost, ALP_t = annual loan payment, D_t = depreciation allowance, TC_t = tax credit, and t_t = corporate income tax rate.

The value of energy savings would depend on the amount (kcal) of energy saved, the price of energy (shadow or market) and the escalation of energy prices. The annual loan repayment would depend on the debt interest rate and loan period. Similarly, the O&M costs will depend on the rate of growth of the costs of labour and spare parts. All these factors are accounted for in the cost–benefit model that has been used in this study to analyse the value of an energy saving measure (Fig. 1).

The net present value (NPV) of the stream of net cash flows derived from an energy saving is simply the discounted sum of the stream, the discounting being done at an appropriate rate of interest r:

$$NPV(r) = \sum_{t=0}^{N} \frac{NCF_t}{(1 + r)^t} \tag{4}$$

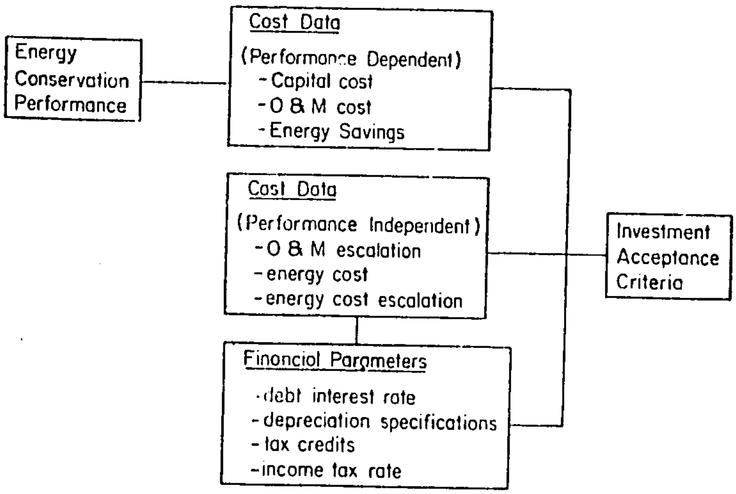

Fig. 1. Cost–benefit model used to analyse the value of energy savings.

2.3 Project Acceptability Criteria

Present Value of Public Net Benefits

The present value of public (social) net benefits was estimated in current dollars exclusive of taxes and subsidies for each of the energy conservation projects selected. In other words, in equations (1) to (3), $T_t = 0$. The Btu savings are valued at shadow prices. At a given social discount rate, an energy conservation project is considered to be acceptable if the net present value of the before-tax benefits as determined by equation (4) is positive.

Present Value of Private Net Benefits

The present value of private net benefits of each of the energy conservation projects selected is estimated in current dollar inclusive of taxes and subsidies. All values are estimated in market prices and discount rates reflect the cost of capital in the market with appropriate risk aversion corrections. Investments in an energy conservation project is assumed to be acceptable to a firm if the net present value of the after-tax benefits as determined in equation (4) is positive.

Internal Rate of Return

The internal rate of return (IRR) is the discount rate at which NPV [equation (4)] is zero. Because IRR is used by private firms to evaluate projects, we compute it on the basis of after-tax cash flows and market prices. The internal rate of return may be compared with the cost of capital or, more appropriately, with the industry's investment hurdle rates (required rates of return). If the internal rate of return lies below the hurdle rate, we can assume that the energy conservation measure would not be implemented by industry.

Supply Price[12]

For much of our analysis, supply price is the most important criterion. The supply price is essentially the marginal economic cost of an energy conservation investment. It is calculated on a per energy unit (kcal) basis as the present cost of the project divided by the present value of the energy 'supplied' (in the form of energy saved by not being used) over the economic life of the project.

The present cost of the project is given by

$$NPC = \sum_{t=0}^{N} \frac{(K_t + OM_t)}{(1 + r)^t} \qquad (5)$$

where at time t, K_t = capital costs, OM_t = operation and maintenance costs, and r = real (inflation adjusted) discount rate.

It must be noted that all costs are in real before-tax values and that K_t denotes capital costs at the time of investment and is different from the annual loan repayment.

