Distribution Utilities Forum

COST OF SUPPLY OF ELECTRICITY

A Systemic Review and Way Forward for Indian DISCOMs

Raghav Pachouri | Balaji Raparthi | Ashish Sharma

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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Creating Innovative Solutions for a Sustainable Future

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We thank Shakti Sustainable Energy Foundation (SSEF) for supporting this initiative, and Mr Vivek Sen, Associate Director (Clean Power Program), Ms Gayatri Ramanathan, Associate Director (Projects), for the interaction and their inputs during the course of this study as well as review of the final report.

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About the Authors

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MESSAGE FROM

GIREESH B PRADHAN HONORARY CHAIRMAN, DUF

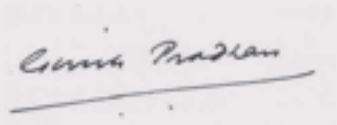
At the tail end of retail supply chain, DISCOMs are crucial to not only delivering last mile connectivity to the end-consumer but also in meeting the Government's vision of reflecting true and prudent cost in electricity tariff.

Determination of Cost of Supply is an integral part of the tariff fixation process as it helps in determining the cost imposed by a consumer category to avail supply from the system. So far, most of the Indian utilities are following simplified/average approach to estimate the cost of supply. To move from simplified or average cost computation method to an embedded cost, or better, to the marginal cost method, utilities require a large volume of voltage and consumer-category wise data, availability of which is one of the biggest challenges faced by Indian DISCOMs.

I am happy to note that the meeting witnessed robust discussions with DISCOMs airing their challenges/constraints in estimating CoS using the embedded approach and coming forward with suggestions that can enable them to adopt ECoS by improved data availability, IT infrastructure, and metering at various levels.

Discussions at the meeting along with responses from preliminary discussions with DISCOMs on the subject and the suggested way forward have been captured in this report.

I trust that you will find the report to be an interesting read.



Gireesh B Pradhan

MESSAGE FROM
DR AJAY MATHUR, DIRECTOR GENERAL, TERI

The Energy and Resources Institute (TERI) and the Shakti Sustainable Energy Foundation (SSEF) have constituted the Distribution Utilities Forum (DUF), so as to enhance and accelerate sharing and learning amongst distribution utilities from each other's experiences. This Forum is a platform for DISCOMs to come together to discuss issues of importance to them in the electricity distribution sector and to deliberate on ways to achieve their common goals. The Forum focussed on Rural Electrification and on Impact of Solar Rooftop on DISCOMs as its first two themes. The Cost of Supply of Electricity for Indian DISCOMs was the third theme selected for study, and is the subject of this Report.

The DISCOMs, during the Forum meeting and during one-on-one interactions, shared both their current approaches for estimating the Cost of Supply as well as their views regarding alternate approaches for estimating it. They also brought out the issues and challenges in the more-realistic estimation of the Cost of Supply. The apportioning of losses and of asset costs to various consumer categories, at different voltage levels, emerged as the key challenge in this regard.

This Report, based on discussions, literature review, and analyses by TERI, suggests that the Embedded Cost of Supply (ECoS) approach is best suited to Indian DISCOMs based on their needs, circumstances, and data availability. An additional advantage is that the ECoS approach is widely followed in developed and developing countries, and therefore has a large corpus of experiences and learning to draw upon. It captures voltage level wise asset costs and losses and makes it possible to compute realistic cost of supply for various consumer categories. Finally, the Report also suggests a practical way forward to implement an ECoS-based approach to estimate the Cost of Supply. We suggest that in the absence of metered data and segregated network costs, simulation studies for estimation of voltage level wise losses, load research for assessing demand cost, and compilation of data in respect of assets would help the DISCOMs to graduate, over time, to the full-fledged application of the ECoS approach.

Dr Ajay Mathur

MESSAGE FROM
CHINMAYA ACHARYA, INTERIM CEO, SHAKTI SUSTAINABLE ENERGY FOUNDATION

As you are aware, Shakti Sustainable Energy Foundation and The Energy and Resources Institute launched the Distribution Utilities Forum together, last year, to provide Indian power distribution companies with an independent platform where they can meet with their peers and share perspectives on the issues and challenges that confront the sector and discuss potential solutions to these problems.

In June 2019, the Forum held a meeting on the Cost of Supply and focused on the issues faced by DISCOMs in calculating Cost of Supply and how to progressively move towards Embedded Cost of Supply method. Participating DISCOMs highlighted multiple challenges/issues that must be addressed for estimating the final cost of supply of each unit of electricity using the embedded cost approach.

This report flows out of our initial findings, discussions with DISCOMs at the Forum along with the suggested way forward.

I trust you will find this report to your interest.

