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OPTIMIZATION OF THE ECONOMICS OF ENERGY MANAGEMENT

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Abstract. In the world of economics the words "Energy Management" carry different connotations for different groups of people. From the point of view of producers, they mean the scheme of optimization of all the different factors costing productions of different types of energy such that the total amount of revenue is maximized and the total cost of operation is minimized. They attempt to achieve both. But they must achieve at least one of these primary objectives. From the point of view of consumers, "Energy Management" means use of all different types of energy to sustain life and health most economically. Often both producers and consumers fail to understand what environmentalists mean by "Energy Management." To this group energy management must be done in such a way, so that all factors needed for production and usage of all forms of energy must meet all the stringent criteria to control pollutants released into the atmosphere by all agents of production and consumption of energy.

Unfortunately, companies who are in the business of production, look into how to manage energy by considering different forms of energy production in order to make their investment most profitable. However, they are bound by the rules of the department of energy and they must follow the guidelines of the Environmental Protection Agency (EPA) and other mandates of federal, state and local governments. This topic is energy management in production control and it has a strong impact on the global economy.

In this article energy management is studied applying mathematical methods of optimization. The model is quite general and the solution is quite simple which may be done using the calculator. The model predicts how many units of types of energy must be produced to maximize the revenue which depends on the demands for those types of energy in the market and the protocol and policies that the company plans to adopt for production. Thus the method developed in this article is to be applied at the planning stage for optimization of the economics of energy management. A model illustration has been used in the text explaining the step-by-step application of the theory.

1. Introduction

Energy sustains life. Life exists in social and physical environments. Economy is the very foundation for maintenance of these environments. Industries support and control economy. They play a most significant role on production of energy while balancing all the essential ingredients of nature so that life can roll on. But they need cooperation from all of us. In March 2009, EPA (Environmental Protection Agency) of the United States has set up some energy conservation action plans. They show how "opportunities for energy conservation are increasingly available in almost every application in any setting. Home, school, office, and industrial environments have all benefited from cost-saving and energy-saving innovations. The advantages of energy conservation have been quantified on the local level as tons of air-pollutants avoided and dollars saved." But one must understand that industries work with agencies working on pollution control, on the basis that they must make profits so that they could be in business. The fact is: all over the world, demand for energy is continuously increasing. We are all hungry for comforts and these comforts require a large amount of consumption of energy, primarily electricity and petroleum. This urge for comfort often becomes greed for comfort.

The Science Education Foundation of the United States [2] reported that per megawatt of electricity produced: 854 pounds of CO2 causing global warming, 0.048 pounds of particulates, that contribute to smog causing lung diseases, 0.024 pounds of sulfur oxides causing acid rain are released into the atmosphere. Our greed for luxury and comfort is indeed one of the most significant sources of our misery. This is also putting more pressure on industries to generate more energy.

There are two sources of energy: primary and secondary. Primary sources are fossil fuels (like coal, petroleum and natural gas), nuclear energy, biomass, geothermal, hydro- electricity, solar power, tidal power, wind power, etc. These sources can not be readily used by the consumers. They must be converted into secondary sources into secondary energy resources like electricity, hot water, hot gas, etc. using some mechanical/chemical processes so that consumers will be able to make use of them. These transformations from primary to secondary, are some of the main culprits for environmental pollution.

All of these topics are discussed very analytically with many statistical surveys in the references [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. But we have to keep in mind that energy is a most needed commodity of the society and we need industries to invest on converting primary sources of energy into the secondary sources and stay in business as partners for better life and health.

Scientists, economists, environmentalists, must look into conditions under which in- dustries in charge of production of energy must prosper and at the same time consumers must see how energy should be used efficiently minimizing any waste.

For most industries, before manufacturing and marketing their products, manage- ments put most emphasis on detailed analysis of all constraints for various services required to start their business. They must consider all the possible line items in the service category like labor, equipments, transportation, storage, maintenance, pollution control, marketing, legal expenses, etc. and their limitations which are imposed upon the industry by the economical and political environments. Sometimes, these cause severe global issues which must be resolved before the industry may begin any operation. All limitations put forward constraints whose units often depend on time, tool, technology and money, or combinations of some of them. For instance constraints on labor depend on hours, available tools, technical training and of course, money.

