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Life Cycle Costing Analysis of Energy Options: In Search of Better Decisions towards Sustainability in Indian Power & Energy Sector

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GJMBR-A Classification : *JEL Code: M11, M19.*

LIFE CYCLE COSTING ANALYSIS OF ENERGY OPTIONS IN SEARCH OF BETTER DECISIONS TOWARDS SUSTAINABILITY IN INDIAN POWER ENERGY SECTOR

Strictly as per the compliance and regulations of:

Life Cycle Costing Analysis of Energy Options: In Search of Better Decisions towards Sustainability in Indian Power & Energy Sector

Vivek Soni [α], A.P. Dash [σ], S.P. Singh [ρ] & D.K. Banwet [ω]

Abstract- The utilization of energy from fossil fuels has becoming important driver and plays a vital role for all the economies. The alternative resources have wider concerns over the issues of energy security and sustainable development in the sector. In this context, for meeting the national power deficit and addition to thermal power generation capacity, power generation from thermal plants has been a very important history of the Indian power sector. The optimization of electricity tariff and assessment of investments cost is significant in capacity addition. These investments contribution to overall achieving targeted national gross domestic product of the country. In continuing this investments tradition, the current agenda of sustainable development brings to ensure that new and renovated financial mechanisms which may meet the needs as effectively and efficiently as possible. In this context, the life cycle costing (LCC), the technique has emerged from practice of life cycle management (LCM) practices and approaches of UNEP global environmental agenda, which promotes the coherent implementation of the environmental dimensions of sustainable development.

This paper highlights a good literature review on LCC, learning from important international case studies, detailed methodology, its applications and feasibility of its applications in Indian power & energy sector. The data of typical thermal & solar power plants have collected from the plants managed by the national thermal company. It is found that, the total life cycle cost of the solar power plant for 25 years of operations is lesser than the levelized cost of the electricity produced by typical thermal power plant. The possibilities to have sensitivity analysis and breakeven point of comparison of LCC costs for both type of energy resources gives policy makers and investors to have clear picture on investments in thrust agenda of sustainability.

Keywords: life cycle costing (lcc), life cycle management, thermal power plant, solar power plant, sustainability, india.

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I. Introduction

Recent trends in the investment in energy sector required the decision making capability for a healthy economy. The international framework of United Nations Environment Program (UNEP) targets the mandate to become the leading global environmental authority that sets the global agenda, promotes the rational implementation of the Environmental dimensions of sustainable development. Thus the business guide to sustainability provides the linkages between the effective use of resources with better capacity to have better understanding and difference critical approach to deal with the shortage of resources. In this context the journey towards sustainability needs that businesses should find innovative ways to be profitable and at the same time expand the traditional frontiers of business to include the environmental and social dimensions, in other words take account of “the triple bottom line”, and to introduce “Life cycle thinking”.

The concept of life cycle management (LCM) projects with the effective role to minimize the environmental and socio-economic burdens associated with a product throughout its entire life cycle. LCM makes life cycle thinking and product sustainability operational for businesses through continuous improve-ements of product systems and supporting business assimilation of integrated product policies. It is worthy to say that LCM is not only a single tool or methodology but also management system collecting, structuring and propagating product-related information from various programs, concepts and tools. It incorporates the aspe-cts such as environmental, economic, asocial issues ofaproducts, which are applied throughout a product’s life cycle. The organizations must ‘go beyond its facility boundaries’ and be willing to expand its scope of collaboration and communication to all stakeholders in the value chain LCM can be specfically adapted and gradually introduced, in any organization, including small and medium enterprises.

It is, therefore important to have clear picture on investments on the various energy supply options which factor in the electricity costs to the consumers. This paper flows in six parts and has numbered accordingly.

The part one of this study is the introductory part. The rest of the study is organized into another five parts. The second part of the study presents the contextual information, where it discussed about the emergence of the life cycle costing (LCC) technique from the international agenda of sustainability. Part three is the review of the related studies highlighting literature review from various international journals, important case studies and the possibility of its applications in Indian energy sector. This section also draws the gaps in the literature and the feasibility for its applications in the Indian energy sector. The next part four gives the research methodology and the reference to the nature and sources of data for the applications of methodology. Finally, the part six of the paper provides the conclusion and assumptions and few limitations that may point out the possible policy recommendations of the study.

II. Contextual Information of the Study

a) Introduction to life cycle thinking

Life cycle thinking is essential to sustainable development. It is about going beyond the traditional focus on production site and manufacturing processes to include the impacts on the grounds of environmental, social, and economic value of a product over its entire life cycle. Extended producer responsibility and integrated product policies mean that the producers can be held responsible for their products from cradle to grave and therefore, should develop products, which have improved performance in all stages of the product life cycle.