The present value of the energy conserved ('supplied') is given by

$$NPS = \sum_{t=0}^{N} \frac{Q_t}{(1 + r)^t} \qquad (6)$$

where Q_t = quantity of energy saved (in million kcal). Thus the supply price or the marginal economic cost of an energy conservation investment is given by the equation:

$$PS = NPC/NPS \text{ (US \$/10}^6\text{ Btu)}.$$

The proposed energy conservation project would be economically viable as long as the shadow or supply price of the alternative energy supply is greater than the 'supply' price of energy conservation.

Other results

In addition to estimates of net present value (public and private), internal rate of return and supply price, estimates were also generated on the volume and the value of the energy saving for each conservation investment.

3. ASSUMPTIONS

The following assumptions were used in the analyses:

Project Life

It was assumed that all investments take one year or less to mature and that the projects all have a 20 year life-span. It was also assumed that all conservation projects would be in place throughout the 20-year period as would all energy supply projects.

Energy Prices

The 1980 market prices of fuels were used for all the analyses. Thus 1980 was the base year for the study. The fuel prices are given in Table I. To convert market prices to their per Btu values, the conversion factors suggested by the Working Group on Energy Policy were used.[13]

4

TABLE I
Energy Prices Used in Analysis

	1980 Price in Rupees	*Conversion factor*
Coking Coal	150/tonne	5.82 Gcal/tonne
Non Coking Coal	136.50/tonne	5.15 Gcal/tonne
Electricity	0.21/kWh	0.86 Gcal/MWh
Diesel	1.86/liter	8.64 Gcal/kilo-litre
Fuel Oil	1.96/liter	9.71 Gcal/kilo-litre

US$1 = Rs10.

Price Escalation

Over the 20-year life of the project operation and maintenance costs are assumed to escalate by the average wholesale price index of the past five years, i.e. 8.75%. Energy cost is assumed to increase at 3% over the general price escalation;[14] i.e. the fuel price escalation has been assumed to be 11.75% per annum.

Shadow Prices

The shadow price of any tradeable commodity in India is assumed to be 25% higher than its market price.[15] For this study focus is on the outflow of foreign exchange and therefore a premium of 25% has been added to fuels that are imported. Capital investments involve domestic technology and are costed at market prices although strictly speaking they can be considered 'tradeable' as well.

Discount Rate

All estimations assumed a nominal discount rate of 12.0%. This figure is based on the price escalation rate of 8.75% and a real social discount rate of 3%.[16]

Corporate Income Tax Rate and Allowances

For evaluating the private net present value, a corporate income tax rate of 50% has been assumed.

TABLE II
Descriptions of Industrial Energy Conservation Projects

Project number	*Description*	*Project category*
1. STEEL (industry-wide)		
1.1	Sizing of raw materials	A
1.2	Use of LD converters	C
2. CEMENT (industry-wide)		
2.1	Change to dry process	C
2.2	Addition of pre-calcinator	C
3. CHEMICALS (specific company)		
3.1	Heat recovery from blowdown	B
3.2	Vapour absorption refrigeration system for heat recovery from flue gases	B
3.3	Waste heat recovery boiler	B
3.4	Preheat feedwater from condensate and flash steam	A
4. TEXTILES (specific company)		
4.1	Insulation of cylindrical dryers	A
4.2	Heat recovery from flue gases	B
4.3	Use of economizers	B
4.4	Power factor improvement	A
5. FOOD PROCESSING (specific project)		
5.1	Insulation of steam lines	A
5.2	Preheat furnace oil by flue gases	B
5.3	Heat water from condensate	B
6. REFINERY (industry-wide)		
6.1	Preheat crude with waste heat	B
6.2	Replace gland packing with mechanical seals	A
6.3	Preheat air with flue gases	B
6.4	Insulate fuel tanks	A
6.5	Replace burners	C
6.6	Heat recovery from flare gases	B

Note: Project Category: A = Insulation and General House keeping; B = Waste Heat Recovery; C = Process Changes.

No provision has been made for tax credit on losses or for carrying losses over an accounting period.