Optimization of revenue or profit is a huge econo-mathematical challenge when all these factors are taken into consideration, because it may take months or years to collect available data and analyze all of them before they could be useful for the model. These efforts are expensive. Finally consumers pay for these expenses. Because the bottom line in an industry is how to make their business profitable. Thus some form of optimization of revenue is an absolute requirement for an industry.

A burning question is: Can the tedious task of collection of hundreds of data from various sources and a complete analysis of them before being applied in the model for optimization be simplified by some simplistic set of data for an effective optimization scheme? The answer is: This may be possible.

In this article, an attempt has been made to collect available data from the reports of progress and expenses incurred as stated by industries to produce and distribute various forms of energy. For example a coal-fired station producing electricity must report their expenses related to megawatts of electricity produced monthly/quarterly and the same is true for a nuclear power station, solar power station, etc. They also report in general total expenses for each line item of service. These information may be collected from several companies and will form the necessary data to be implemented in the algorithm developed here. Such implementations could be simplified considerably by considering the optimization model developed in this article. Emissions from coal-fired power plants represent one of the largest sources of emission of carbon dioxide, a main cause for global warming and all forms of lung disease. Ristinen and Kraushaar [15] reported in October, 1998.

National Average Emission Factor
Per Megawatt of Electricity Generation

	$C0_2$ lb/MWhe	NO_x lb/MWhe	SO_2 lb/MWhe
Coal	2400	8.8	17
Fuel Oil	2000	4.2	1
Natural Gas	1300	4.6	0

where $C0_2$ = carbon-dioxide, NO_x = nitrogen oxide and SO_2 = sulphur-dioxide. These gases are being continuously emitted ruining our environment and health. Thus our badly needed energy is the primary cause of deterioration of our greatly needed health. This suggests that every industry must look into all the necessary means to minimize release of pollutants in the atmosphere. These operations cost money. In the model this has been included.

We have not been able to use actual data from any company. In that sense our work is theoretical in nature. However, we expect that in the future our model will generate relevant data in the study on applied modeling of cost effective energy management which should be more environment friendly.

2. The Model for Optimization

Let an energy enterprise decide to produce and supply J number of different forms of energy for an estimated cost C_{max} amount of dollars. To administer production and supply let I number of various schemes of service be deployed. These are labor, equipment, transportation, storage, maintenance, etc. Under each of these schemes, there may be other kinds of services.

Let x_j $(j = 1, 2, \dots J)$ represent the number of units of different forms of energy (like petroleum, natural gas, propane, nuclear, coal, solar, wind, etc.) to be manufactured.

a_{ij} = The estimated cost for the ith (i = 1,2,... I) line item in the category for the production of one unit of the jth form $(j = 1, 2, \dots J)$

r_j = the estimated revenue from one unit of the jth form of energy to be produced.

C_{imax} = *Max* estimated cost for the ith category of service.

Table1. The chart showing line items of service required for productions of different forms of energy, the max line item budget and the estimated revenue from each kind of energy

Estimated Revenue		r_1	r_2	r_3...	r_j...	r_3	
Line Items of Service	Forms of Energy	x_1	x_2	x_3...	x_j...	x_j...	C_{max} = Upperlimit of the operating budget
Service #1	S_1	a_{11}	a_{12}	a_{13}...	a_{1j}...	a_{1j}	C_{1max}
Service #2	S_2	a_{21}	a_{22}	a_{23}...	a_{2j}...	a_{2j}	C_{2max}
Service #3	S_3	a_{31}	a_{32}	a_{33}...	a_{3j}...	a_{3j}	C_{3max}
...	...	...	...	...	...	...	...
Service #i	S_i	a_{i1}	a_{i2}	a_{i3}...	a_{ij}...	a_{ij}	C_{imax}
...	...	...	...	...	...	...	...
Service #I	S_j	a_{I1}	a_{I2}	a_{I3}...	a_{Ij}...	a_{Ij}	C_{Imax}

Then the optimization of the economics of energy management in terms of cost/revenue is:

$$\text{Maximize } F = r^T x \text{ (Objective Function)}$$
$$\text{subject to } A_x \leq C_{max}$$
$$x \geq 0 \tag{1}$$

a_{ij} = the amount of money spent on the ith type of service to produce one unit of the jth kind of energy.

x_j =the amount of the jth form of energy.

where

$r = (r_1\ r_2 \dots r_j)^T \in R^{J+}$

r_j = The amount of revenue obtained by selling one unit of the jth form of energy.