The main goals of life cycle thinking are to reduce a product's resource use and emissions to the environment as well as improve its socio-economic performance. This creates and ffacilitate the links between the economic, social and environmental dimensions within an organization and throughout its entire value chain.

b) Responsibility in the life cycle thinking

A Corporate Social Responsibility (CSR) strategy can be used to advance life cycle thinking. These CSR strategies are aligned at advancing integration. Many companies creates link for environmental and social responsibilities to address a range of issues associated with the product life cycle, including child labour, discrimination, abuse of union rights, as well as, to make positive contributions to the families of employees and the local community at large. The Principles of UN Global Compact That Can Be Used In Businesses World to Endorse Corporate Environmental and Social Responsibility. It is found that UNEP is responsible for environment related activities under this Compact. In brief, the principles of the UN Global Compact can be used throughout the life cycle to promote Corporate Environmental and Social Responsibility. The Compact was started in the year 2000 and it's voluntarily initiatives are for the business community to help promote sustainable development through the power of collective action. The Compact also seeks to promote responsible corporate citizenship so that business can be part of the solution to the challenges of globalization. Now days, most of the organizations all regions of the world, and international labour and civil society organizations are engaged in the Global Compact, working to advance ten universal principles in the areas of human rights, labour standards, the environment and anti-corruption. *(UNEP Official website)*.

c) Life cycle management (LCM)

Life Cycle Management (LCM) is a product management system aiming to minimize environmental and socioeconomic burdens associated with an organization's product or product portfolio during its entire life cycle and value chain. In the business and management practices world, the term LCM is making life cycle thinking and product sustainability operational through the continuous improvements of product systems, and it also supports the all together business of policies such as integrated product policies. LCM is not a single tool or methodology but a management system for collecting, structuring and disseminating product-related information from the various programs, concepts and tools incorporating environmental, economic, and social aspects of products, across their life cycle. The organization must 'go beyond its facility boundaries' and be willing to expand its scope of collaboration and communication to all stakeholders in its value chain.

d) Business agenda and International thrust for life cycle costing

There are many approaches, programmes and activities in the life cycle thinking basket that are essential in a green economy. These approaches have been developed to assist in decision-making at all levels of effective deployment from its beginning and final disposal of the product. The applications can be done in all sectors, and offer the possibility to examine a range of key impact categories e.g. carbon and water footprints, as well as the ultimate effects of these on all three key sustainability pillars. In general aspects, the LCM puts life cycle thinking and LCA into a business context.

It has been now 20 years after the Earth summit, nations are again on the same path to Rio, but in a world which is mainly changed from that of 1992. Today, many of those challenges concerns are becoming a sobering reality, challenging not only our ability to reach the United Nation's Millennium Development Goals but also the very opportunity for close to seven billion people to be able to thrive in increasing crowded world. The international agenda on Summit also provided the vision and set in place important pieces of the multilateral machinery to achieve a sustainable future. Along with the debate about corporate responsibility over the past two decades, which led to the ISO 26000 standard on social responsibility and to which UNEP contributed actively, there has been growing demand for direction and guidance on environmental challenges and how to incorporate social and economic issues into sustainability strategies and impact assessments, both in the public and the private sector. *(Green Economy Report, 2013).*

e) About the SETAC

The Society of Environmental Toxicology and Chemistry (SETAC) is a non-profit, worldwide professional society comprised of individuals and institutions engaged in conducting the study, analysis, and solution of environmental problems, management, regulations of natural resources, environmental education and the research and development. Its mission is to support the development of principles and practices for protection, enhancement and management of sustainable environmental quality and ecosystem integrity. SETAC also promotes the advancement and application of scientific research related to contaminants and other stressors in the environment, relevant education areas. *(Official website of SETAC).*

f) About life cycle initiatives

The United Nations Environment Programme (UNEP) and the SETAC launched in 2002 an International Life Cycle Partnership, known as the Life cycle initiative (LCI), to enable users around the world to put life cycle thinking into effective practice. During the Malmo Declaration which was started in the year 2000, the Initiative responds the call by Governments around the world for a Life Cycle economy. It also provides, the 10-Year Framework of Programmes to promote types of sustainable consumptions and productions, as discussed at the World Summit on Sustainable Development (WSSD) in Joannesburg during 2002. It aims to promote life cycle thinking globally and facilitate the exchange of knowledge of over 2,000 experts worldwide and four regional networks from different continents.