4. ECONOMICS OF INDUSTRIAL ENERGY CONSERVATION

4.1 PRELIMINARIES

We selected a total of 21 projects from six industries to evaluate the economics of energy conservation in the industrial sector. Table II identifies the industrial sectors, describes the energy conservation activity and classifies it as being either insulation and general housekeeping, waste heat recovery, or process change. Each project was assumed to be in place over a twenty-year investment horizon (1980–2000) resulting in equal annual energy savings over the same period.

The projects are quite heterogenous. The conservation measures ranged from project-level investment to industry-wide applications and incorporate both short-term and long-term investment.

4.2 SUPPLY PRICE ANALYSIS

Our preliminary analysis concentrated on estimating the 'supply' price for each project. As explained above, the supply price is essentially the marginal economic cost of an energy conservation investment calculated on a Rupee per energy unit basis. The supply price is obtained as follows:

(1) The Net Present Value of total project implementation costs (NPC) (capital and operating) in 1980 Rupees is estimated.

(2) Annual energy savings, in kilocalories (ES) resulting from implementation of the project is estimated.

The supply price is obtained by dividing NPC by the discounted sum of ES (equation 7 in section 2).

The NPV of total project cost, the energy saving per year and the supply price have been calculated for each of the industrial energy conservation projects described in Table II and the results are presented in Table III.

The results from the analysis show that the supply

TABLE III
Economics of Selected Energy Conservation Projects — Supply Price

Project Number[a]	*NPV of Total Project Cost (10^3 (1980) Rupees)*	*Energy Savings Per Year (kcal × 10^9)*	*Supply Price (1980 Rs/10^6 kcal)*	*Project Category*
4.2	115	5.40	2.05	B
6.4	2130	98	2.10	A
5.1	0.29	0.0012	2.34	A
3.4	58	1.42	3.94	A
6.5	2874	65	4.26	C
4.1	21	0.42	4.82	A
5.3	2.30	0.036	6.16	B
6.3	199 200	2356	8.15	B
4.4	194	2.15	8.70	A
3.1	23	0.22	10.08	B
1.1	112 250	1067	10.15	A
5.2	4.31	0.036	11.55	B
6.1	1437	9.25	14.98	B
6.2	260	1.63	15.38	A
2.1	421 900	1814	22.43	C
4.3	1782	6.20	27.71	B
3.3	575	2.0	27.73	B
2.2	96100	261	35.10	C
3.2	1580	4.2	36.28	B
1.2	1 919 500	5000	37.02	C
6.6	57 480	36	153.98	B
WEIGHTED AVERAGE	2 817 486	10 732.96	25.32	

[a]See Table II for identification.

b

TABLE IV
Supply Prices by Project Category and Industry

	Number of Projects	Energy Savings Per Year (kcal × 10^9)	Weighted Average Supply Price (1980 Rs/10^6 kcal)
Project Category			
A. Insulation and Housekeeping	7	1171	9.46
B. Waste Heat Recovery	10	2419	10.45
C. Process Changes	4	7143	32.95
Industry			
1. Steel	2	6067	32.29
2. Cement	2	2078	24.04
3. Chemicals	4	7.84	26.05
4. Textiles	4	14.17	14.37
5. Food Processing	3	0.084	7.92
6. Refinery	6	2566	9.90

price for energy conservation measures ranges from Rs 2.05 to Rs 153.98 per million kcal supplied; with the exception of one, all projects have supply prices of less than Rs 40 per million kcal. The average supply price for all 21 projects, weighted by the annual energy savings for each project, is Rs. 25.32/10^6 kcal.

Category A (Insulation and Housekeeping) conservation measures are the most economical on a cost per energy saved basis. These simple measures all have a supply price of less than Rs 15/10^6 kcal (Column 4, Table III). The weighted average supply price of category A conservation measures is the lowest at Rs 9.46/10^6 kcal (Table IV). Three out of the four energy conservation measures which involved process changes (Category C) cost more than Rs 20/10^6 kcal. The average cost of process change conservation measures was Rs 32.95/10^6 kcal. As expected, waste heat recovery (Category B) is more costly than simple housekeeping measures but less costly than process changes (see Table IV).