Chinmaya Acharya

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ABBREVIATIONS

ACoS	Average Cost of Supply
AERC	Assam Electricity Regulatory Commission
APDCL	Assam Power Distribution Company Limited
APERC	Andhra Pradesh Electricity Regulatory Commission
APTEL	Appellate Tribunal of Electricity
ARR	Aggregate Revenue Requirement
AT&C	Aggregate Technical and Commercial
BESCOM	Bangalore Electricity Supply Company Limited
BRPL	BSES Rajdhani Power Limited
CoS	Cost of Supply
CPD	Coincidental Peak Demand
DBT	Direct Benefit Transfer
DBTE	Direct Benefit Transfer of Electricity
DISCOM	Distribution Company
DT	Distribution Transformer
DUF	Distribution Utilities Forum
EA	Electricity Act
ECoS	Embedded Cost of Supply
EHT	Extra High Tension
ERP	Enterprise Resource Planning
GDP	Gross Domestic Product
HPERC	Himachal Pradesh Electricity Regulatory Commission
HT	High Tension
ISTS	Inter-State Transmission System
JBVNL	Jharkhand Bijli Vitran Nigam Limited
JKPDD	Jammu and Kashmir Power Development Department
LT	Low Tension
MCoS	Marginal Cost of Supply
MERC	Maharashtra Electricity Regulatory Commission
MPMKVVCL	Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Limited
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MU	Million Units
MYT	Multi-Year Tariff
NCPD	Non-Coincidental Peak Demand
NEP	National Electricity Policy
O&M	Operation and Maintenance
POWERGRID	Power Grid Corporation of India Limited
POSOCO	Power System Operation Corporation
PSERC	Punjab State Electricity Regulatory Commission
PSPCL	Punjab State Power Corporation Limited
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
ROE	Return on Equity
SERC	State Electricity Regulatory Commission
SLDC	State Load Despatch Centre
SSEF	Shakti Sustainable Energy Foundation
TP	Tariff Policy
TSSPDCL	Telangana State Southern Power Distribution Company Limited
UDAY	Ujjwal DISCOM Assurance Yojana
UDAN	Ude Desh ka Aam Nagrik
UPCL	Uttaranchal Power Corporation Limited
UT	Union Territory
VCoS	Voltage-wise Cost of Supply
WBERC	West Bengal Electricity Regulatory Commission
WBSEDCL	West Bengal State Electricity Distribution Company Limited

EXECUTIVE

SUMMARY

Cost of Supply is the cost incurred by the utility to supply one unit of electricity at its consumer's metering point and is a crucial part of the tariff setting process. The purpose of computation of Cost of Supply (CoS) is to apportion all costs required to serve consumers of different categories in a fair and an equitable manner giving proper price signals and identifying subsidy/cross-subsidy among consumer categories for developing an appropriate policy and a regulatory way forward. In India, industrial and commercial consumers are generally charged a higher electricity tariff in order to subsidize agricultural and domestic consumers, who are charged a tariff which is lower than the actual CoS.

Worldwide, most common approaches to calculate CoS are Embedded Cost of Supply (ECoS) approach and Incremental/Marginal Cost of Supply (MCoS) approach. The difference between the two approaches lies in the treatment of the costs. The Embedded Cost approach uses the accounting costs on the books of accounts of the utility, whereas the Marginal Cost approach estimates the resource costs of the utility in providing each additional unit of power to its consumer base. As of now, in India, no specific mandates are there in any act or policy – Electricity Act, 2003, National Electricity Policy and Tariff Policy – to follow a particular methodology to calculate CoS of electricity. Furthermore, both Embedded and Marginal Cost approaches demand a large quantum of reliable data, which is so far not available with almost all the Indian DISCOMs. Majority of DISCOMs, therefore, opt for Simplified/Average Cost of Supply (ACoS) approach to estimate voltage-wise CoS. APTEL in their Appeal No. 102 of 2010 advised initiating a simple formulation for computation of voltage-wise CoS. In this approach, it is adequate to determine the voltage-wise CoS taking into account the major cost elements which would be applicable to all the categories of consumers connected to the same voltage level. Different SERCs are using different factors and assumptions in computing the CoS using the simplified approach. Though most of the developed nations are adopting either a Marginal Cost approach or an Embedded Cost approach to calculate the CoS, 90% of DISCOMs in India are still following the simplified approach using average cost at system level or at various voltage levels primarily due to lack of reliable and accurate granular data.

