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Renewable Purchase Obligations (RPO) Mix Determination: A Case of West Bengal, India

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ABSTRACT
Electricity Supply Limited (SECL) has been the player involved both in generation and transmission of electricity. The study aims at forecasting annual electricity consumption of the company and suggest an optimal combination of renewable options namely wind, small hydro, solar photo voltaic, solar thermal and biomass to meet the RPO targets of subsequent 25 years. A linear regression model has been used for forecasting the consumption and RPO contributions whereas linear programming model has been used for determining the optimal combination of renewable sources under consideration over the segments of generation and short term power purchase agreements for meeting overall REC requirement from non-solar and solar sources. The study recommends for long term PPAs of 1 MW for wind, 30 MW of small hydro and 20MW of biomass instead of 1-year short term PPA and a need for promoting wind farms in the near future.

Keywords: Renewable Energy Sources, power purchase, power generation, Renewable Purchase Obligation.

NONMENCLATURE

Abbreviations

SECL	Electricity Supply Limited
RPO	Renewable Purchase Obligation
PPAs	Power purchase agreements
MNRE	Ministry for new and renewable energy sources
WBERC	West Bengal Renewable Energy Development Agency
CESE	Calcutta Electric Supply Corporation

1. INTRODUCTION

The energy security of the country is bringing about prioritized importance and increasing significance of the role of renewable energy. MNRE was established for policy formulation & its proper implementation along with designing programs and promoting research and development in the mentioned sector. Post establishment the regulatory body had to face issues arising out of sudden rise in the price of crude oil, the supply uncertainties and the adverse balance of payments. Subsequently the State Electricity Regulatory Commissions (SERCs) were empowered by Electricity Act 2003 (EA2003) for the specification of the electricity procurement by the entities obligated from the renewable sources of energy in terms of percentages. The percentage so specified is termed as Renewable Purchase Obligation' (RPO). The State of West Bengal has a considerable Renewable Energy Potential, which can be utilized for electricity generation. Renewable Energy sources include Solar Thermal, Solar Photovoltaic, Wind Turbines, Biogas Plants, Biomass Gasifier, Small Hydro and Tidal Power etc. West Bengal Renewable Energy Development Agency (WBREDA) has encouraged development of industries in an environmental friendly manner since it aims for promotion of Renewable Energy Technologies in its state. WBERC has specified RPO targets to all distribution licensees under its area of jurisdiction. CESC Ltd is one of the distribution licensees under WBERC's area of jurisdiction. In order to meet RPO targets, CESC Ltd has to develop short term and long term strategies. Besides a distribution company, CESC is also a generating company with strong financial statements can go for renewable generation.

1.1 RENEWABLE ENERGY SCENARIO IN WEST BENGAL

The State of West Bengal is implementing one of the largest programs on Renewable Energy in India covering a broad spectrum of energy technologies like Solar Thermal, Solar Photovoltaic, Wind Turbines, Improved stoves (Chullas), Biogas Plants, Biomass Gasifier, Small Hydro and Tidal Power. These activities are mainly taking place in areas where it is very difficult, cost prohibitive or almost impossible to supply power through conventional grid. The various renewable source options, with their potential estimates and achievements of West Bengal are detailed in Table 1, below:

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Table 1. Renewable Power Potential and Achievement in West Bengal

Energy Source	Potential (MW)	Cumulative Achievement (MW)
Wind (w/o offshore)	450	3
Biomass	350	80
Small Hydro	300	100
Solar Photovoltaic	16,000	11
Solar Thermal	400	0
Urban & Industrial Waste	150	0
Tidal	100	0

Source: Renewable Energy Policy - West Bengal (PWC, 2010) and WBREDA (2010)

1.2 **REC Mechanism**: A Renewable Energy Certificate (REC) is a market-based instrument, which provides evidence that a generator has produced a certain amount of electricity from a renewable energy resource.