If we examine conservation measures by industry we see that conservation measures in the steel industry have by far the highest average supply price while those in the food processing industry have the lowest price (Table IV). This result reflects more the type of conservation measure chosen in each industry rather than an industry characteristic. For individual industries our study did not contain a large enough portfolio of projects of every category to draw conclusions about the cost-effectiveness of conservation in each industry.

4.3 ECONOMIC ANALYSIS FROM A PUBLIC AND A PRIVATE PERSPECTIVE

The analysis in the previous section dealt with the public cost of energy conservation on a per unit basis. In this section we shall evaluate energy conservation project acceptability in terms of public and private net benefit (or cost), internal rate of return and payback period.

The net present value (public) and the net present value (private) as well as the internal rate of return have been calculated for each of the 21 energy projects selected and the results are presented in Table V.

The results of this analysis show that eleven conservation projects are economic from the public perspective when energy savings are evaluated at shadow prices and no taxes are factored in. However, at market prices and a 50% corporate income tax rate four of the energy conservation measures are not economical from the industry's perspective. These uneconomic measures involve process changes (use of LD converters in the steel industry and the addition of pre-calcinators in the cement industry) and waste heat recovery in the chemical and textile industry. All conservation measures that involve only simple housekeeping or insulation are economical from both the public and private perspective.

The internal rates of return to private investors from energy conservation measures, even in the absence of any investment incentives by the government, are quite high. The best result obtained seems

TABLE V
Economics of Selected Energy Conservation Projects — Project Acceptability Criteria

Industry	*Project Number*	*Project Category*	*NPV Public (10^3(1980)Rs)*	*NPV Private (10^3(1980)Rs)*	*IRR (Nominal) (%)*
Steel	1.1	A	270 659	40 914	24
	1.2	C	862 319	−267 473	—
Cement	2.1	C	229 082	4203	14
	2.2	C	50 780	−7638	—
Chemicals	3.1	B	99	26	32
	3.2	B	14 122	4701	48
	3.3	B	538	−21	—
	3.4	A	732	238	62
Textiles	4.1	A	213	72	53
	4.2	B	1823	660	73
	4.3	B	1667	−55	—
	4.4	A	7844	3021	153
Food Processing	5.1	A	0.43	0.005	20
	5.2	B	15.7	3.7	29
	5.3	B	17.7	5.7	44
Refinery	6.1	B	3709	622	24
	6.2	B	647	103	24
	6.3	B	646 287	138 995	27
	6.4	A	33 039	11 938	67
	6.5	C	20 452	6456	42

to be in a power factor improvement project in the textile industry (project No. 4.4). All projects with a positive internal rate of return have discounted payback periods of less than 3.5 years, which is the usual upper limit for private industries. More than half of these projects paid back their investments in less than two years. It must be noted that the gross payback period would be even less.

5. COMPARISON OF ENERGY CONSERVATION AND DOMESTIC SUPPLY

5.1 COST OF PRODUCTION OF DOMESTIC CRUDE

The Oil and Natural Gas Commission (ONGC) is one of two main oil producers in India. The other is Oil India Limited (OIL). The costs for crude oil production in India were estimated using exploration and exploitation data from ONGC plans for 1980 to 1990. The 'supply price' of oil is, by definition, the cost of production (i.e. supply of oil). The average cost of production is obtained by dividing the discounted production cost by the total oil produced using a discount rate of 15% (Table VI). The average cost of production of domestic crude oil in India ranges from \$6.21/bbl (approximately Rs 62.10/bbl) for off-shore oil to \$7.33/bbl for on-shore oil. At 1.45×10^6 kcal per barrel of oil, the supply price becomes Rs $42.8/10^6$ kcal and Rs $50.6/10^6$ kcal respectively. At a discount rate of 10%, the domestic production cost of crude is \$6.34/bbl off-shore and \$8.54/bbl on-shore. It should be noted that the international price of oil, the shadow price in India, is \$29.00/bbl.