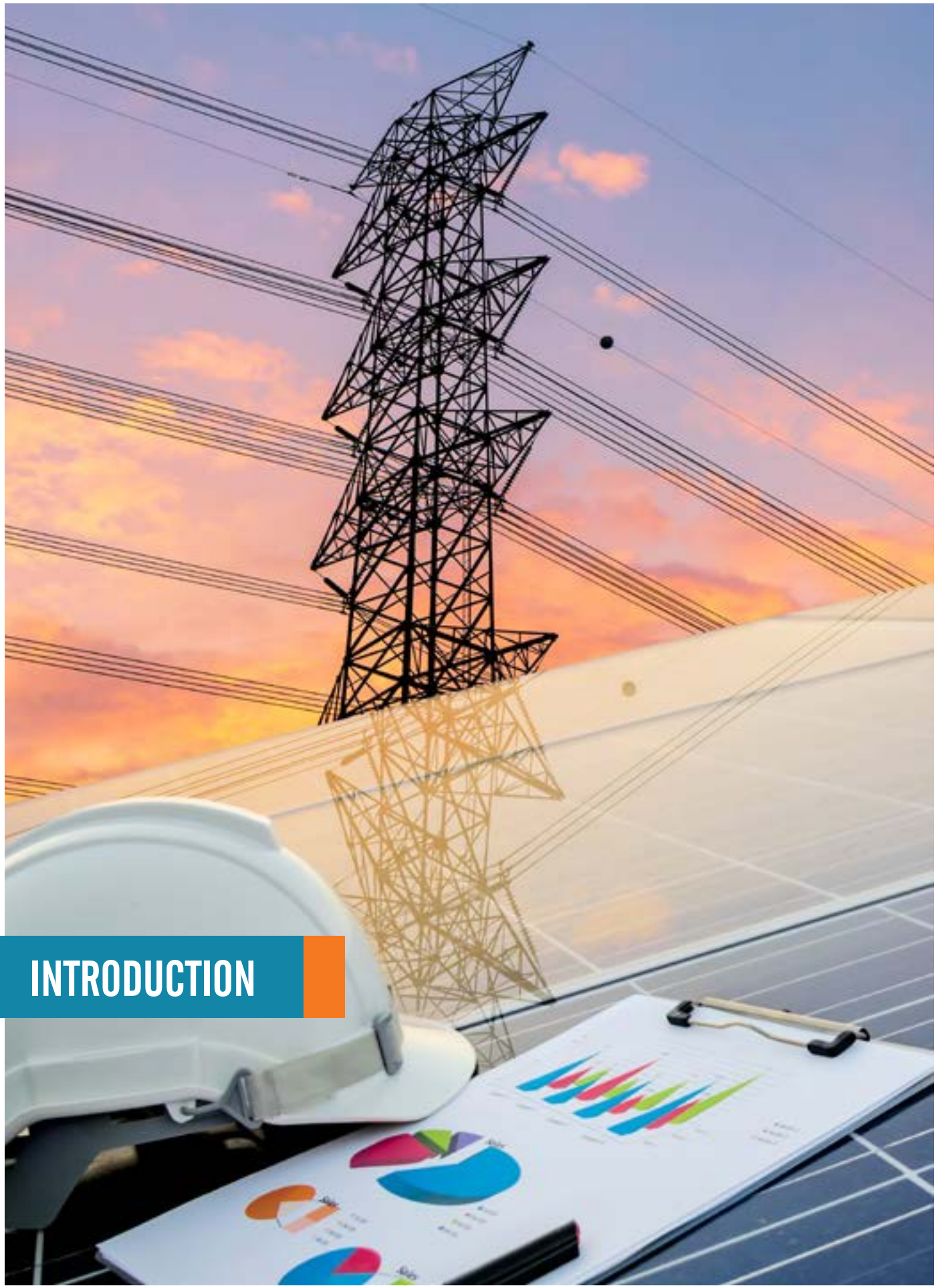
It is essential to allocate various costs – demand, energy, and customers – judiciously among different consumer categories, based on different factors such as supply voltage level, load factor, time of usage, distribution losses, etc., for true and prudent cost reflection among various consumer categories. The major disadvantage associated with the simplified approach is that the CoS value computed is common for all voltage levels and consumer categories. The tariff specified for different consumer categories with the common CoS computed based on the simplified approach, doesn't provide prudent cost comparisons. The Embedded Cost approach is, therefore, recommended for DISCOMs in India to estimate voltage-wise/category-wise cost of supply in order to bring tariff rationalization.

The primary advantage of ECoS is that costs embedded among different consumer categories across various voltage levels and their corresponding allocation factors can be worked out based on granular data that is available with the utility. The ECoS approach requires data pertaining to power purchase cost, voltage-wise/category-wise transmission and distribution assets cost, assets (including line lengths, voltage-wise transformer cost, voltage-wise substation cost, etc.), number of consumers, energy sales,

connected load, load research data (system level and feeder level load data) and technical and commercial loss data, etc. The availability of the aforementioned data on a year-to-year basis would help in building a credible data base for computation using the Embedded Cost of Supply approach.

During the discussions with DISCOMs in the country, we found that non-availability of granular data is a major challenge due to non-availability of feeder/DT meters, absence of load research data, limited implementation of Enterprise Resource Planning (ERP), in moving from simplified to Embedded Cost approach. The feeder level load research becomes essential to gather voltage-wise/ consumer-wise data, essentially required for the proper estimation of ECoS.

In order to address the issues and challenges, suggestions from the utilities were discussed during the 4th Distribution Utilities Forum (DUF) meeting on 10 June 2019. Some important propositions that emerged include the need for immediate attention of state governments and SERCs for achieving 100% feeder, DT and consumer metering in a time-bound manner, proper implementation of ERP system and periodic load research studies. Along with the aforementioned propositions, an alternative for computing ECoS in the absence of granular data during the transition from the simplified approach to a full-fledged ECoS approach has also been recommended in this report. Additionally, consumer awareness with regard to the quantum of subsidies received from the government is also considered necessary. One of the possible ways of doing this is to mention the actual CoS in the consumers' bills, for all the consumers – subsidizing as well as subsidized consumers, along with subsidies given or received.



INTRODUCTION

Cost of supply (CoS) is the cost incurred by the utility to supply one unit of electricity at its consumer's metering point. It provides detailed cost information that is functionalized, classified, and allocated to respective customer classes for a particular utility. Allocating costs judiciously to the respective consumer categories depends upon various factors such as level of supply voltage, power factor, load factor, time of usage, distribution losses, etc. Therefore, CoS varies across various categories connected at different voltage levels, depending on the aforementioned factors.

Determination of CoS is an integral part of the tariff fixation process as it helps in determining the cost imposed by a particular consumer category to avail supply from the system and the level of cross- subsidy provided to different consumer categories. As per Section 61(g) of the Electricity Act, 2003, "*The Appropriate Commission shall, subject to the provisions of this Act, specify the terms and conditions for the determination of tariff that progressively reflects the cost of supply of electricity and also, reduces cross-subsidies in the manner specified by the Appropriate Commission*". In furtherance to this, Tariff Policy 2006 provided that Appropriate Commission would notify roadmap within six months with a target that latest by the end of year 2010–2011 tariffs are within ± 20 % of the average cost of supply. The road map would also have intermediate milestones, based on the approach of a gradual reduction in cross-subsidy. Further, the draft amendment in Tariff Policy (TP) 2018 proposed that the regulators bring down cross-subsidy and ensure that tariff for a particular consumer category is brought within ± 20% of the average cost of supply by 1 April 2019. While the need for determining an efficient and a prudent cost of supply of electricity and its recovery from various consumer categories to ensure financial sustainability of the distribution utilities requires no emphasis, it must be ensured that any such process does not result in tariff shocks to consumer categories.