g) Sustainability in energy sector: World & Indian focus

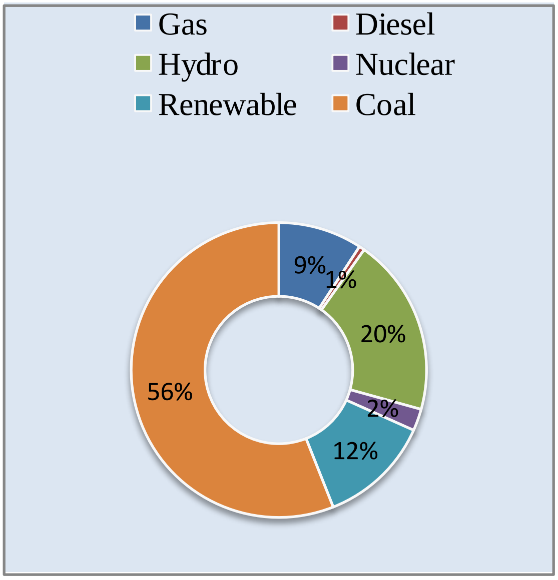
As per the official discussion of UNEP, by 2030, it hopes that there will be universal access to modern energy services, a targeting the double share of renewable energy sources in the global energy mix. Still after decades of work to advance sustainable energy solutions, an energy gap continues to grow as energy systems around the world. Due to new upcoming type of challenges, the global demand for primary energy is expected to increase by between 27% and 61% by 2050. It is seen that the policy decisions reached during this historic moment of flux in energy policymaking could tip the balance.

The new editions of the World Energy Trilemma report released by the Oliver Wyman, examines the drivers and risks preventing the development of sustainable energy systems. It then recommends an aagenda for change to address these risks and to accelerate a global transition to more diversified, and therefore sustainable, energy systems that will present opportunities for economic growth. The report also reflects the results of the 2013 Energy Sustainability Index prepared by the World Energy Council (WEC). WEC defines as the ‘energy trilemma’ and the Index evaluates how well countries balance the three often conflicting goals of energy sustainability i.e. energy security, energy equity, and environmental sustainability. The Each of the three legs of the trilemma is vital to the economic and social development of a country. Secure energy is critical to fuelling economic growth, energy must be accessible and affordable at all levels of society, and the impact of energy production and energy use on the environment needs to be minimized to combat climate change and maintain good air and to combat climate change and maintain good air and water quality. *(World Energy Council Report, 2013).*

h) Robust growth outlook in Indian energy sector

In India, the eenergy has becoming as a `strategic commodity’ and any uncertainty about its supply can threaten the functioning of the economy. Achieving energy security in this strategic sense is of fundamental importance not only to India’s economic growth but also for the human development objectives that aim at alleviation of poverty, unemployment and meeting the Millennium Development Goals (MDGs) at large. Holistic planning for achieving these objectives requires either quality energy statistics that is able to address the issues related to energy demand, energy poverty and environmental effects of energy growth or clear picture to take decision on investments in various energy resources.

The country’s energy basket has a mix of all the resources available including energy from the renewables. The dominance of coal in the energy mix is likely to continue in foreseeable future. At present India's coal dependence is borne out from the fact that 54 % of the total installed electricity generation capacity is coal based and 67% of the capacity planned to be added during the 11 Five year Plan -



Graph 1: Status of installed capacity by mode

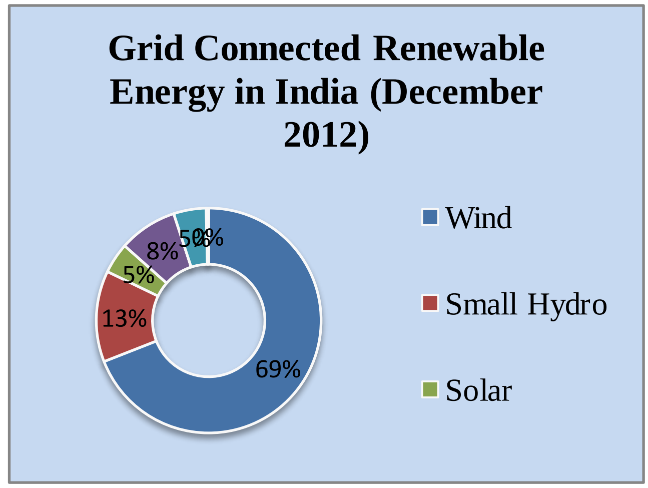
(Sources: CEA, 2012)

period 2007-12, is coal based. Furthermore, over 70 % of the electricity generated is from tcoal based thermal power plants. The sources of renewables such as wind, geothermal, solar, and hydroelectricity represent approximates 2 % share of the Indian fuel mix. Nuclear holds a around 1% share. *(Energy Statistics Reports, 2013 & Five Year Plan Document, Planning Commission, Govt. of India)*