The marginal cost of oil production ranges from \$25.0/bbl (off-shore) to \$28.4/bbl (on-shore). A simple method to estimate long-run marginal costs (LRMC) of oil production is to obtain a function relating total costs (TC) to production (Q):

$$TC = f(Q) \tag{8}$$

Then the long-run marginal cost is simply:

$$LRMC = \frac{\partial TC}{\partial Q} = \frac{\partial f(Q)}{\partial Q} \tag{9}$$

For this preliminary study we assumed a simple linear relationship:

TABLE VI
Estimated Production of Cost of Crude Oil — Indian Oil and Natural Gas Commission 1980 to 1990

	On-shore		Off-shore	
	Total Costs *(Rs × 10⁷)*	*Total Production* *(10^6 tons)*	*Total Costs* *(Rs × 10⁷)*	*Total Production*[a] *(10^6 tons)*
Year				
1982–83	170	5.8	297	13.1
1983–84	303	6.7	537	18.0
1984–85	396	7.9	633	21.9
1985–86	637	9.7	1332	25.2
1986–87	713	10.45	1927	28.0
1987–88	800	12.95	1922	33.0
1988–89	923	15.95	2907	38.4
1989–90	996	20.00	2117	46.2
Discounted Sum				
at 15%	2730	50.80	5841	128.3
at 10%	3767	60.15	7038	151.5
Production Cost[b] ($/bbl)				
at 15%	$7.33/bbl		$6.21/bbl	
at 10%	$8.54/bbl		$5.54/bbl	

[a]Includes gas and lpg; [b]at 7.33 bbl/ton.
Source: Raw data from ONGC (1982). *Plan Frame of Accelerated Exploration and Exploitation: 1980–1990.* Oil and Natural Gas Commission, Dehra Dun, March, 1982. Discounted Sum and Production Cost estimated by the author.

$$TC = \alpha + \beta Q \quad (10a)$$

where

$$LRMC = \hat{\beta} \quad (10b)$$

From the ONGC data and the simple cost function given by equation (10a) and (10b), we obtain that the long-run marginal costs of crude oil production in India is $62.42/bbl off-shore and $35.59/bbl on-shore.

These average costs of production of domestic crude in India are similar to those in other countries. On the basis of estimated investment and production expenditures over a 20-year period, the average cost of crude oil production in Latin American countries is around $5/bbl in the case of oil producing energy endowed countries and $11/bbl in the case of oil producing energy deficient countries.[17] A recent World Bank study estimates (in 1980 US dollars) the well-head cost of oil production at between $5/bbl for low cost producers and $12/bbl for high cost producers.[18] In the United States the cost of on-shore oil production is $2 to $8/bbl whereas the cost of off-shore production is $6 to $12/bbl [19] In more difficult regions such as the North Sea, the cost of crude oil production is $10 to $20/bbl.[20]

5.2 COST OF COAL PRODUCTION IN INDIA

The cost of production of coal in India is very difficult to estimate because there is a general unavailability of credible data on production.[21] The market price of coal includes a variety of direct subsidies and cross subsidies through transportation. Hence it would be very difficult to extract the cost of production from the market price without a thorough investigation of the level of subsidization.

However, for this study it was decided to use the most recent average market price in I[illegible] of coal as the cost of production. Hence in the analysis which follows, the cost of coal production is taken as Rs 168.28/t (approximately $16.83/t) which is equivalent to Rs 23.34/10^6 kcal.[22]

5.3 COMPARATIVE ECONOMICS

A comparison of the supply prices associated with the various energy conservation projects and the supply of oil and coal in India shows that with one exception all conservation projects are less costly than the domestic production of oil, whether off-shore or on-shore (Fig. 2). The one exception is in the refinery industry when the supply price of heat recovery from