$x = (x_1\ x_2 \dots x_J)^T \in R^{J+}$

$A : R^I_+ \times R^J + \rightarrow R^I_+$

defined by $A = [a_{ij}]_{\substack{i=1,2,\dots I\\ j=1,2,\dots J}}$

and $C_{max} = (C_{1max}\ C_{2max} \dots C_{Imax})^T \in R^{I+}$.

R^I_+ = Real non-negative I-dimensional space

R^J_+ = Real non-negative J-dimensional space

In general, a_{ij}'s are found out through tedious, laborious data analysis costing a huge amount of man hour and money. We will now make an attempt to simplify this whole system.

C_{imax} = The upper limit of the operating budget to be spent for the production of the ith form of energy. The model for optimization is (1) subject to I number of inequalities which are the constraints of the objective function.

F_{max} = Maximum Revenue to be collected.

3. Computation of Maximum Ravenue

Let E_{max} = the upper limit of the total operating budget

$$= \sum_{i=1}^{I} C_{i\max} \tag{2}$$

Let E = the total operating budget. Obviously,

$$E \leq E_{max} \tag{3}$$

$E_{max} - E$ = the amount of leeway, reserved for an allowable margin of freedom or variation needed for inflation and/or emergency expenses.

Let E_j = the operating budget for the jth form of energy.

Then

$$E_j = \sum_{i=1}^{I} a_{ij} x_j, \qquad j = 1, 2. \dots J \tag{4}$$

If C_i = the operating budget for the ith form of service.

$$C_j = \sum_{j=1}^{I} a_{ij} x_j, \qquad i = 1, 2. \dots J \tag{5}$$

Let E = p% of E_{max} = $p \cdot E_{max} \cdot 10^{-2}$. Hence

$$\frac{E_{\max}}{E} = \frac{10^2}{p} \tag{6}$$

Also in general, for each category of service and for each form of energy-investment a given percentage of E is kept aside.

Let $E_j = \alpha_j$ % of the operating budget, then

$$E_j = \alpha_j \cdot E \cdot 10^{-2} \tag{7}$$

From available data published by energy-producing companies, it can be figured out howmuch they are spending and/or willing to spend to generate 100 units of a particular form of energy.

These units could be 100 barrels of crude oil, or 1000 BTU's of heat or 1000 megawatts of electricity etc. From those data one can compute for one unit of that form of energy, how much expenses are estimated. Let for one unit the expense for the *j*th form of energy = β_j % of E_j = β_j ($\alpha_j \cdot E \cdot 10^{-2}$) $\cdot$ 10^{-2}

$$= \alpha_j \beta_j G \tag{8}$$

where

$$G = E \cdot 10^{-4}. \tag{9}$$

Also, estimations are done by each company for each line item of service.

Let for the ith line item of service the estimation for the *j*th product be γ_i % of E_j

$$= \gamma_i \cdot E_j \cdot 10^{-2} \tag{10}$$

Then

a_{ij} = estimated cost for the ith line item of service for the expenses of pro-duction of one unit of the jth form of energy (here $x_j = 1$).

$$= \gamma_i \cdot (\alpha_j \beta_j G) \cdot 10^{-2} \tag{11}$$

Then for the expenses for the ith category of service,

$$\sum_{j=1}^{J} a_{ij} x_j \le C_{i\max} \tag{12}$$

gives,

$$\sum_{j=1}^{J} \gamma(a_j \beta_j) x_j \cdot G \cdot 10^{-2} \le C_{i\max}$$

or

$$\sum_{j=1}^{J} \sigma_j \cdot x_j \le \frac{C_{\max} \cdot 10^2}{\gamma_i \cdot G} \tag{13}$$

where $\sigma_j = \alpha_j \cdot \beta_j$.

We should observe that $C_{i\max}$ and G are to be given in terms of dollars; and σ_j 's and x_j's are pure numbers with no dimension.