1.3 **Renewable Purchase Obligation targets:** Under Section 86(1) (e) of the EA2003, the SERCs are empowered to specify the percentage of electricity to be procured by the obligated entities from the renewable sources of energy. Most SERCs have put significant emphasis on this provision and have issued Orders/Regulations specifying such percentages.

2. LITERATURE REVIEW:

RECs were originally proposed during the US electricity restructuring debates of the mid-1990s as a tradable environmental commodity and accounting device for renewable energy policies. The concern at the time was that newly competitive electricity markets would drive renewable energy generation out of the market [1]; [2]; [3] [4].

Goyal & Jha (2009), states India faces a power generation deficit of 9%. The prices of the crude oil are reaching higher percentages every year raising the environmental concerns. Energy security and environment concerns have raised a demand for promotion of renewable energy sources in the country. A framework was developed that emphasized on placing Renewable Purchase obligation mechanism by the author. The framework included renewable purchase obligations target settings, in case of noncompliance of renewable purchase obligation targets. He further suggests a surcharge may be levied on not meeting renewable purchase obligation targets through trading of certificates [5].

Ringel Marc, (2006) suggests that the targets for incorporating alternative energy sources can be sought by green certificates model and feed- in- tariffs. However, the pros and cons of both the models in terms of economic efficiency and ecological effectiveness needs to be given due consideration [6].

In a study by Verbrugge Aviel, (2009) the performance of renewable energy support systems were evaluated on the criterion of effectiveness, efficiency and equity. The framework proposed in the study sufficed the qualifying factors of renewable energy sources in details [7].

Aune et al. (2012) proposed the use of green certificates to meet the renewable targets and defined the potential of cost reductions thereon which turned out to be helpful in the implementation of renewable energy certificates. The Impact of renewable energy certificates in the study carried out was 70% cut in the total cost [8].

The possibilities of incorporating current renewable tradable green certificates and tradable white certificate schemes have been discussed by Bertoldi & Huld [9]. In another study by Jensen & Skytte , (2003) it has been found that ambiguous increase in the consumer prices have been concluded after the introduction of green certificates and emission permits and regulatory mechanism in the form of corresponding quotas [10]. Similarly, Verhaegen et al. (2009) concludes that after the application of a common framework for renewable energy sources it was found that one cannot think of a combination of tradable green certificate systems [11]. Further redefining renewable energy certificates with respect to the on- site attributes would give space for compliance and involve renewable energy in voluntary terms and a conflict free functional emission market. A more general discussion on the relationship between RECs and emission markets, along with recommendations for how to resolve conflicts between REC and emissions trading markets, has been pointed out by Gillenwater M [12].

Gaul C & Carley S, (2012) observed renewable energy certificates as a support mechanism when one thought of compliance market of solar power for its installation and financing [13]. A mathematical description of supply and demand balance for electricity and green certificates has been proposed by Marchenko [14]. Highlighting the importance of supply of renewable certificates Jensen & Skytte,(2002) states that renewable energy supplies shall give rise to power production when we talk about its

liberalization. Target assured, a policy in the form of green certificates must be developed to eliminate the ambiguity of price and consumption effects [15].

A. Kildegaard, found in his research that when exclusively high fixed-cost technologies comprise the eligible technology pool, the equilibrium form of contracting obviates and the principal efficiency advantages claimed for certificate markets [16].

A study by Morthorst P E, (2000) emphasizes that the green-house gas effects were bound to decrease with the implementation of RES. For its development, a need to define a market for TGCs or equal valued instruments needs to be discovered. The author suggested that a separate green market would help in securing technologies for renewable energy while giving comfort to the government from subsidies thereon. These technologies should be environmental favorable as compared to the traditional power production [17].

P. Fristrup, considered managing the coexistence of multiple types of RES-E suppliers with just one policy instrument as a prominent obstacle. The first issue considered is the development of incentives for fresh RES-E deployment. The second issue concerns unfortunate mixes of RES-E sources. The final problem mentioned is the issue of overflowing manufacturing [18].