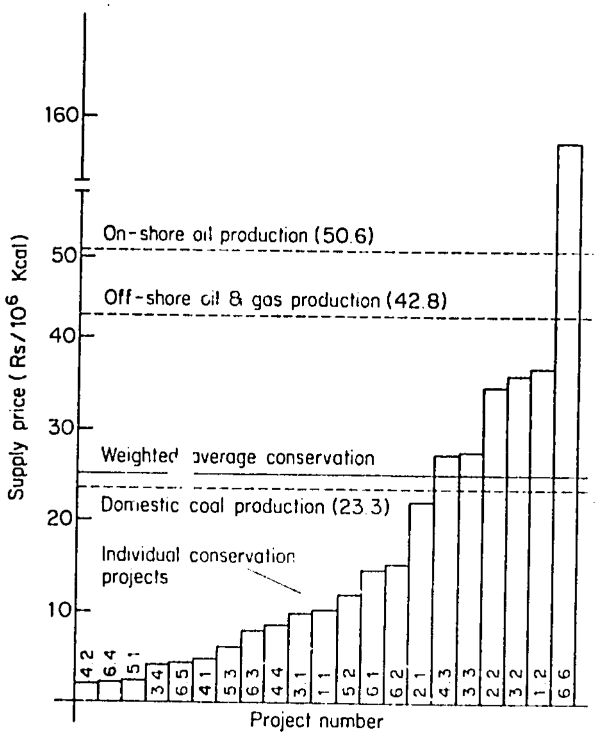

Fig. 2. Supply prices for energy conservation and oil and coal supply.

flare gas exceeds the supply price of on-shore oil by a factor of 3. A comparison between the supply price of Indian coal, which is highly subsidized, and the energy conservation projects studied shows that six out of 21 projects are more costly than domestically supplied coal. All projects are economical in their own right if compared to the price of imported oil.

6. ANALYSIS OF INVESTMENT INCENTIVES

There are several investment incentives which governments can use to encourage industries to engage in energy conservation. These include:

(a) direct cost-sharing in the investment;

(b) allowing soft loans vith low interest rates;

(c) reducing corporate income tax rates for firms that engage in energy conservation;

(d) extending investment tax credits;

(v) allowing rapid depreciation of conservation equipment.

All of these measures reduce the cost of capital in one way or other.

As we have seen previously, four out of the 2 projects that were analysed for this study we economical from a national perspective but u economical to the industry or firm that would have invest in the conservation equipment. For these fo projects, we estimated changes in cost-effectivene due to investment tax credits, reduction in tax rat for additions to income from conservation, ar soft loans.

The financial analysis of the four conservatic projects which were uneconomic to industry used tl analytical methods described in section 2. It is cle from the results (Tables VII–IX) that all investme incentives improve the *private* net-present value ar internal rate of return of all projects. Investment Ta Credits seem the most effective while the debt intere rate needs to be much lower than even 3% encourage investment in LD converters in the ste industry and pre-calcinators in the cement industr Private investment in LD converters in the Indi steel industry seems to be quite uneconomical unle the investment incentives are extremely large. Was heat recovery in the chemical and textile indust requires the smallest of incentives. In all cases, whe the interest rate on debt capital went above 10%, tl investment became quite uneconomical.

The magnitude of revenue losses due to the inves ment incentives depended on the size of the individu project. For instance, at a 40% investment tax credi the government would lose tax revenues of abo $308 million if there was investment in L converters in the steel industry as a whole; revenu loss would be only $9200 for a waste heat recover project in the chemical industry. If one makes th pessimistic assumption that the 'shadow' value c government revenue is twice the market value, the the public (social) net present value would decreas by the same amount as revenue loss. Even in such case, our analysis shows that investing in L converters in the steel industry would lead to positive public (social) net present value. In othe words, even though the magnitude of income transfe from the government to the steel industry is aroun $308 million, it would be worthwhile from th national perspective to provide a 40% investment ta credit for this purpose. Analyses of the othe projects, all of which are more economical from th point-of-view of the industry, led to a simila conclusion.

What we have not estimated is the distortion cost t the economy of encouraging investment into conser

TABLE VII
Impact of Investment Tax Credits

	Investment Tax Credit (%)				
	0	10	20	30	40
1.2 Steel-LD Converters					
IRR (%)	8.1	9.1	10.1	11.3	12.8
NPV (Rs × 10^3)	−267 473	−190 543	−113 613	−36 683	40 247
Revenue Loss (Rs × 10^3)	0	76 934	153 868	230 802	307 736
2.2 Cement-Pre-calcinator					
IRR (%)	9.9	10.9	12.0	13.4	15.1
NPV (Rs × 10^3)	−7638	−3786	66	3917	7770
Revenue Loss (Rs × 10^3)	0	3852	7704	11 556	15 408
3.3 Chemicals-WHR[a] Boiler					
IRR (%)	11.9	13.1	14.4	16.0	17.9
NPV (Rs × 10^3)	21	23	46	69	92
Revenue Loss (Rs × 10^3)	0	23	46	69	92
4.3 Textiles-Economics					
IRR (%)	11.9	13.1	14.3	15.9	17.8
NPV (Rs × 10^3)	−55	66	137	209	280
Revenue Loss (Rs × 10^3)	0	71	143	214	286