There are different approaches for computing the CoS depending on various cost allocations, supply voltage levels and consumption patterns of different consumer categories. Most commonly used approaches for estimation of CoS are Simplified (average) Cost approach, Embedded Cost approach and Marginal Cost (incremental cost) approach. In simplified approach, the CoS is computed simply by taking ratio of total cost incurred to serve consumers to the total electricity injected in to the system. This approach gives a simple average cost that is incurred to serve consumers but fails to present the true cost incurred to supply electricity to various consumer categories at different voltage levels. In the Embedded Cost approach, the historical or accounting costs that make up a utility's revenue requirements are allocated to different consumer categories. The Marginal Cost approach is based on the concept that the cost of procuring one additional unit of electricity with other conditions remain the same. These methodologies are discussed in Section 3 of this report.

The selection of the approach for allocation of these costs primarily depends upon the availability of data and operating conditions of the utility, which may vary from utility to utility. Both Embedded and Marginal Cost approaches require a large volume of reliable granular data which is difficult to obtain in case of majority of Indian DISCOMs. Therefore, most DISCOMs opt for 'simplified approach' or 'average cost of supply' to estimate the cost of supply. In this approach, it would be adequate to determine the voltage-wise CoS, taking into account the power purchase cost and other major cost elements which would be applicable to all the categories of consumers connected to the same voltage level. Different SERCs have suggested different factors and assumptions to undertake the exercise of calculating the CoS to DISCOMs.

The study undertaken in the previously mentioned backdrop aims to present those approaches adopted by the DISCOMs in India to determine their CoS, identify challenges faced by them in estimating category-wise/ voltage-wise CoS through ECoS approach and to present way forward to address these challenges.

LEGAL & POLICY PROVISIONS AND REGULATORY APPROACHES IN RESPECT OF COST OF SUPPLY

This section presents legal and policy provisions and regulatory approaches pertaining to Cost of Supply. The relevant provisions under the Electricity Act, 2003, various policies and directions have been briefly presented . It is pertinent to mention here that principles guiding determination of tariff and cross-subsidies have been stipulated in the Electricity Act, 2003 (hereinafter referred to as Act), [1] Tariff Policy (TP),[2] and National Electricity Policy (NEP) [3] (see Figure 1). However, the Electricty Act 2003, policies and regulations do not mandate any specific methodology to be followed for calculating CoS of electricity.

Section 61(g) of the Act stipulates that the Appropriate Commission(s) while specifying the terms and conditions for the determination of tariff shall be guided by the objective that the tariff progressively reflects the efficient and prudent cost of supply of electricity. On 30 May 2018,

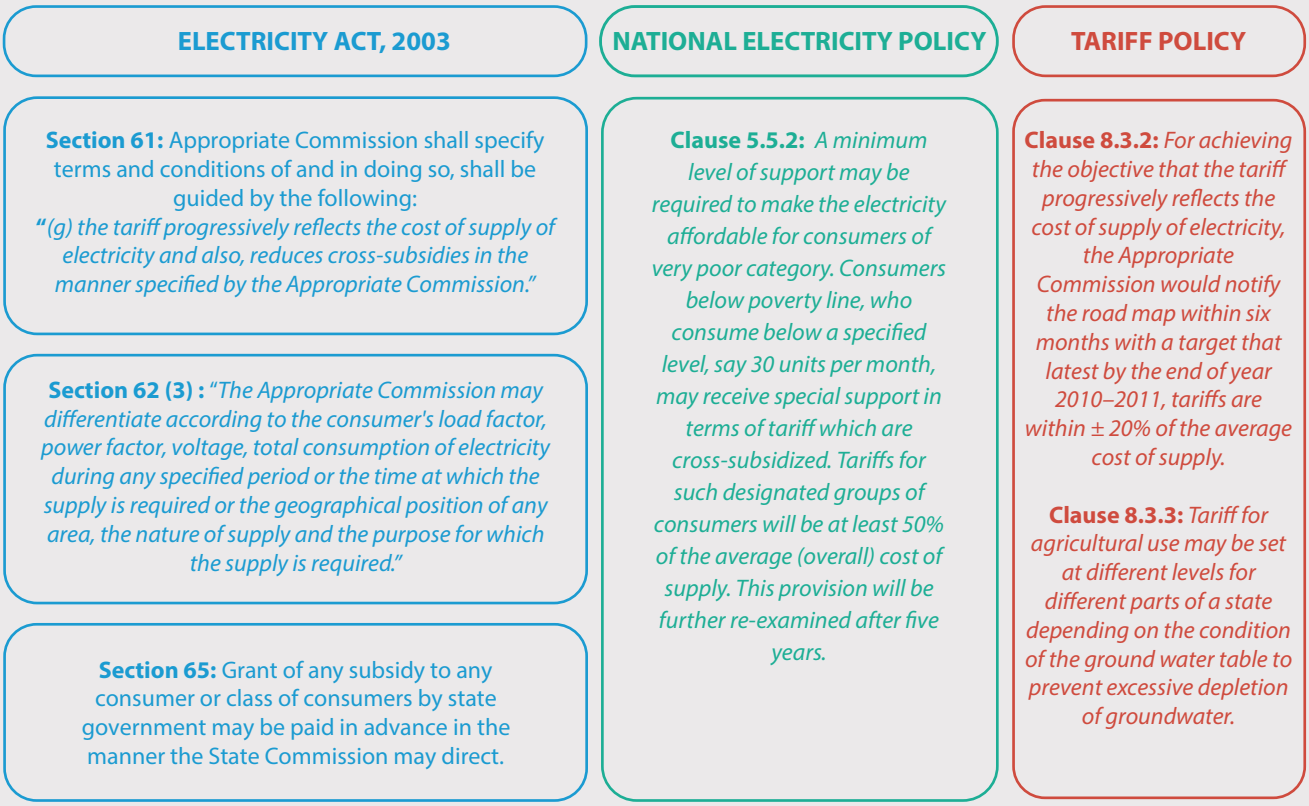


Figure 1: Legislative and regulatory framework of CoS

[1] Ministry of Law and Justice. 2003. The Electricity Act, 2003, Part VII. Details available at http://www.cercind.gov.in/Act-with-amendment.pdf, last accessed on 26 March 2020