According to Berendt (2006) renewable energy certificates have been the drivers for the growth of renewable electricity [19]. Analyzing the contributors to the greenhouse emissions Verma Y P & Kumar A. (2012) identifies the electricity sector to be the major contributors of green-house gas emission in the Indian context. Within this sector they found an alternative to reduce this emission namely renewable energy source [20]. Another study by Singh A, (2009) mentions that there are a few number of fiscal policies and preferential tariffs which help in the promotion of renewable energy sources in India with special mark to electricity generation. The study not only identifies the factors affecting the performance of individual players for meeting the REC requirements but also highlights the importance of accuracy in estimating the demand and supply [21].

The previous researches as discussed above also points that mere policy formulation will not prove to be the magical wade for effective implementation there is a need for proper projection of the REC requirements and their optimal mix that may be economically attained. The present study aims at filling this identified research gap.

3. Objectives:

Since West Bengal has a considerable renewable energy potential for electricity generation and Calcutta Electricity Supply Limited (CESC) has been the major player involved both in generation and transmission of electricity the study aims

a. To forecast the annual electricity consumption of the company namely CESC

b. To suggest an optimal combination of renewable options namely wind, small hydro, solar photo voltaic, solar thermal and biomass to meet the RPO targets of subsequent 25 years.

4. Methodology:

A linear regression model has been used for forecasting the consumption and RPO contributions whereas linear programming model has been used for determining the optimal combination of renewable sources under consideration over the segments of generation and short.

The Linear Programming Model used to determine the optimal combination of renewable options to meet RPO targets is as below:

$$Y = \sum_{1}^{12} C_i X_i$$

where

Y = Total Cost (objective:- Minimize)

C_i = Present Value of per unit cost of i^{th} renewable option

X_i = Number of Units of i^{th} renewable option

The constraints for the linear programming model is as below:

$$\sum_{1}^{12} X_i = RPO\ \ target\ \ for\ \ that\ \ year$$

$$X_i \leq Availabale\ \ potential\ \ for\ \ i^{th}\ \ Renewable\ \ option$$

$$X_i \geq 0$$

Table 2: Details of 'I'

Value of 'i'	Renewable option
1	Wind Power Generation
2	Small Hydro Power Generation
3	Solar Photovoltaic Power Generation
4	Solar Thermal Power Generation
5	Biomass Power Generation
6	Wind Power Purchase

7	Small Hydro Power Purchase
8	Solar Photovoltaic Power Purchase
9	Solar Thermal Power Purchase
10	Biomass Power Purchase
11	Non Solar REC
12	Solar REC

5. Results

Using appropriate forecasting technique, the annual electrical consumption for the subsequent period from 2013-2037 has been estimated(see table 3).

Table 3: Renewable sources based on RPO targets

Year	Consumption (MU)	RPO (%)	RPO (MU)
2011	8225.58	2%	164.51
2012	8385.24	3%	251.56
2013	8544.9	4%	341.8
2014	8704.56	5%	435.23
2015	8864.22	6%	531.85
2016	9023.88	7%	631.67
2017	9183.54	8%	734.68
2018	9343.2	9%	840.89
2019	9502.86	10%	950.29
2020	9662.51	10%	966.25
2021	9822.17	10%	982.22
2022	9981.83	10%	998.18
2023	10141.49	10%	1014.15
2024	10301.15	10%	1030.12
2025	10460.81	10%	1046.08
2026	10620.47	10%	1062.05
2027	10780.13	10%	1078.01
2028	10939.79	10%	1093.98
2029	11099.45	10%	1109.94
2030	11259.11	10%	1125.91
2031	11418.77	10%	1141.88
2032	11578.43	10%	1157.84
2033	11738.09	10%	1173.81
2034	11897.75	10%	1189.77
2035	12057.4	10%	1205.74
2036	12217.06	10%	1221.71
2037	12376.72	10%	1237.67

In order to facilitate the process of determining the optimal combinations of different renewable sources a suitable Linear Programming model has been designed. The variables considered in the model are the options available to meet RPO target. The present value of per unit cost of each option chosen is determined using financial analysis based on the regulation prescribed by CERC for renewable energy sources. The unit costs thus resulted is used as coefficients of each variable (option) in the model. The renewable potential and cumulative achievement and RPO targets are used as constraints of the model. The model has been run for each year from 2013 to 2037 with coefficients and constraints updated after each year.

