FORECASTING OF ENERGY CONSUMPTION IN BANGLADESH

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Abstract This paper describes mathematical technique for forecasting of energy consumption in Bangladesh based on statistical analysis. It helps to suggest how to meet the predicated demand efficiently and effectively.

Keywords: Energy consumption, modeling

INTRODUCTION

During the very primitive days human beings need energy. It is a crucial resource for development of a country. The rate of consumption of energy is a measure of the level of development achieved by a country. The higher energy consumption per unit GDP is a broad indicator of higher economic development [1]. For the development of a country, proper emphasis should be given on energy sector and this requires an appropriate and efficient energy consumption model.

Modeling of energy consumption gives us the following advantages:
(i) To meet the increased demand of energy at most economical cost and in most economical way. (ii) To reduce the use of the imported energy and to optimize the use of indigenous energy resources. (iii) To remove the imbalances of energy demand and supply in rural and urban areas. (iv) To consider environmental and atmospheric pollution in generation and consumption of energy. (v) To forecast future technical changes, population growth and subsequent requirement of energy considering industrial and agricultural development. (vi) To accelerate research on development of non-conventional energy technology. (vii) To assess the impact of energy demand/supply changes on the rest of the system.

This paper presents the energy consumption model of Bangladesh. Total energy consumption and electricity energy consumption model has been taken as a case study.

REGRESSION ANALYSIS

Multiple regression analysis based on least square method has been applied to find out the mathematical model for energy consumption in Bangladesh [2]. Lets assume regression line is of the form $Y = b_0 + b_1 X$.

Then we can write the linear first order model:
$Y = \beta_0 + \beta_1 X + \epsilon$ where ϵ is the increment by which any individual Y may fall off the regression line. β_0 and β_1 are called the parameter of the model. If we have n sets of observation then sum of the squares of deviation from the true line is:

$S = \Sigma \epsilon^2 = \Sigma (Y_i - \beta_0 - \beta_1 X_i)^2$ -------(i).

For sum of the squares to be minimum, we differentiate the equation (i) with respect to β_0 and β_1 and equating to zero we get the following equation:

$\delta S/\delta\beta_0 = -2\, \Sigma (Y_i - \beta_0 - \beta_1 X_i) = 0$

i.e. $n\beta_0 + \beta_1 \Sigma X_i = \Sigma Y_i$ -----(ii)

$\delta S/\delta\beta_1 = -2\, \Sigma X_i (Y_i - \beta_0 - \beta_1 X_i) = 0$

i.e. $\beta_0 \Sigma X_i + + \beta_1 \Sigma X_i^{\ 2} = \Sigma X_i Y_i$ ----(iii)

Equation (i) and (ii) can be written in the matrix form as below:

$$[\beta_0 \quad \beta_1] \begin{bmatrix} n & \sum X_i \\ \sum X_i & \sum X_i^{\ 2} \end{bmatrix} = \begin{bmatrix} \sum Y_i \\ \sum X_i Y_i \end{bmatrix} \text{------------(iv)}$$

Following the above procedure, for n independent variables we can write:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 ++ \beta_3 X_3 + \ldots\ldots\ldots.+ \beta_n X_n + \epsilon$ ----------------------(v)

In matrix form:

$$[\beta_0 \;\; \beta_1 \;\; \beta_2 \;\; \beta_3 \ldots \beta_n] \begin{bmatrix} n & \sum X_1 & \sum X_2 & \ldots\ldots & \sum X_n \\ \sum X_1 & \sum X_1^{\;2} & \sum X_1 X^2 & \ldots\ldots & \sum X_1 X_n \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ \sum X_n & \ldots\ldots & \ldots\ldots & \ldots\ldots & \sum X_n \end{bmatrix} \ldots\ldots = \begin{bmatrix} \sum Y \\ \sum X_1 Y \\ \ldots\ldots \\ \ldots\ldots \\ \sum X_n Y \end{bmatrix} \quad \ldots(vi)$$

Solving the above matrix equation, the values of $\beta_0 \;\; \beta_1 \;\; \beta_2 \;\; \beta_3 \ldots \beta_n$ can be find out.

SOFTWARE DEVELOPMENT

Software has been developed to solve matrix equation with multiple variables using FOTRAN 77 language. The software is flexible for modeling total energy consumption as well as electricity energy consumption. The software is user-friendly. In accordance with user's instruction, it can read file with necessary data for past years and can calculate the data for the future years. Flow chart of the program is as bellows.