[2] The Gazette of India. 2006. Resolution: Tariff Policy; Section 8.3, p. 17. New Delhi: Ministry of Power, Government of India. Details available at https://powermin.nic.in/sites/default/files/uploads/Tariff_Policy.pdf, last accessed on 26 March 2020

[3] The Gazette of India. 2005. National Electricity Policy. New Delhi: Ministry of Power, Government of India. Details available at https://powermin.nic.in/en/content/national-electricity-policy, last accessed on 26 March 2020

Ministry of Power proposed an amendment to the Tariff Policy 2016[4] to address the emerging trends in the power sector and to carry forward distribution sector reforms. The proposed amendments target to address the challenges of an evolving power sector and in the direction of reforms being contemplated by the government. The draft Tariff Policy 2018 proposed that the Appropriate Commission(s) shall endeavour to determine the cost of supply for each category and sub-category of consumers. Also, sub-categorization for each category will be based on 'supply voltage level' (LT/HT) to enable reflection of the actual cost of supply in tariffs. The LT domestic sub-category may further contain consumption-based slabs in addition to a slab for economically weaker sections of society as mentioned in Section 8.3 of the draft Tariff Policy.

In September 2018, the Ministry of Power proposed a set of amendments to the Electricity Act 2003, which is an extension to the draft amendments tabled in the Lok Sabha in 2014. The amendments proposed include reframing existing provisions of the Act that have not been achieved till date. For example, the amendments include a three-year phase-out of cross-subsidies with a 20% cap and propose a direct transfer of subsidies to end-users through Direct Benefit Transfer (DBT) and a mandate for the DISCOMs to supply quality power.

Since the enactment of the Electricity Act, 2003, several disputes have arisen over the issue of cross-subsidies in tariff and in some cases, consumers approached Appellate Tribunal of Electricity (APTEL) citing non-compliance of provisions of the Act, Tariff Policy, and National Electricity Policy. The judgements by APTEL in these appeals provide further clarity in regard to the methodology to be followed for computing CoS. APTEL has also not accepted the plea of SERCs that calculation of category-wise cost of supply may not always be possible. In Appeal No. 102 of 2010, APTEL[5] spelt out a transitionary approach rather than waiting indefinitely for the availability of entire data as under:

> **"In our opinion, it will not be prudent to wait indefinitely for availability of the entire data and it would be advisable to initiate a simple formulation which could take into account the major cost elements. There is no need to make a distinction between the distribution charges of identical consumers connected at different nodes in the distribution network. It would be adequate to determine the voltage-wise cost of supply taking into account the major cost element which would be applicable to all the categories of consumers connected to the same voltage level at different locations in the distribution system."**

Taking into account the difficulties faced by the state commissions, APTEL suggested that those state commissions which do not have granular data as previously mentioned can opt for a 'simplified approach' in order to calculate the voltage-wise/category-wise CoS.

[4] Government of India. 2018. Proposed amendments in Tariff Policy, 2016. New Delhi: Ministry of Power, Government of India. Details available at https://powermin.nic.in/sites/default/files/webform/notices/Proposed_ame ndments_in_Tariff_Policy_0.pdf, last accessed on 26 March 2020

[5] Appellate Tribunal for Electricity. 2011. Appeal Nos. 102, 103 & 112 of 2010; p. 63. Appellate Tribunal for Electricity (Appellate Jurisdiction). Details available at http://aptel.gov.in/judgements/30.05.2011%20%20102,%20103%20&%20112%20of%202010.pdf, last accessed on 26 March 2020

COST OF SUPPLY: COMPUTATIONAL APPROACHES

The most commonly used approach for computation of CoS in India is the simplified approach based on the average cost of supply; many utilities have attempted to compute the voltage-wise CoS as well. Since losses at high voltage levels are lower than losses at lower voltage levels, the CoS at higher voltage tends to be lower than cost of supply to consumers at a lower voltage. Also, while high-voltage category consumers utilize high voltage assets, the low-voltage category consumers also utilize the high voltage assets in addition to specific low voltage assets. Though there is a need for appropriately determining the cost of supply of electricity and its recovery from various consumer categories to ensure financial sustainability of the DISCOMs, it must be ensured that such a process does not result in tariff shocks to consumer categories. Approaches, described in the following sections could be followed to determine the cost of supply, depending on the availability of data, consumer mix, etc.

3.1 Simplified Approach

Different State Electricity Regulatory Commissions (SERCs) have been using different factors and assumptions while carrying out the exercise of calculating the cost of supply using the simplified approach. Figure 2 broadly depicts the steps involved in the calculation of category-wise CoS using this approach.

3.1.1 Average Cost of Supply

ACoS is the average cost imposed by all consumers on the distribution system irrespective of their individual cost of supply. ACoS is simply the ratio of the total cost for providing power supply to the end consumer to total electricity input/purchased for the total number of consumers.