Economies all over the world, including the Indian economy, are struggling with aftershocks of the global financial crisis that occurred in the year 2008. Consequent upon this, the Indian economy has also been gripped into the downward spiral. The national thermal company is playing major role in the resilience demonstrated by the Indian economy in coping with the first waves of the crisis. It is seen and believes that the Indian economy will weather the storms and regain its desired growth trajectory, aided by the company. Despite current economic downturn, the country has to work for regaining its growth momentum. The feeling goes to energy demand in the country is bound to grow due to increasing population, changes in standards of living, increasing urbanization and thereby industrial growth. While, on capacity expansion requirements, it feels that large power capacity requirement translates into an overall estimated capacity of 778 GW for 8% GDP growth and 960 GW for 9% growth by 2032. Thus the massive investments are envisaged in the power sector (about Rs. 15 lakh crore in the Twelfth Plan. As per the Planning Commission, the twelfth plan capacity addition target has been set about 88,500 MW. *(Annual Reports, NTPC Limited).*

i) Security concern of renewable energy in India

Energy security concerns: India ranks fourth and sixth globally as the largest importer of oil, and of petroleum products. It is expected that the increased use of indigenous renewable resources is expected to reduce India's dependence on expensive imported fossil fuels. The key drivers for the renewable sectors in the recent years have be identified, which includes: Government support, climate change, Increasing cost competitiveness of renewable energy technology distributed electricity demand, favorable foreign investment policy.



Graph 2 : Grid Connected Renewable Energy

(Sources: CEA, December, 2012)

j) Need for better decision for investments in energy sector

The primary fuels used for power generation in India are fossil based, such as coal and natural gas. By projecting the future power demand (9,50,000 MW by 2030), Indian government's focus has now shifted to capacity additions using cleaner fuels, such as renewable and nuclear energy. To this effect, it has taken several initiatives, such as promoting the Renewable Power Obligations Scheme, allowing 100 percent foreign direct investment through the automatic route, setting up of ultra mega power projects and encouraging joint ventures through the PPP route to step up private sector participation. It is also expected that the private sector is expected to contribute nearly 60% of the total capacity additions planned over 2012–17. Further, the Government has also allowed foreign investments up to a limit of 49 per cent in power trading to aid the rapid development of the sector *(Five Year Plan Document, Planning Commission, Govt. of India).*

III. Review of Related Studies

a) Literature review

The life cycle costing (LCC) technique has been widely used since long back in the history. The term LCC and its application used and found mainly in the United States and developed countries. The literature and international studies shows that its applications and modeling are of the greater importance in the energy sector worldwide. It is also seen, just because of first understanding the technique and the dependency of the accuracy of the data, the previous studies tried to have emphasis on assessment of LCC in the various energy options including the renewable energies. While there has been a considerable research on LCC approaches, bulk of literature on LCC is largely conceptual in nature. There is less data available on what LCC approaches and applications are being used. Instead, the focus is on potential benefits of LCC and technical aspects. While doing preliminary research on the subject, the few literature documents in the different aspects of its applications have been listed on the next page.

b) Gaps identified in the literature reviewed

As per the need of managing the emerging issues of demand-supply and reporting practices for sustainable development, the investments in energy and power sector has emerged as citing area for the Government. On the supplements, due to complex Indian electricity tariff calculations, issues related to coal availability, blending, its prices and dependency for tariff calculation and coal mining, LCC study and its application focusing to Indian energy and power sector is totally missing in the literature. None of the author has depicted and found good use to assess the investments in the Indian energy sector using the technique. Previous five years of Indian economy includes the fluctuations and the decade has seen the global recession, thereby uptowns in energy sector with variations in national GDP figures. Thus it is important to government to have overall the picture factor in present values of total cost of the plant capacity. In such a scenario, the application of such methodology is found most viable. The next section discusses the research gaps, data sources, and methodological framework.

c) Salient points on research gaps

First issues are too much emphasis on financial returns: After the much heated debate on global warming worldwide, there is an overwhelming consensus among developers/procurers to factor in the socio-economic costs associated with different alternatives. Traditional pay back method completely avoids this critical aspect. Such gains/costs need to be demonstrated for wider acceptability of LCC method over the still being used pay back methodology. Apart from calculating the Net Present Value (NPV), Internal Rate of return (IRR) for a project, LCC can be extended to introduce the concept of Economic Internal Rate of return (EIRR) which gives a much more holistic picture of actual costs from the economic perspective.