The inequality (13) should be valid for all *i = 1, 2 ... I*. Hence all constraints are reduced to

$$\sum_{j=1}^{J} \sigma_j x_j \le \underset{i}{\min} \left(\frac{C_{i\max}}{\gamma_i} \right) \cdot \frac{10^2}{G} \tag{14}$$

Now, from (9)

$$\frac{10^2}{G} = \frac{10^6}{E} = \frac{10^8}{p \cdot E_{\max}} \tag{15}$$

From (14) and (15)

$$\sum_{j=1}^{J} \sigma_j x_j \le \underset{i}{\min} \left(\frac{C_{i\max}}{\gamma_i} \right) \cdot \frac{10^8}{p \cdot E_{\max}} \tag{16}$$

If

$$C_{i\max} = \gamma_i \text{ \% of } E_{\max} = \gamma_i \cdot E_{\max} \cdot 10^{-2} \tag{17}$$

then (16) becomes

$$\sum_{j=1}^{J} \sigma_j x_j \le \frac{10^6}{G} \tag{18}$$

If

$$K - 10^6/p \text{ and } \quad \theta_j = \frac{K}{\sigma_j} \tag{19}$$

then (18) may be written as

$$\sum_{j=1}^{J} x_j / \theta_j \le 1 \tag{20}$$

This defines the feasible region on which *F* must be maximized.

According to the Simplex Algorithm *F* will be a maximum at one of the vertices which are given by (θ_1, 0, 0, ... 0), (0, θ_2 , 0, 0 ... 0), ... (0, 0, ... 0, θ_J).

Thus

$$x_j = \theta_j = \frac{K'}{\sigma_j} \forall_j \tag{21}$$

From the point of view of consumers in the market, demands for the types of energy to be produced will determine *r_1, r_2 ... r_J*, the coefficients of the objective function, and the objective function is given by

$$F = \sum_{j=1}^{J} r_j x_j$$

Thus

$$F_{\max} = \underset{i}{\max} (r_j \theta_j)$$

$$= \underset{j}{\max} \frac{r_j}{\sigma_j} \cdot K \tag{22}$$

where K and σ_j are pure dimensionless numbers and r_j 's are expressed in dollars. If the company has to follow a mandate which requires that for $j = J1, J2, J3,$ where $J1 < J$, $J2 < J$ and $J3 < J$, it must produce x_{J1}, x_{J2}, and x_{J3} respectively, then

$$F_{\max} = \max_{j} (r_j/\sigma_j)K + V$$

$$j \neq J1, j \neq J2, j \neq J3$$

$$V = r_{J1}X_{J1} + r_{J2}X_{J2} + r_{J3} \cdot X_{J3} \qquad (24)$$

Depending upon the amount of total investment (22) and (23) will determine a profit or a loss for the company.

Now let us understand thoroughly what we have done so far.

$K = 10^6/p$ is a dimensionless number where p is chosen somewhat arbitrarily. To compute $F_{\max}$ we choose the largest value of (r_j/σ_j). If for $j = m$, (r_j/σ_j) is the max, then the corresponding x_j is

$$x_m = \frac{K}{\sigma_m} \qquad (25)$$

is dimensionless (given in units), and the vertex of the feasible region is $(0, 0, \ldots x_m, 0, \ldots 0)$ in the R^{J+}, where F attains a maximum, given by

$$F_{\max} = r_m x_m \qquad (26)$$

We note that this $F_{\max}$ depends only on r_j's α_j's, β_j s and p. These are all known from the analysis of the data collected from various sources and not directly on the value of the operating budget. We need to choose operating budget such that revenue must exceed this budget so that a profit can be made. Thus for profit, (from (6), (9), and (19))

$$F_{\max} > E_{\max} = KG \qquad (27)$$

suggests,

$$r_m \cdot \frac{K}{\sigma_m} > K \cdot G$$

Giving selling price of one unit of $x_m = r_m > \sigma_m \cdot E \cdot 10^{-4}$ (from (9))

$$= \beta_m (\alpha_m \cdot E \cdot 10^{-2}) \cdot 10^{-2} \qquad (28)$$

$$= \beta_m \cdot E_m \cdot 10^{-2} \qquad (29)$$

= expense to manufacture one unit of x_m

Thus our formula (25) is compatible with the market economics.