3.1.2 Voltage-wise Cost of Supply

VCoS is the voltage-wise average cost imposed by all consumers on the system irrespective of their individual cost of supply. VCoS is computed in the same manner as done in the simplified approach but the computations

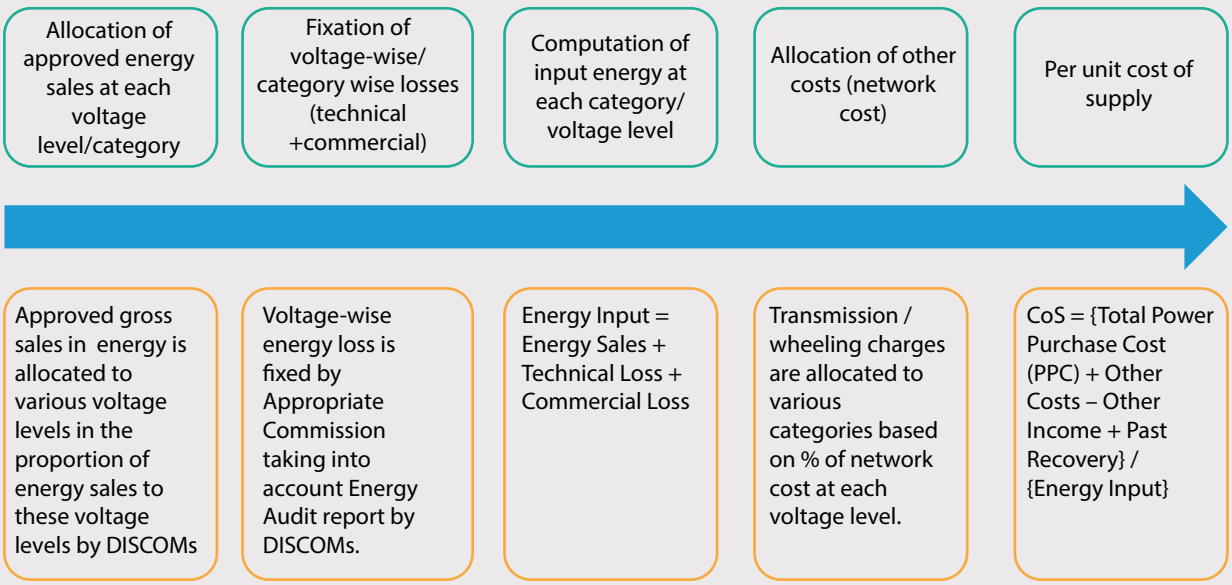


Figure 2: Steps involved in Simplified Approach

are voltage-level wise. The input energy and total cost are computed for individual voltage level and VCoS is computed by taking the ratio of these two components. VCoS gives an idea of the cost of supply at the individual voltage level. The estimation of losses at various voltage levels requires proper metering infrastructure and system flow studies.

3.2 Embedded Cost Approach

The Embedded Cost approach allows allocation of historical/accounting costs to various classes of customers and provides cost information that is functionalized, classified, and attributed to various customer classes for a given utility. In such an analysis, revenue requirement is allocated to different consumer categories to set their respective tariffs, based on various allocation factors. The factors can be the contribution of each class to the peak demand, the energy purchased by each class as a percentage of total sales, the number of consumers in the class, etc. The Embedded Cost approach requires detailed data in respect of the following for the calculation of category-wise CoS:

1) Power purchase cost data from various sources and time frames
2) Transmission cost data
3) Distribution cost data
4) Voltage-wise/Category-wise details:
   - » Voltage-wise assets (including of lines, transformers and substations, etc.)
   - » Number of consumers
   - » Energy sales
   - » Connected load
   - » Weightage factors for allocation of customer-related costs
5) Voltage-wise loss levels
6) Load research data of sample predominant feeders among different consumer categories

The Embedded Cost approach for calculating the CoS can be divided into three steps (see Figure 3):

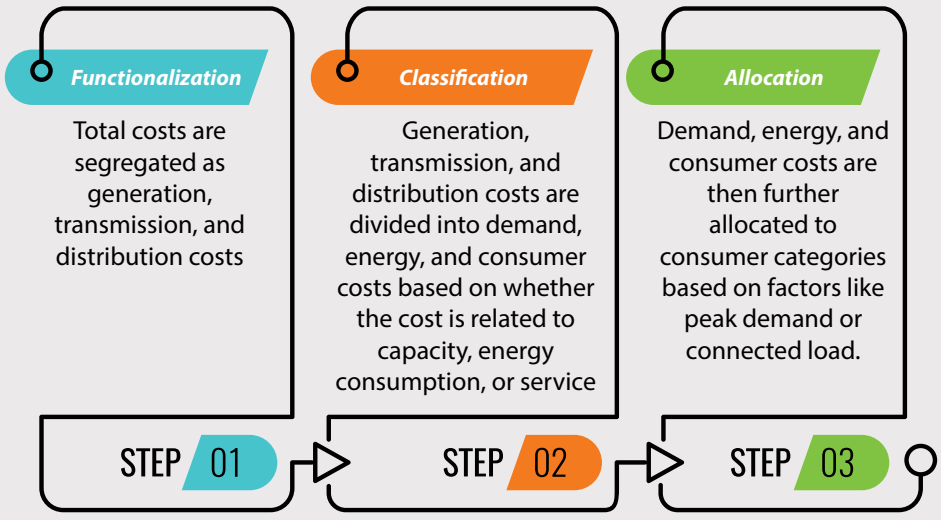


Figure 3: Steps to allocate the costs in Embedded Cost Approach

Step 1:

Functionalization is the process of dividing the total cost of a distribution utility on the basis of functions performed, such as power purchase, transmission, and distribution. This facilitates determination of function-wise cost incurred in supplying power to a consumer category.