Second issue is top Inclusion of renovation and modernization(R&M) cost: In the currently used pay back methodology, the focus is on the time period when the entire costs are recovered i.e. the pay back threshold. However, for assets like generation assets, lifetime is often enhanced by undertaking R&M at the end of asset life. Such costs are very important but often ignored. Hence, there is a wide scope for introduction of LCC methodology in valuing power generating alternatives which we intend to explore. Though many businesses are aware of benefits of LCC methodology, its applicability is far from being systematic and calculation methodologies are far from being robust because of data constraints in most practical research on the subject. As a result of no clear demonstrations on the subject, Developers are not able to use LCC to make more sustainable and strategically advantageous decisions. The above analysis highlights that the decision makers get carried away by immediate gains and if more practical and mathematical findings on benefits of LCC are established, they will be able to make more sustainable and financially viable investment decisions. This builds a strong case for testing the applicability LCC methodology in valuing power generation alternatives so that the concepts like “thinking for whole life and beyond” and “green power costing” can be suitably highlighted for use presently and in times to come.

d) Why is LCC important to a utility?

The LCC analysis allows utility to examine projected life cycle costs for comparing competing capital and O&M project solutions and allows for appropriate comparison of alternatives of different capital values, and lengths of time. Given the condition of the utility’s assets, the amount of capital available from the budget, and historical evidence, the project manager must decide which project alternatives will incur the least life cycle costs over the life cycle.

Table1 : Overview of LCC related literatures and case studies

Year	Author name	Research for the country	Title of the LCC case study/ research orientations	Identifying research issues
2002	Joan M. Ogden et.al.	Car industry: Global reach	Societal lifecycle costs of cars with alternative fuels/engines	Formulating a strategy toward the car of the future
2004	European Commission	EU	Procurement in municipalities for integrated solutions on energy	A life cycle costing: A guide for local authorities
2005	G.A. Keoleian et al.	USA	Life cycle cost model for evaluating the sustainability of bridge decks	Addresses our macro scale research effort and presents life cycle based environmental, economic and social indicators for assessing the sustainability of a bridge deck
2006	Priscilla Bloomfield	USA	Incorporating Sustainability into asset management through critical LCC analysis	Applying the hidden synergies leading to efficiency improvements possible through whole systems design, coupled with the relative ecological impact assessments
2007	Matthew S. Orosz and Amy Mueller	Southern Africa	Small scale solar ORC system for distributed power	Solar thermal organic rankine cycle (ORC) mentioning affordable energy supplies in remote regions. Construction and testing , including benchmarking of scrolls expanders and the field testing of solar collectors, the results shows construction of a full-scale 3kW solar ORC power system designed to support a rural health clinic in the country
2008	Lyle Turner et al.	Australia	Life cycle cost analysis report	Describing engineering cost method, Analogous cost method, Parametric cost method, Parabalistics estimation method
2010	C. Richard Donnelly et al.	North America	An assessment of the life cycle costs and GHG emissions for alternative generation technologies	Comparison of life cycle costs of various low emission technologies with coal-fired generation
2010	Oshani Perera et.al.	USA	A white paper on life cycle costing: A question of value (International Institute of Sustainable Development)	Using LCC as robust methodology, Moreover, procurers are not using life cycle costing to inform strategically advantageous decisions. Criticizing the sustainable public procurement model is not delivering the best value for tax payers 'money.
2011	Erwin M. Schau et al.	Germany, India or Sierra Leone	Life cycle costing in sustainability assessment: A case study of remanufactured alternators	Investigating the application of LCC as part of a wider sustainability assessment where also social life cycle assessment (SLCA) and LCA are combined
2011	A. Boustani	USA	Appliance remanufacturing and life cycle energy and economic savings	To evaluate the energy and economic consequences of appliance remanufacturing relative to purchasing new / total life cycle energy and economic savings potential of extending the service life of an old appliance through remanufacturing
2012	Amy S. Rushing et.al.	USA	Energy price indices and discount factors for life cycle cost analysis – 2012 (Annual Supplement to NIST Handbook 135 and NBS special publication 709)	Supporting the life-cycle costing methodology described in 10 CFR 436A and OMB circular A-94 by updating the energy price projections and discount factors that are described, explained, illustrated in NIST Handbook 135 Also supports private-sector life-cycle cost analysis by updating the energy price indices that are described, explained, and illustrated in NBS Special Publication
2012	M. L. Marceau and L. Bushi	USA	Life cycle assessment for sustainable design of precast concrete commercial buildings in Canada	Presenting the cradle-to-grave LCA of precast concrete commercial buildings with precast structure and precast wall envelope, relative to alternative wall envelope systems
2013	Michael Dale	USA	A comparative analysis of energy costs of photovoltaic, Solar thermal, and Wind electricity generation technologies	Presenting meta-analyses of life-cycle assessments (LCA) of energy costs of three renewable technologies: solar photovoltaic (PV), concentrating solar power (CSP), and wind., The findings suggest that wind energy has the lowest energy costs, followed by CSP and then PV