Thus, at the planning stage, once we choose r_j, α_j, β_j ($j = 1, 2, \ldots J$), we will compute first

$$F_{\max} = \frac{r_m}{\sigma_m} . K \text{ , where,}$$

$$\sigma_m = \alpha_m \cdot \beta_m.$$

Then we choose an operating budget E such that

$$E < \frac{r_m}{\sigma_m} \cdot \frac{10^6}{p} = \frac{r_m}{\sigma_m} 10^4 \qquad (30)$$

when $p = 100$.If and when this is possible, one may go ahead with the planned investment, else the project should be dropped. It may also be observed that γ_i's do not directly affect $Fmax$. That suggests that if the management decides to cut costs in all or some of the line items of service, the total revenue and hence profit may not be affected.

4. A Model Illustration

A company plans to spend E (to be determined) amount of dollars to generate electrical energy using six different sources, namely, coal, nuclear, biomass, hydro-power, solar and wind. This will be done by applying several different forms of services like labor, equipment, transportation, storage, pollution control, maintenance, marketing, etc. The management has decided to spend on each category of energy as follows:

E_1 = operating budget $\leq$ E:
j

Expenditures	Total	Per Unit
Coal	$E_1 = 24\%$ of E	0.1% of E_1
Nuclear	$E_2 = 21\%$ of E	0.15% of E_2
Biomass	$E_3 = 19\%$ of E	0.2% of E_3
Hydro-power	$E_4 = 16\%$ of E	0.1% of E_4
Solar	$E_5 = 11\%$ of E	0.13% of E_5
Wind	$E_6 = 9\%$ of E	0.2% of E_6

Let the fluctuating market show that on the average if r_j = revenue from one unit of x_j (types of energy) then r is given by

$$r = (r_1, r_2 \ldots r_J)^T \; (J = 6)$$

$$= (30 \;\; 42 \;\; 45 \;\; 19 \;\; 22 \;\; 19)^T$$

We will now compute how to optimize the revenue function

$$F = r_1x_1 + r_2x_2 + \cdots + r_6 x_6.$$

under the limitations of the operating budget given by the table above and demands for the various forms of energy in the market as recorded by r_j's.

Solution: From the given data

$\alpha_1 = 24,$	$\alpha_2 = 21,$	$\alpha_3 = 19,$	$\alpha_4 = 16,$	$\alpha_5 = 11,$	$\alpha_6 = 9$
$\beta_1 = .1,$	$\beta_2 = 0.15,$	$\beta_3 = .2,$	$\beta_4 = .1,$	$\beta_5 = 0.13,$	$\beta_6 = 0.2$
$\sigma_1 = 2.4,$	$\sigma_2 = 3.15,$	$\sigma_3 = 3.8,$	$\sigma_4 = 1.6,$	$\sigma_5 = 1.43,$	$\sigma_6 = 1.8$

The constraint is

$$24x_1 + 31.5x_2 + 38x_3 + 16x_4 + 14.3x_5 + 18x_6 \le K$$

where

$$K = 10^6/p$$

Now to compute F_{max} we need to see

$$\max_j \left(\frac{r_j}{\sigma_j} \right) = r_m/\sigma_m$$

We have	$r_1/\sigma_1 = 30/2.4 = 12.5$	$r_2/\sigma_2 = 42/3.15 = 13.33$
	$r_3/\sigma_3 = 45/3.8 = 11.84$	$r_4/\sigma_4 = 19/1.6 = 11.87$
	$r_5/\sigma_5 = 22/1.43 = 15.39$	$r_6/\sigma_6 = 19/18 = 10.56$

Thus $r_m/\sigma_m = 15.39$, and, $F_{max} = 15.39 \times \frac{10^6}{p}$ (from (26)).

If $p = 80$, $F_{max} = 192375.00$.
If $p = 90$, $F_{max} = 171000.00$.
If $p = 100$, $F_{max} = 153900.00$.

In each case, E = operating budget < $\frac{r_m}{\sigma_m} \cdot 10^4$ (from (30)), p = 100. That means,

$E < 15.39 \times 10^4 = 153900.00$.