Step 2:

Each of the functionalized cost is further classified based on their fundamental nature as follows:

» **Demand-related costs**: Demand-related costs are generally of fixed nature. Such costs are related to capacity creation and hence are inclusive of costs, such as interest on capital borrowing, depreciation, income tax, and return on equity.

» **Energy-related costs**: Energy-related costs depend on the quantum of electricity consumption of the users. Such costs are generally termed as variable costs and include costs mainly related to fuel consumed.

» **Customer-related costs**: Customer-related costs are directly related to the services provided to the customers. These vary according to the number of customers served in each category. Though fixed in nature, these costs are associated with metering, service connection, and customer-related activities. They include operating expenses associated with meter reading, billing, and accounting.

Load research is conducted in order to arrive at the contribution of each consumer category to peak demand to arrive at class load factor, coincident factor, estimation of coincident peak (see Figure 4) and non-coincident peak demand of individual categories.

Step 3:

The costs, once classified, are allocated to the consumer categories. The objective is to allocate costs to the respective customer category in relation to the cost impact imposed by the consumer category on the power system. The different types of cost – demand, energy, and consumer – as classified in the previous step are allocated to the consumer categories according to the following principles:

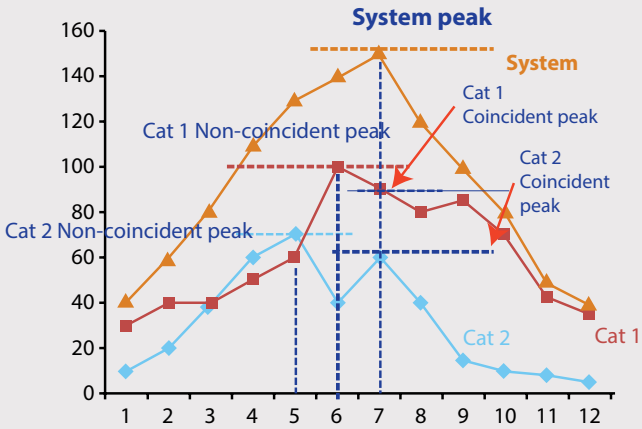


Figure 4: Illustration of category contribution in system peak

» **Allocation of demand costs**: The demand costs of all the three functions such as generation, transmission, and distribution are allocated to the consumer categories on the basis of the coincident peak demand or peak demand.

» **Allocation of energy costs**: The energy cost component of power purchase is allocated to the categories on the basis of the ratio of consumption of the category to the total consumption of the utility based on the status of power availability – surplus/ deficit in the state.

» **Allocation of customer costs**: Customer-related costs of all the three functions are allocated to the consumer categories on the basis of the ratio of number of consumers in a category to the total consumers of the utility or sanctioned load, or it is done on the basis of contract demand.

3.3 Marginal Cost Approach

In case of Embedded Cost approach, the historical or accounting costs that make up a utility's revenue requirement is allocated to different consumer categories. While the Marginal Cost approach is based on the concept that the amount the consumers are willing to pay for the last unit of a good or service equals the cost of producing the last unit, that is, its marginal cost. In a competitive market, this equilibrium is achieved as each firm expands its output until its marginal cost equals the price established by the forces of supply and demand.[6]

The Marginal Cost approach seeks to determine incremental (marginal) change in total costs imposed on the system by a change in output (whether measured by kWh, customer group or other relevant cost driver). This is accomplished by the following:

» Determining the level of revenue realization, if marginal costs were charged as prices to each class.

» Closing any gap in a way that minimizes the distortions in consumption resulting in any necessary price deviations from the marginal cost.

It may be further noted that although the demand for electricity increases in small steps with increase in the consumption of existing consumers/addition of consumers, capacity addition always occurs in significant steps in the form of capacity of generating stations, transmission infrastructure, and distribution infrastructure.

It is important to note that the difference between an embedded cost of service approach and a marginal cost of service approach lies in their different concepts of cost. The embedded cost study uses the accounting costs on the company's books (asset register) as the basis for the study. In contrast, the marginal cost study estimates the resource costs of the utility in providing the last unit of production. Once 'cost' is determined, methodology for allocating costs among services, jurisdictions and customers are largely the same. Merits and demerits of both the approaches are presented in Table 1.

Table 1: Comparison between Embedded Cost and Marginal Cost approaches, TERI Analysis

	Merits	Demerits
Embedded Cost Approach	Embedded costs and allocation factors can be measured based on data that is recorded in the books of the utility. Thus, the data is readily available and verifiable as well as the historic cost of past year ensures that the costs are realistic.	This is not forward looking as it uses historic cost. It does not account for the inflation and thus, does not reflect the true economic cost of the power delivered to the consumer.
Marginal Cost Approach	Marginal cost represents the economic cost that the utility has to incur in order to provide consumers with an additional unit of electricity. As a result, marginal cost based tariffs provide efficient price signals to consumers. The method also has an advantage of looking into the future for projecting the costs.	This requires wide range of data, which is not readily available. Moreover, when the forecasted values are used, the results may not be very accurate.

[6] The Energy and Resources Institute (TERI) and Dhiya Consulting Private Limited. 2010. Assessment of cost of service for supply to agricultural consumers and methods to reduce cross subsidy for agriculture category. http://www.forumofregulators.gov.in/Data/Reports/TERI_Report_FOIR.pdf, last accessed on 26 March 2020

Both the approaches, Marginal and Embedded, demand a large quantum of reliable data which is quite difficult to collect under the present state of operation among Indian distribution utilities.