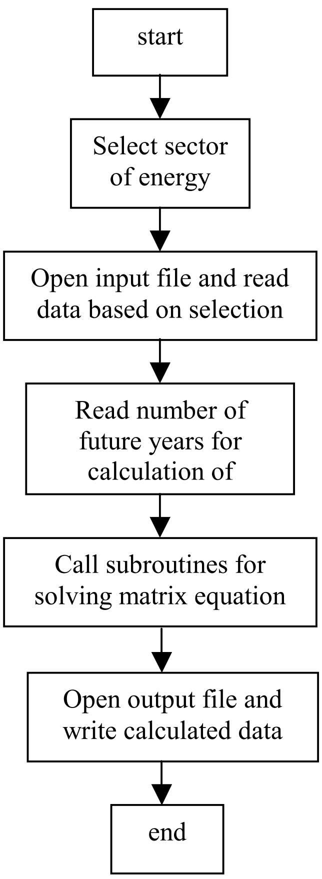


Fig 1: Flowchart of software operation

TOTAL ENERGY CONSUMPTION MODEL

Variables used for total energy consumption model are as below [3,4,5]:
X1=Dummy variable
X2=Energy cost in paisa per thousand B.T.U
X3=Per-capita energy consumption in B.T.U (exp 5)
X4=Per-capita income in hundred taka
X5=Population in million
X6= G.N.P (Gross National product) growth rate
Y= Total energy consumption in B.T.U (Exp13)

Table 1: Data on total energy consumption for Past years.

Year	X2	X3	X4	X5	X6	Y
1981	4.92	10.96	31.45	89.9	2.5	9.85
1982	5.17	12.1	33.05	92.1	1.1	11.14
1983	5.43	11.71	33.67	94.3	2.4	10.04
1984	5.69	11.55	35.05	96.5	2.6	11.15
1985	5.95	12.17	36.93	98.7	2.4	12.01
1986	6.2	13.32	37.66	100.8	2	13.43
1987	6.46	14.15	39.45	103.1	2.27	14.59
1988	6.72	12.84	40.07	105.3	1.65	13.52
1989	6.97	16.13	40.09	107.6	0.23	17.36
1990	7.23	17.32	41.51	110	4.28	19.05
1991	7.482	16.56	43.07	111.98	2.30	18.04
1992	7.738	17.16	44.20	114.19	2.33	18.98
1993	7.994	17.77	45.32	116.40	2.36	19.93
1994	8.25	18.37	46.45	118.61	2.38	20.88
1995	8.506	18.98	47.57	120.82	2.41	21.83
1996	8.762	19.59	48.70	123.03	2.44	22.78
1997	9.018	20.19	49.82	125.24	2.47	23.73
1998	9.27	20.80	50.95	127.45	2.50	24.68
1999	9.53	21.41	52.07	129.66	2.53	25.63
2000	9.78	22.01	53.20	131.87	2.56	26.57

Table2: Software-calculated data for future years

Year	X2	X3	X4	X5	X6	Y
2001	10.04	22.62	54.32	134.08	2.59	27.52
2002	10.29	23.23	55.45	136.29	2.62	28.47
2003	10.55	23.83	56.57	138.50	2.65	29.42
2004	10.81	24.44	57.69	140.71	2.67	30.37
2005	11.06	25.04	58.82	142.92	2.70	31.32
2006	11.32	25.65	59.94	145.13	2.73	32.27
2007	11.57	26.26	61.07	147.34	2.76	33.22
2008	11.83	26.86	62.19	149.55	2.76	34.16
2009	12.09	27.47	63.32	151.76	2.82	35.11

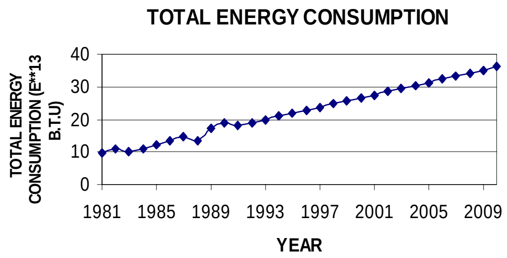


Fig 2: Total energy consumption model

The total energy demand naturally depends on energy cost, per capital income and population. The other two variables included were for taking more consideration of economic activities on total energy consumption. The resulting demand equation in simple linear form:

$$Y = -29.4187 - 3.0584X_2 + 1.1122X_3 + 0.121X_4 + 0.41643X_5 + 0.036886X_6$$

The data for the total energy consumption model has been obtained by adding the sectoral demands for conventional energy consumption. Non-conventional energy shares a major part of our total energy consumption and it is supposed to play more important role in our future total energy consumption in the context of high price rise of conventional fuels. But in our paper, we have omitted their share on total energy model for lack of sufficient and authoritative data.