Since the market fluctuates continuously, an industry cannot and should not depend only on one product. Thus several relatively high values of (r_j/σ_j) should be taken into serious consideration and productions of those forms of energy should be undertaken. That will increase both the revenue and the operating costs, and profit will fluctuate.

One must remember that mathematical optimizations give some guidelines and should not be considered to be the exact code of action of a company. The real world is full of many unknowns and unpredictables. Nevertheless, the help that we receive from mathematical optimization cannot be ignored.

Once *E* is known the total amount to be spent on each category of service, will be known if γ_i's are known. If the company plans to spend for labor, transportation, storage, maintenance, pollution control, and marketing 22%, 20%, 8%, 32%, 10%, and 8% of E respectively which means $\gamma_1 = 22$, $\gamma_2 = 20$, $\gamma_3 = 8$, $\gamma_4 = 32$, $\gamma_5 = 32$, $\gamma_6 = 8$, and if we choose $E = 150,000$, then expenses for labor = 33,000.00, expenses for transportation = 30,000, expenses for maintenance = 48,000, expenses for pollution control = 15,000, expenses for marketing = 12,000.

The complete picture is as follows:

E = operating budget = \$150,000.00. Cost for labor = \$33,000.00
Cost for transportation = \$30,000.00
Cost for storage = \$12,000.00
Cost for maintenance = \$48,000.00
Cost for pollution control = \$15,000.00
Cost for marketing = \$12,000.00

To be spent under the given market conditions, on x_j $(j = 5)$ which is solar energy and the number of units to be produced is give by

$$x_5 = \frac{K}{\sigma_5} = \frac{10^6}{1.4 \times p}$$

$= 8741.26$ if $p = 80$
$= 7770.01$ if $p = 90$
$= 6993.01$ if $p = 100$

$F_{max} = 192,375.00$ if $p = 80$
$= 171,000.000$ if $p = 90$
$= 153,900,00$ if $p = 100$

The time-span for all these expenses may be daily, weekly, monthly and each unit of and these give a max revenue as follows: *xj* may be 10 Megawatts, 20 Megawatts or much more.

This is of course a theoretical model.

We should note that α_j, β_j and γ_i, all of these parameters should be estimated, after relevant data from other industries doing similar business are reviewed and analyzed.

From the algorithm it is quite clear that at the planning stage, the algorithm works as follows:

Step #1From available data find γ_i, α_j, β_j, r_j.

i = 1, 2, . . . I = Number of types of services to be used.

j = 1, 2, . . . J = Number of different energies to be produced.

Step # 2 Find maximum revenue, and x_j's to be manufactured.

Step # 3 Find the operating budget to be invested.

Step # 4 Find the budgets for all line items for service. Make the final decision to undertake the project or not.

5. Cost Optimization Scheme

We have discussed the scheme for optimization of revenue. But this is valid provided the industry is running efficiently. Iin order that an industry may function efficiently, all line items of service must function at an optimum capacity. Every industry requires a minimum amount of these services, measured in time and translated into dollars.

Let us now consider the model for optimization of cost. We will study how to compute the minimum amount of time needed in each category of service.

Let,

b_{mn} = the amount of the mth type of energy production requiring one unit of the nth type of service which is measured in time.

y_n = the amount of units of time needed for the nth type of service.

The units of time may be measured in hours, days, weeks or even months as decided by the company.

Then,

$\sum_{n=1}^{I} b_{mn} y_n$ = Total amount of the *m*th type of energy produced by *I* number of different services. (31)

If there are *J* -types of energy *(m = 1, 2, . . . J)* the company understands that $E_{m\min}$ = the minimum amount of the *m*th type of energy must be produced to meet the demands in the market.

Thus the constraints are

$$\sum_{n=1}^{I} b_{mn} y_n \geq E_{m\min}. \qquad (32)$$

m = 1, 2, ... J

If C_n = the cost per unit of time for production of energy using nth type of service, the cost function to be minimized is:

$$Cost = \sum_{n=1}^{I} C_n Y_n. \qquad (33)$$

Statistical surveys will show that the company should need a minimum amount of service in each category. That means

$$y_n \geq Y_{n\min}, \ (n = 1, 2, \ldots J) \qquad (34)$$

Thus (33) will be minimized applying constraints (32) and (34).