As a study result, the LCC analysis will enable the utility to:

i. Make decisions for capital and O&M investments based on least life cycle costs
ii. Rank each of the projects based on total cost of ownership
iii. Combine the costing data with the Project Validation and Risk Reduction scores to prioritize the projects
iv. Make more informed decisions, and allow better reporting to key stakeholders

e) The nature and source of data for analysis

It is always found that the outcomes and assessment from the results depends on accuracy of the data. The methodology and technique itself has criticized and also depends on the availability and quality of the appropriate data. It is therefore essential to discuss about the nature, sources, and limitations of the data that one may encounter in empirical analysis. This paper considers the data of a typical thermal power plant managed by the national thermal company (best performance among all the thermal power plants of the country),has been taken to assess the its life cycle cost based on some assumptions and parameters fixed by the Central Electricity Regulatory Commission (CERC) and tariff regime fixed by Ministry of Power, Govt. of India.

On the other hand for making comparative scenarios between the investment options for energy from thermal and solar power plants, the 5 MW typical solar plant is studied and its operations is being managed by the same thermal company. All data taken from the plants, its detailed project report, feasibility report and the project development documents submitted for certified emission reductions (CERs) to United National Framework Convention on Climate Change (UNFCCC).

IV. Research Methodology

a) Life cycle costing as technique

LCC as a technique to calculate and manage costs, especially for large investments has been used to support decision-makers in procurement and investments for decades, with a rigorous focus on private costs. In this methodology, future costs, such as operation and maintenance costs associated with an item, have to be discounted to their present values before adding them to the item's acquisition or procurement cost. Over the years, many formulas have been developed in the area of economics for converting money from one point of time to another. Such formulas are considered indispensable in LCC.

This section presents various aspects of economics considered useful in performing LCC studies. Time-dependent formulas for application in life cycle cost analysis, includes as follows and may vary model to model in consideration.

i. Single Payment Future Worth Formula
ii. Single Payment Present Value Formula
iii. Uniform Periodic Payment Future Amount Formula
iv. Uniform Periodic Payment Present Value Formula
v. Formulas to Calculate Value of Annuity Payments When Annuity's Present and Future Values Are Given

Experience indicates that engineering equipments procured at the lowest cost may not necessarily be that which also costs the least amount of money over its useful life. More specifically, the equipments ownership cost could be quite significant and frequently exceeds the procurement cost. For example, various studies performed by the United States Department of Defense indicate that the maintenance cost over equipment's useful life could be many times the procurement cost. Combining detailed engineering math with robust financial, the following is the general formula of for estimating the total LCC. In general, the flow of methodology to adopt for any general applications is given as:

Determine life cycle cost analysis objectives
Define and scope the system/support system
Choose the effective estimating methodology/ life cycle cost models
Obtain all essential data and make the appropriate inputs to the selected methodology
Conduct sanity checks of outputs and inputs
Conduct essential sensitivity analysis and risk assessment
Formulate life cycle cost analysis results
Document the life cycle cost analysis
Present the life cycle cost analysis as appropriate
Update the life cycle cost analysis as appropriate

However, the general LCC formula may be modeled according to the different issues and priority of the models in considerations.

Life Cycle Cost = Initial capital costs+ Present values of (Life-time operating costs + Life-time maintenance costs + Capital rehabilitation costs +Disposal costs - residual value)

Knowing with certainty the exact costs for the entire life cycle of an asset is, of course, not possible; future costs can only be estimated with varying degrees of confidence. Future costs are usually subject to a level of uncertainty that arises from a variety of factors, including

i. The prediction of the utilization pattern of the asset over time
ii. The nature, scale, and trend of operating costs
iii. The need for and cost of maintenance activities
iv. The impact of inflation
v. The opportunity cost of alternative investments
vi. The prediction of the length of the asset's useful life.

The main goal in assessing total LCC is to generate a reasonable approximation of the costs (consistently derived over all feasible alternatives), not to try and achieve a perfect answer.

c) The management of cash flow

The application of LCC analysis to find that alternative with the lowest LCC figure is important, but there will also likely be organizational cash flow issues that need to be considered. There will always be competing demands for the available cash resources of the organization at any given time. Management of cash flow is simplified if the pattern is predictable over the long term. It is conceivable that the lowest cost solution might not be the best solution from the aggregate cash flow perspective. Thus the technique provides a sound basis for projecting cash requirements which can assist in managing the cash cycles of the organization.

The typical learning from the international projects studies, literatures gives analysis for the life cycle cost analysis to consider not only the "first costs" of a thermal power plant (design and construction expenses) but also long-term costs, including operations and maintenance, cost of employing manpower.