Table 4: Regression Output of Consumption Data

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.95
R Square	0.91
Adjusted R Square	0.90
Standard Error	269.15
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	10400357.36	10400367.36	143.568392	4.41231E-09
Residual	15	1086628.527	72441.9018		
Total	16	11486995.88			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5351.713235	136.5398714	39.1952415	1.58146E-16	5060.68539	5642.741081	5060.68539	5642.741081
X	159.6593137	13.32492705	11.98200284	4.41231E-09	131.2579042	188.0607233	131.2579042	188.0607233

The output of model in each year has given the optimal combination of renewable option to meet the RPO target.
The Linear regression model for the consumption data can be specified as;

Average Consumption = α + β * Year + μ

Where Average consumption is dependent variable and the Year is independent variable. α and β are the parameters of the model and μ is the random variable. On applying the above model to consumption data the linear regression model was obtained (given in table 4), which may be used for forecasting the future consumption.
The outcome of the linear programming model may be stated in Table 5 as below:

Table 5: Optimal Combination of Renewable Sources

		Generation (MW)					SHORT TERM PPA (1 Year) MW					REC	
		Wind	SHP	Solar PV	Solar Thermal	Biomass	Wind	SHP	Solar PV	Solar Thermal	Biomass	Non Solar	Solar
Year1	2013	0	20	0	0	0	0	25	0	0	0	48089	0
Year2	2014	0	53	0	0	0	0	25	0	0	0	48569	0
Year3	2015	20	53	0	0	0	0	26	0	0	8	49055	0
Year4	2016	40	53	0	0	0	1	26	0	0	16	49546	0
Year5	2017	94	53	0	0	0	1	26	0	0	17	50041	0
Year6	2018	94	53	0	0	15	1	26	0	0	17	50541	0
Year7	2019	94	53	0	0	30	1	27	0	0	17	51047	0
Year8	2020	94	53	0	0	45	1	27	0	0	17	51557	0
Year9	2021	94	53	19	0	45	1	27	0	41	17	52073	0
Year10	2022	94	53	19	0	45	1	27	0	49	17	52594	0
Year11	2023	94	53	19	0	45	1	28	0	56	18	53120	0
Year12	2024	94	53	19	0	45	1	28	0	64	18	53651	0
Year13	2025	94	53	19	0	45	1	28	0	67	18	54187	7003
Year14	2026	94	53	19	0	45	1	28	4	69	18	54729	9377
Year15	2027	94	53	24	0	45	1	29	5	71	18	55276	9471
Year16	2028	94	53	30	0	45	1	29	6	73	19	55829	9566
Year17	2029	94	53	35	0	45	1	29	6	76	19	56388	9662
Year18	2030	94	53	40	0	45	1	30	6	78	19	56951	9758
Year19	2031	94	53	45	0	45	1	30	7	80	19	57521	9856
Year20	2032	94	53	50	0	45	1	30	7	83	19	58096	9954
Year21	2033	94	53	55	0	45	1	31	7	85	20	58677	10054
Year22	2034	94	53	60	0	45	1	31	8	88	20	59264	10154
Year23	2035	94	53	64	0	45	1	31	8	90	20	59857	10256
Year24	2036	94	53	69	0	45	1	31	8	93	20	60455	10359
Year25	2037	94	53	73	0	45	1	32	9	96	20	61060	10462

6. Conclusion & Discussion:

The study has attempted a review of the present scenario of West Bengal and identify the renewable potential and its cumulative achievement so far in line with the state regulations regarding generation and purchase of renewable energy. The study also aimed at Forecasting annual electrical consumption of CESC distribution area and suggests an optimal combination of different renewable sources over a period of 25 years. The outcome of the study suggests that instead of short term PPA of 1 Year CESC Ltd may go for Long term PPA (25 years) of 1MW for Wind, 30 MW of Small Hydro and 20 MW of Biomass as the change in requirement over the years is very small. The outcome also suggests a need for developing Wind farms as early as possible as it contributes for major part of combination (94MW).
Renewable Energy sources like Municipal Solid Waste/Industrial Waste, Tidal energy and Cogeneration have been out of the scope of the study. In the future this work may be extended to include these energy sources.