From the previous section, if the company decides to produce only one form of energy (say m = M), then (32) reduces to only one inequality.

$$\sum_{n=1}^{I} b_{Mn} Y_n \geq E_{M\ \min} \qquad (35)$$

giving

$$\sum_{n=1}^{I} \frac{Y_n}{\varphi_n} \geq 1 \qquad (36)$$

where

$$\varphi_n = E_{M\min} / b_{M\min} \qquad (37)$$

and $y^T = (0, 0, \ldots 0, \varphi_n, 0 \ldots 0)^T$. This gives the least cost in the service category

$$(\text{cost})_{\text{least}} = \min_{n}(C_n\varphi_n) \qquad (38)$$

Obviously an industry cannot function if it uses only one kind of service. In fact, there are several categories of services which are absolutely essential for an industry to stay in operation.

The inequality (36) shows that the values of y where the minimum value of Cost could be found must stay on or above the hyper *I* -dimensional plane

$$\sum_{n=1}^{I} y_n/\varphi_n = 1.$$

giving $y_n = \varphi_n$ for *n = 1, 2, ... I,* and when $y_n = \varphi_n$, all other y's are zero. The points on the *I* -dimensional plane at the intersections with the axes y_i *(i = 1, 2, . . . I)* are: $(\varphi_1, 0, 0, \ldots 0)$, $(0, \varphi_2, 0, 0, \ldots 0)$, $(0, 0, \varphi_3, 0, \ldots 0)$, . . . $(0, 0, \ldots 0, \varphi_I)$ respectively. If yi 's exceed φ_i's the inequality (36) will be satisfied, but total cost will increase.

Thus if all the services are to be retained, the minimum cost will be

$$(\text{Cost})_{\text{least}} = \sum_{i=1}^{I} c_1\varphi_1. \qquad (39)$$

This brings forth the concept of "Minimum Wage" and the minimum hours of service in each category to be used. Ironically, minimum hours of service required by the industry is the same as the maximum hours of service that workers can work for.

This principle may be extended if the industry plans to produce other forms of energy.

If

$$E_{M\min} = x_{j\max} \qquad (40)$$

then,

$$Y_n = y_{n\min} = \frac{x_{j\max}}{b_{Mn}} \qquad (41)$$

Obviously, $M_{\min} = j_{\max}$. This is compatible with the basic economic principle which implies that if the production of a particular kind of energy is increased that will require the units of time in some service category like labor, maintenance, storage etc. to be increased.

This cost minimization scheme is really not needed by householders. They must use their common sense instead. Like, "turn the lights off" when you do not need it; "stop burning gasoline" when you need it, etc. No mathematical theory is required. We all know energy costs money and production of energy causes pollution in the environment.

Thus saving energy means saving money and improving health, which means saving more money.

6. Application of Dual of (1)

If γ_i , α_j , β_j are not properly found then the method discussed above will certainly fail. At that point the model (1) may be directly solved by the standard Simplex method by applying the laborious survey to collect data for A. If that is hard one may consider the dual of (1) for minimization.

Since r^T is known, the dual of (1) given by

Minimize $W = C_{\max}^T z$

subject to

$$A^T z \geq r, \quad z \geq 0 \tag{42}$$

may also be solved with x_j's as slack variables for this model.

A^T = Transpose of $A : R^{J+} \times R^{I+} \rightarrow R^{J+}$

$z \in R^{I+}$

$C_{\max} = (C_{1\max}, C_{2\max}, \ldots C_{I\max})^T$

It is well known that dual leads to the same solution given by the original problem.

7. Discussions

The study conducted by Stromberg [16] indicates the following chart for future de- mands for primary sources of energy:

Energy	Demand in 2006	Demand in 2030
Fossil Fuel	80%	85%
Nuclear	15%	6%
Renewable	6%	8%

Renewable energy sources include biomass, geothermal, hydropower, solar, wind, tidal, etc. They are renewable because they may be replenished in a short time. Sun shines. Wind blows. River flows. They supply primary energy continuously. We need to trap these sources economically. Obviously Stromberg thinks that such an energy economy is not attainable within the next 30 years.