In the pursuit of a cleaner and sustainable environment, solar photovoltaic (PV) power has been established as the fastest growing alternative energy source in the world. This extremely fast growth is brought about, mainly, by government policies and support mechanisms world-wide. Solar PV technology that was once limited to specialized applications and considered very expensive, with low efficiency, is becoming more efficient and affordable. Solar PV promises to be a major contributor of the future global energy mix due to its minimal running costs, zero emissions and steadily declining module and inverter costs. Indian Government and businesses are waking up to the business case of sustainable development. "Green" and socially preferable assets may carry considerably higher price tags than their less sustainable substitutes. Decision makers should now be conscious that price premiums paid for sustainable assets may be largely offset through efficiency gains, cost savings during the product/project lifetime. To achieve the goals of sustainable development, approaches like LCC have to gain wider acceptance over the traditional methods which may cover purchasing cost and all associated costs such as delivery, installation, commissioning and insurance, operating, including utility costs such as fuel and water use and maintenance costs and social and environmental costs. Thus the extensive literature survey and research gaps strongly recommend having a rough picture on the least life cycle cost of the various energy options available to the Indian government.

The next section highlights the application of the technique on the live data of a typical thermal and solar power plant available in the northern part of the country.

d) Estimating the LCC in Indian thermal power plants

The power sector in India is currently in the developing stage, and supports the growth of various sectors, such as infrastructure, manufacturing, commercial enterprises and railways. Therefore, it is a key enabler for India's economic growth, and has historically shown similar growth trends as compared to the economy. For the sake of better investment decisions, the cost components of a typical thermal power situated in the northern part of the country is taken for estimating its total LCC value. The different cost component like capacity charges, variable charges and significant cost of operations and maintenance has been calculated at the present value over the regulatory –life of the plant. All together sums up of NPV give the total value of LCC.

Table 2 : Cost components and Project details of thermal power project

	Cost components of thermal power plant	Tariff components (CERC regulations)block 2009-14	Remarks / Assumptions
A	Capacity charges		
	Return on Equity	15.5	Pre Tax , allowed additional .5 % of project commissioned after April 2009
	Interest on loan capital	As per actual	DER : 70:30 (Re- financing -1/3 benefits retention allowed)
	Depreciation	5.28%	Previously, AAD/ Presently (3.6% to 5.28%)
	Interest of working capital	Based on normative parameters	Coal stock, SFOS, Sales Receivables, O&M Expenses, Maintenance Spares,
	Operations and Maintenance Costs	Based on normative parameters	Rs. Lakhs /MW (13 for MW) / For multiple units -Multiply reduction Factor
	Cost of Secondary Oil	Based on normative parameters	Based on parameters & on PAF
	Special allowance in lieu of Renovation & Modernization	Based on plant life	Added to previously approved gross block to determine future tariff / Now avail beyond the useful life of the plant
B	Energy charges	Based on normative parameters (CERC Regulation)	
	Plant load factor (PLF)		0.85
	Gross station heat rate (500 MW & Above Capacity)		2425
	Specific fuel oil consumption (ml./kWh)		1
	Aux. consumption (500 MW & Steam driven)		6.5

Table 3 : Financial parameters of thermal project

	Financing parameters	Values
C	Equity (Project cost)	30%
	Debt	70%
	Domestic Debt	40%
	Foreign Debt	30%
	Domestic debt interest rate	12.50%
	Foreign debt interest rate	11%
	Repayment period from COD (years)	12

Table 4 : Working capital components

	Working capital	Values
D	Fuel stock for coal (months)	2
	Fuel stock for oil (months)	2
	O&M expenses (month)	1
	O&M spares (%age 0f O&M cost)	20%
	Receivables (months)	2
	Interest on bank finance	13.5%

a) Application of LCC in Solar-PV based plants in India

While it may be argued that coal-based power is the cheapest electricity source, cost of environmental degradation must also be factored into determination of cost of power. Further, future from Europe's declining solar sector. It has attracted investments worth $4.2 billion in 2011, growing nearly seven-fold from 2010.

The Ministry of New and Renewable Energy has set a target of generating 3800 MW of solar power in the Twelfth Five-year Plan and 16 000 MW in the Thirteenth Five-year Plan. The CERC had also noted that the solar PV industry had seen significant cost reductions over the last three years showing a declining trend of over 20-22% on annual basis. It was pointed out that the cost of solar PV crystalline module cost was in the range of 0.6-0.65 USD/Wp during recent years. This remarkable reduction in module prices was due to a combination of factors like economies of scale, technological advances and manufacturing process advances, and over production vis-avis demand. *(MNRE, Govt. of India & CERC official website)* *b) Various cost components and assumptions in typical Solar PV -power plant*

In the pursuit of a cleaner and sustainable environment, solar photovoltaic (PV) power has been established as the fastest growing alternative energy source in the world. This extremely fast growth is brought about, mainly, by government policies and support mechanisms world-wide. Solar PV technology that was once limited to specialized applications and considered very expensive, with low efficiency, is becoming more efficient and affordable. Solar PV promises to be a major contributor of the future global energy mix due to its minimal running costs, zero emissions and steadily declining module and inverter costs. The various cost components has been considered in different way to look up to calculate rough LCC in different countries. The replacement and maintenance cost of the battery has significant cost and present values of the same contributes much in assessing the rough LCC of the project. In the given calculations the same has not been considered.