[a]WHR = Waste Heat Recovery.

vation measures that are not currently economical for the industry or firm. It would be better for the nation as a whole, if investment is directed to the most economical projects, whether energy related or otherwise. Hence incentives for energy conservation could lead to additional (distortion) costs due to the misallocation of resources from economical to non-economical investments. As we have discussed previously, incentives are provided because the energy savings have a greater value to the economy than that estimated at market prices. Hence an important task in the analysis of investment incentives is to compare the additional (shadow less market) benefits of energy savings with the distortion costs of misallocating capital investment. This is left for future research.[23]

Most developing countries subsidize energy prices, especially the price of fuels such as kerosene, which is used by the poorest section of the population. In India, coal prices are subsidized quite heavily. A recent committee set up by the Bureau of Industrial Costs and Prices has recommended that 'scarcity

TABLE VIII
Impact of Tax Rate Reduction

	Tax rate (%)				
	50	40	30	20	10
1.2 Steel-LD Converters					
IRR (%)	8.1	9.2	10.1	10.9	11.6
NPV (Rs × 10^3)	−267 473	−209 633	−151 793	−93 953	−36 113
Revenue Loss (Rs × 10^3)	0	57 840	115 500	173 520	231 360
2.2 Cement-Pre-calcinator					
IRR (%)	9.9	10.9	11.8	12.6	13.4
NPV (Rs × 10^3)	−7638	−4165	−691	2783	6257
Revenue Loss (Rs × 10^3)	0	3473	6947	10 421	13 895
3.3 Chemicals-WHR[a] Boiler					
IRR (%)	11.9	13.1	14.1	14.9	15.7
NPV (Rs × 10^3)	−21	26	52	78	104
Revenue Loss (Rs × 10^3)	0	47	73	99	125
4.3 Textiles-Economics					
IRR (%)	11.9	13.0	14.0	14.8	15.6
NPV (Rs × 10^3)	−55	75	155	235	315
Revenue Loss (Rs × 10^3)	0	130	210	290	370

[a]WHR = Waste Heat Recovery.

TABLE IX
Impact of Debt Interest Rate

	Investment rate (%)				
	3	5	10	15	20
1.2 Steel-LD Converters					
IRR (%)	9.1	8.6	8.1	6.7	5.8
NPV (Rs × 10^3)	−151 745	−179 040	−267 473	−316 462	−385 173
2.2 Cement-Pre-calcinator					
IRR (%)	10.3	10.1	9.9	9.6	9.4
NPV (Rs × 10^3)	−5683	−6435	−7638	−8154	−9014
3.3 Chemicals-WHR[a] Boiler					
IRR (%)	14.4	13.9	11.9	11.6	10.6
NPV (Rs x 10^3)	38	31	−21	−81	−276
4.3 Textiles-Economics					
IRR (%)	14.3	13.8	11.9	11.5	10.5
NPV (Rs x 10^3)	1147	912	−55	−293	- 900

[a]WHR = Waste Heat Recovery.

rents' be added to the cost of production of coals as a basis for setting new coal prices.[24] It is expected that if this measure is followed, coal prices would increase by at least 20% (author's estimate). The changes in private NPV due to an increase in coal prices by 20% for the two least cost-effective projects, LD converters in the steel industry and pre-calcinators in the cement industry, were calculated and the results are presented graphically in Fig. 3.

Even without an investment tax credit, the cement industry project becomes economical to the firm if the price of coal is increased by 20%. The steel project that required almost a 40% investment tax credit becomes cost-effective with less than a 10% tax credit. It is clear that increases in fuel prices, i.e. removal of price subsidies, would provide one of the most powerful incentives for firms and industries to invest in energy conservation.