Experts believe, that is not the case. We have to achieve it for our own survival. Apollo PAC [17] reported from the Official Earth Day Guide to Planet Repair, that wind energy production in North Dakota alone could produce a third of the United States' energy needs. All other nations are also eager to do the same. Thus the prediction of Stromberg' that about 90% of our demand for energy "will be supplied by the fossil fuel" by 2030 is not acceptable. Fossil fuel is non-renewable. Experts believe that oil production in North America is fast approaching a plateau and EIA (Energy Information Administration) believes that roughly in 60 years we will have used up 80% of the world oil reserve (at the rate we are consuming now).

The world attention is now focused on "Green Energy" which refers to sources of energy which have been found to be less polluting and as such environmentally more safe. These are solar, wind, hydroelectric, geothermal etc. Green Energy is being used for electricity, heating and cooling and all consumers including various kinds of businesses and industries could purchase green energy according to their energy requirements fully or at least partially. That will greatly reduce pollution level and save lives and better our ecosystem. Many media used the term "Green Energy" and "Renewable Energy" interchangeably. However, it must be noted that production of all forms of energy depends on technologies which will have some negative impact on our environment. Several countries, states and cities are purchasing electricity from utility and/or some green energy provider. In the city of San Francisco, California, they are trying to use

51% renewable energy for their energy requirements. The Dutch government exempts green power from pollution taxes. That made green energy no more expensive than other standard energy. In Massachusetts and California, a new approach to community energy supply has provided several communities with necessary means to solicit a competitive electricity supplier and use municipal revenue bonds to finance and develop local green energy resources. In the European Union and in India several incentives have been undertaken to develop and distribute green energy to consumers. However, for all these efforts industries and consortium working on these projects must look into models which are mathematically sound, to maximize the revenue and minimize the cost of operation.

8. Conclusion

We have looked into the study of "Energy Management" and its impact on economy mostly from a theoretical standpoint. However, the theory is quite general and applica- ble. In the model we have included the concept of pollution control and costs that go with it. This cannot be ignored and should not be ignored.

"Energy Management" is a vital task of every nation, every city and every individual. Else, health will deteriorate, medical cost will skyrocket, GNP will decline and disasters in environment and economy will devastate all that we need to maintain a better life.

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ENERGETINĖS EKONOMIKOS VADYBOS OPTIMIZAVIMAS

Suhrit K. Dey

Santrauka. Energetikos vadybą nagrinėja įvairių sričių atstovai. Gamintojai orientuoti optimizuoti visas produkcijos sąnaudas, energijos sistemas taip, kad sumažintų išlaidas. Energetikos vadyba suprantama kaip visų rūšių energijos naudojimas gyvybei ir sveikatai palaikyti, labiausiai akcentuojant ekonominį naudingumą. Dažnai gamintojai ir vartotojai nesugeba suprasti, ką aplinkosaugai reiškia energetikos vadyba. Visi veiksniai, turintys įtakos gamybai, visų formų energijos naudojimui turi atitikti griežtus kriterijus, turi būti kontroliuojama teršalų į atmosferą išmetimo lygis, gamybos ir energijos suvartojimo lygiai. Deja, gamybos bendrovės į tai dėmesį kreipia tik jei tokios investicijos yra pelningos. Reikia pažymėti, jog numatytas reguliavimas yra privalomas, ir Energetikos departamentas parengęs taisyklių sąvadus, ir šios taisyklės privalomos Aplinkos apsaugos agentūrai, taip pat kitoms įgaliotoms institucijoms. Energijos valdymo ir gamybos kontrolė turi didelę įtaką pasaulio ekonomikai. Šiame straipsnyje energijos valdymas yra tiriamas taikant matematinio optimizavimo metodus. Modelis yra bendras ir sprendimas yra paprastas, viskas gali būti atliekama naudojant skaičiuotuvą. Modelis prognozuoja, kiek vienetų įvairių rūšių energijos turi būti pagaminta, siekiant padidinti pajamas, kurios priklauso nuo šių rūšių energijos rinkoje. Sukurtas metodas turėtų būti taikomas planuojant optimizuoti energijos valdymą.

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