As per the detailed report of the plant, the total energy available to the grid yearly as per METEONORM data =7263088.94 kWhr (7.26 Million Units). On estimating the LCC of the solar power plant, it is assumed that no maintenance and replacement cost is invested over the period. Simply, the capital and operating cost for the plants have been considered.

V. Applications & Results Discussions

The data analyzed in MS Excel Ver. 2010. The empirical results includes analysis using graphs representations, tables outputs, have been laid down in five sub-sections. Sub-section *(a),* there is a preliminary analysis using graphs analysis. Sub-section *(b) Defining and selection of time period of the study in both the case of thermal power plant and solar power plant c)* Net present value of the total cost followed by total life cycle costing.

a) Comparison of LCC values

After making relevant assumptions in both the case of LCC application estimations, the total LCC for a solar power plant is approximately 2.5 less than that of a thermal power plant of equivalent capacity i.e. 1000 MW. This lesser factor is high on the assumptions that no maintenance and replacement cost is invested over the period. The above LCC of solar is estimated and extended at the capacity of 1000 MW for the comparison purpose.

Table 5 : Solar PV module-cost components

Cost components particulars of a typical 5 MW Solar PV plant	Capital cost for Solar PV Project (Rs. Lakhs/ MW)	% Total cost
PV modules	344.5	43%
Land cost	16.8	2%
Civil & general works	94.5	12%
Mounting structures	105	13%
Power conditioning units	60	7%
Evacuation cost	105	13%
Pre-operative & Interest during construction (IDC)	80	10%
Total capital cost	805	100%
# Operating cost	58.15	-

Remarks : Not considering replacement and renovation cost, # as per the plant detailed feasibility report

Table 6 : LCC of Coal based power plant

Sl. no.	Cost components	Sub-Components	Rs. Cr.
1.	Capital cost		6,000
2.	Running costs	O&M cost	1,072
		Coal cost	14,519
		Oil cost	142
		Int. on term loan	1,385
		Int. on working capital	327
3.	*Terminal value (10% SV)	-	600
	Total LCC value	-	22,846

** Not On Basis Of Actual Definition Of The Terminal Value (Not Considering To Carbon Emission Reduction)*

Table 7 : LCC of Solar based power plant

Sr. no.	Cost description	Rs.
1.	Capital cost	80,50
2.	Operating cost	5,80
3.	Total cost	86,30
4.	Total LCC value	8,630 (Rs. Cr.)

The assumptions in the applications have very important and the accuracy of LCC analysis diminishes as it predicts further into the future. While the technique is little time consuming as one has to have fair idea about the tariff structure of the technology used. During the literature survey, it is found that for making the analysis at the micro levels, the sensitivity analysis may be carried out using the few software applications available free of the cost. For assessing the close values of total LCC, the model may be incorporated and simulation work can be done to have better picture on the application area.

VI. Conclusion and Limitations

Using and application of LCC could increase propagation of knowledge for taking effective decision towards sustainable energy systems and help enable governments to enact long-term energy policies. The importance and benefits of such methodology in using sustainable energy systems are clear but creating a policy framework to achieve those goals remains a challenge for all countries. These challenges may include the complex tariff structure and cost components and lack of manpower to handle the new technologies. The limitation of the paper is that the accuracy of LCC analysis diminishes as it predicts further into the future and is time consuming. However for projecting and comparing the nearest LCC values, one can have the simulation based approach, but again LCC is an expensive concept, not appropriate for all applications.

In case of power from Solar energy, sometimes the direct normal irradiance in the prominent states has been questioned which is dominating factor for estimating the generation cost from the module. Governments view the energy industry as a key player in managing the technological and behavioural change needed to realize sustainable energy systems. By providing information about evolving energy options, the cost of energy, the benefits of new technologies, and the need to foster energy efficiency, the clear cut investment approach in alternative energy resources can support this transformation.

Lastly, this paper may be useful for development of the draft guidelines based on the more comparatively study. These guidelines define LCCA, explain their relevance to the plants, projects, and instruct plants /project teams on their implementation to adopt least energy cost and further this may provide technical specifications for preparing LCCA studies in India. But it will always be restricted to the assumptions taken for the LCC applications.

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