The total energy consumption model is prepared based on data from 1981-2000 and a projection is made for the period of 2001-2010, with the assumption that the present trend in economic activity remains the same for the prediction. The graph is shown in Figure 2.

ELECTRICITY ENERGY CONSUMPTION MODEL

Variables used for electricity energy consumption model are as below [3,4,5]:

X1=Dummy variable

X2=Population in 10^7

X3=Per-capital electricity consumption in KWH

X4=Number of consumers in 10^5

X5=Number of villages electrified in 10^2

X6= Length of distribution line in thousand miles

Y= Electricity consumption in 10^8 KWH

Table 3: Data on Electricity energy consump. for Past years.

Year	X2	X3	X4	X5	X6	Y
1981	89.90	17.73	5.68	7.06	17.67	15.94
1982	92.10	22.02	6.45	8.31	13.56	20.28
1983	94.30	25.44	6.69	11.79	15.10	23.99
1984	96.50	28.02	7.27	8.78	10.62	27.04
1985	98.70	28.64	8.03	7.32	17.40	28.41
1986	100.80	32.52	8.88	9.45	30.26	33.07
1987	103.10	34.33	9.63	16.11	24.20	34.85
1988	105.30	36.48	10.38	14.68	45.90	37.72
1989	107.60	44.50	11.51	14.43	34.59	46.94
1990	110.00	43.77	11.76	13.85	40.89	47.05
1991	111.98	46.99	12.51	15.92	43.80	64.84
1992	114.19	49.84	13.22	16.78	47.22	70.91
1993	116.19	52.69	13.92	17.65	50.64	76.99
1994	118.61	55.53	14.63	18.51	54.05	83.07
1995	120.82	58.38	15.34	19.37	57.47	89.15
1996	123.03	61.22	16.04	20.24	60.89	95.23
1997	125.24	64.07	16.75	21.10	64.30	101.30
1998	127.45	66.92	17.46	21.96	67.72	107.38
1999	129.66	69.76	18.16	22.83	71.14	113.46
2000	131.87	72.61	18.87	23.69	74.55	119.54

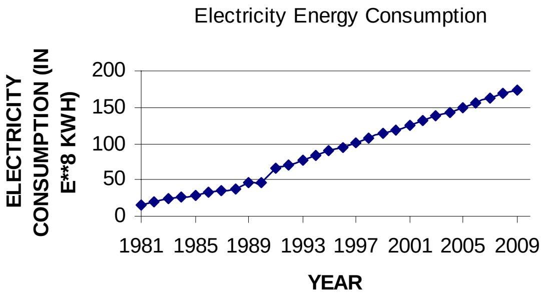
Table 4: Software-calculated data for future years

Year	X2	X3	X4	X5	X6	Y
2001	134.08	75.45	19.57	24.55	77.97	125.61
2002	136.29	78.30	20.28	25.41	81.38	131.69
2003	138.50	81.15	20.99	26.28	84.80	137.77
2004	140.71	83.99	21.69	27.14	88.22	143.85
2005	142.92	86.84	22.40	28.00	91.63	149.93
2006	145.13	89.68	23.11	28.87	95.05	156.00
2007	147.34	92.53	23.81	29.73	98.47	162.08
2008	149.55	95.38	24.52	30.59	101.88	168.16
2009	151.76	98.22	25.23	31.46	105.30	174.24

Considering all the variables mentioned above we get the resulting equation for electricity consumption as below :

$$Y = 33980 - 344.122X_2 + 1547.935X_3 - 6213.741X_4 + 6.4767X_5 + 217.87X_6$$

The electricity energy consumption model is prepared based on data from 1981-2000 and a projection is made for the period of 2001-2010, with the assumption that the present trend in economic activity remains the same for the prediction. The graph is shown in Figure 3.



CONCLUSION

Energy consumption is a very important issue for the development of a country. Future energy demand of a country can be predicted from its proper model and necessary measure can be taken to meet the demand. The method of forecasting for energy consumption is shown in this paper. Total energy consumption and electricity energy consumption has been taken as a case study for Bangladesh. The same method is applicable for any sector as well as any country.

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