References

[1] N. A. Rader and R. B. Norgaard, "Efficiency and sustainability in restructured electricity markets: the renewables portfolio standard," *The Electricity Journal,* vol. 9, no. 6, pp. 37-49, 1996.

[2] UER, "Restructuring Bills Aim to Protect Renewables in Competitive Markets," Utility Environment Report, 1996.

[3] M. Wingate, "REC Tracking Systems Design Guide," *Other Information: PBD: 3 Feb 2004,* 2004.

[4] E. Wood, "Green Trading: Why the case is on for US RECs?," *Renewable Energy World,* pp. 67-75, 2007.

[5] M. Goyal and R. Jha, "Introduction Of Renewable Energy Certificate in the Indian Scenario," *Renewable and Sustainable Energy Reviews,* vol. 13, pp. 1395-1405, 2009.

[6] M. Ringel, "Fostering the use of renewable energies in the european union," *Renewable Energy,* vol. 31, pp. 1-17, 2006.

[7] A. Verbrugge, "Performance evaluation of renewable energy supprt policies applied on flander's tradable certificates system," *Energy Policy,* vol. 37, pp. 1385-1394, 2009.

[8] F. R. Aune, H. M. Dalen and C. Hagem, "Implementing the EU renewable target through green certificate markets," *Energy Economics,* pp. 992-1000, 2012.

[9] P. Bertoldi and T. Huld, "Tradable certificates for renewable electricity and energy savings," *Energy Policy,* vol. 34, pp. 212-222, 2006.

[10] S. G. Jensen and K. Skytte, "Simultaneous attainment of energy goals by means of green certifictes and emission," *Energy Policy,* vol. 31, pp. 63-71, 2003.

[11] K. Verhaegen, L. Meeus and R. Belmans, "Towards an International tradable green certificates system- The challenging example of belgium," *Renewble and sustainiable energy reviews,* vol. 13, pp. 208-215, 2009.

[12] M. Gillenwater, "Redefining RECs-Part 2: Untangling certificates and emission markets," *Energy policy,* vol. 36, pp. 2120-2129, 2008.

[13] C. Gaul and S. Carley, "Solar set asides and renewable electricity certificates: Early lessons from Nort calorina's experience with its renewable portfolio standard," *Energy Policy,* vol. 48, pp. 460-469, 2012.

[14] O. V. Marchenko, "Modelling of a green certifictae market," *Renewable Energy,* vol. 33, pp. 1953-1958, 2008.

[15] S. G. Jensen and k. Skytte, "Interactions between the power and green certifcates markets," *Energy policy,* vol. 30, pp. 425-435, 2002.

[16] A. Kildegaard, "Green certificate markets; the risk of over investment and the role of long term contracts," *Energy policy,* vol. 36, pp. 3413-3421, 2008.

[17] P. E. Morthorst, "The Development of a green certificate market," *Energy Policy,* vol. 28, pp. 1085-1094, 2000.

[18] P. Fristrup, "Some challenges related to introducing tradable green certificates," *Energy Policy,* vol. 31, pp. 15-19, 2003.

[19] C. B. Berendt, "A state based approach to building a liquid national market for renewable energy certificates," *The electricity journal,* pp. 54-68, 2006.

[20] Y. P. Verma and A. Kumar, "Potential impacts of emission concerned policies on power system operation with renewable energy sources," *International Journasl of electrical power and energy systems,* vol. 44, pp. 520-529, 2012.

[21] A. Singh, "A Market for renewable energy credits in the Indian power sector," *Reneable and sustainable energy reviews,* vol. 13, pp. 643-652, 2009.