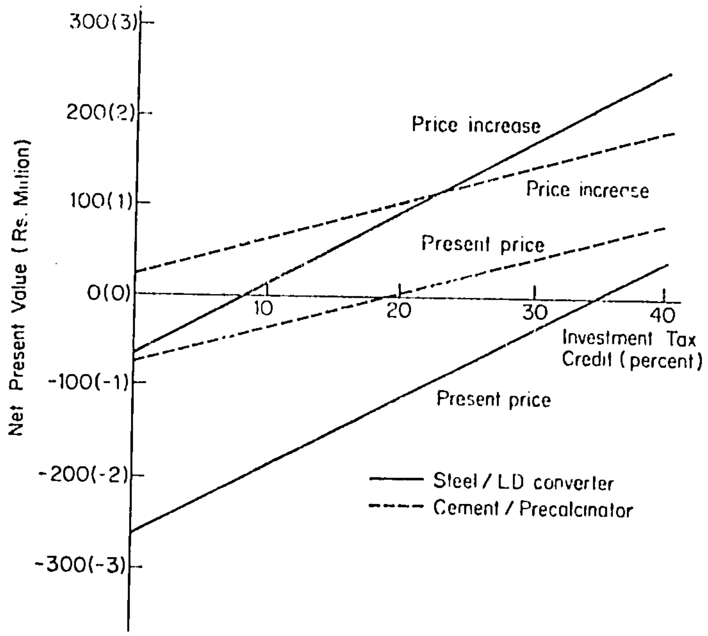

Fig. 3. Net present value as function of investment tax credit (note the figures in parentheses relate to the cement industry project; other figures give NPV of steel project).

7. CONCLUSIONS

The industrial energy conservation projects that were analysed showed a wide range of implementation costs and energy savings depending on the type of project and the industry in which it was implemented. However, the project category, i.e. whether it was a simple housekeeping measure, waste heat recovery, or process change, was more important in determining the economics of energy conservation than was the type of industry.

Clearly, simple housekeeping measures were much more economical than process changes per energy unit conserved even though the latter would lead to greater volumes of energy saved. Waste heat recovery was less cost-effective than housekeeping measures but more economical than process changes.

Oil production in India, whether from off-shore or on-shore sources, was more costly than nearly all the energy conservation measures studied. Coal production was more costly than 70% of the conservation projects on a per kilocalorie basis. The estimate that we used for the cost of production of coal is lower than the expected real cost and certainly less than the Long Run Marginal Cost; using the LRMC would make domestic coal production more costly than energy conservation in India.

For projects which were economical for the country but uneconomical from the point-of-view of the firm or industry, a set of incentives could be provided to make investment financially attractive. All the incentives that were analysed, investment tax credits, reduction in tax rates, soft loans, etc., made energy conservation financially feasible to the industry. However, the most powerful incentive was the removal of fuel price subsidies. A few of the investment incentives studied lead to large revenue losses by the government. Even if one considered these income transfers to be a loss of social (public) NPV, the net social (public) NPV remained positive.

No attempt has been made in this study to either (a) estimate the total economy-wide savings that would accrue if the energy conservation measures are established throughout each industry or (b) to quantify the total savings in implementation costs or energy use that would result from implementing conservation measures as an alternative to investing the same amount of capital in the domestic supply of oil and coal.

However, what is clear is that there is a tremendous scope for energy conservation in Indian industry. Also, the shift of resources from energy supply to energy conservation would be much more cost-effective beause the level of resource reallocation would be smaller. Results from this study could apply to other developing countries as well. It has been clearly established that energy conservation is more cost-effective than the supply of an equivalent amount of oil or coal in the industrialized countries of the north.[25] Resources should be shifted to energy conservation in developing countries to obtain the greatest welfare from an economy-wide perspective.

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FOOTNOTES

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20 *Op. cit.*, p. 51.
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22 At 7.21×10^6 kcal equivalent to 1 metric ton (t) of coal. The coal price is taken from Pachauri *et al.*, *op. cit.*, p. 14.
23 For an example of the analysis of distortion costs due to investment tax credits for energy conservation in the USA, see the study by Brown and Anandalingam (1981).
24 See *The Economic Times*, August 17, 1983, p. 1.
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