3.4 International Practices

The cost of supply approaches followed by a few developed and developing countries are presented in brief in this section. Literature review brings out that cross-subsidies are an integral part of tariff determination in most of the developing countries. Therefore, the tariff may not represent a true reflection of CoS in those countries due to the economic differences among different consumer groups. Table 2 presents salient macro indicators relevant to the context in the chosen countries.

due to economic differences among different consumer groups, the computation of category-wise CoS using more granular approach helps utilities to determine the cross-subsidy more realistically, which in turn can be used in preparing the road map for progressive reduction in cross-subsidy and consumer awareness initiatives. Philippines and South Africa compute the CoS using ECoS and the same is shown in the electricity bill of the consumers to make them aware of the actual cost of electricity being supplied to them. More advanced methodology such as Marginal Cost of Supply is being successfully used in computation of cost of supply in most developed countries. The CoS methodologies followed in Australia, New Zealand, South Africa, and Philippines were studied to understand information and infrastructure requirements to implement advanced methodologies,

Table 2: Cost of Supply – macro indicators of chosen international countries[7]

Indicators	New Zealand	Australia	South Africa	Philippines	India
Population (million)	4.9	24.9	57.80	106.6	1,353
GDP per capita (current US$)	41,966	57,305	6,374	3,103	2,016
Electric power consumption (kWh/capita, 2014)	9,026	10,071	4,198	696	805
CoS calculation methodology	Marginal CoS	Marginal CoS	Embedded CoS	Embedded CoS	Simplified[8]

Various Cost of Supply approaches have been described in the previous section. Different countries follow different CoS approaches and methodologies based on availability of data and infrastructure required for the collection of requisite data. Even though cross-subsidy in tariff determination is unavoidable for many countries such as Embedded and Marginal CoS in computation of the CoS in India. The CoS approaches followed in these countries are given in Annexure 1.

3.5 Indian Scenario

In the recent past, the Indian power sector has seen significant change in terms of digitization. There are individual portals for various data items pertaining to the power sector in India. From Restructured Accelerated

[7] The World Bank. 2014. Electric power consumption (kWh per capita). IEA Statistics © OECD/IEA 2014. Details available at https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?end=2018&start=2018&view=bar, last accessed on 26 March 2020

[8] 32 out of 36 states and UTs are following simplified CoS approach

Power Development and Reforms Programme (R-APDRP) to Ujjwal DISCOM Assurance Yojana (UDAY) scheme, there is a significant fund allocation for IT implementation in each scheme for rural and urban areas. Transparency in publication of performance parameters of utilities has increased. Though Indian power sector has made significant progress in building its IT infrastructure, many distribution companies are still not in a position to accurately measure voltage-wise and area-wise technical and commercial losses – primarily due to non-availability of Distribution Transformer (DT)/feeder meters and non-completion of feeder segregation. Most of the distribution companies in India are, therefore, still following the simplified ACoS approach to calculate their cost of supply.

Table 3 gives a snapshot of the state-wise CoS approaches being followed.

Out of the 36 states and union territories (UTs), 32 states and UTs (89%), are determining their CoS of electricity through the simplified approach of calculating the cost of supply. A simplified version of the voltage-wise cost of supply (VCoS) was suggested by APTEL in 2010, to determine VCoS in the absence of all necessary data for computing the CoS through Embedded approach.

Table 3: State/UT-wise prevailing CoS models

CoS approach	Northern region	Western region	Eastern region	Southern region	North-eastern region
Simplified ACoS	Jammu & Kashmir, Himachal Pradesh, Haryana, Uttarakhand, Uttar Pradesh, Ladakh, Chandigarh	Gujarat, Dadra and Nagar Haveli and Daman & Diu, Lakshadweep*	Odisha, Sikkim	Kerala, Puducherry, Andaman & Nicobar Islands*	Tripura, Meghalaya, Arunachal Pradesh, Nagaland, Mizoram, Manipur
Calculate Simplified VCoS but use ACoS for tariff determination	Rajasthan, Delhi	Madhya Pradesh, Chhattisgarh, Goa	Bihar, Jharkhand, West Bengal	Tamil Nadu, Karnataka	Assam
Calculate ECoS but use ACoS for tariff determination		Maharashtra		Andhra Pradesh	
ECoS	Punjab			Telangana	

* UTs are not connected to any grid regions.

Out of the 32 states and UTs, Commissions in respect of 11 states and UTs compute the voltage-wise cost of supply (Simplified Cost approach), which means that the remaining 21 states/UTs do not calculate the voltage-wise CoS, even with approximations. Only in four states, namely, Andhra Pradesh, Punjab, Maharashtra and Telangana, CoS is computed using Embedded Cost of Supply methodology. Due to limitation of data availability with the required granularity, a number of assumptions in regard to AT&C loss estimation, cost bifurcation in various categories among others, have been made by the utilities in these states.

A review of orders of SERCs in the four aforementioned states brings out the assumptions, approximations, and estimations, made by the utilities in the respective state. As per Andhra Pradesh Electricity Regulatory Commission (APERC), the load curves data used in the Andhra Pradesh CoS model are based on estimations. So far, in case of Punjab, Punjab State Power Corporation Limited (PSPCL) has not completed the work of maintaining centralized asset registers, without which voltage-wise/category-wise assets could not be determined correctly. Thus, the voltage-wise/category-wise cost of supply, worked out on the basis of estimated cost data supplied by PSPCL, may not be depicting the cost of supply realistically. Also, Maharashtra Electricity Regulatory Commission (MERC) estimated the ECoS based on various assumptions in regard to allocation factors for allocating demand, energy and customer-related cost. Telangana State Southern Power Distribution Company Limited (TSSPDCL), has estimated its CoS in quite an exhaustive manner; assumptions and approximations have however been considered in calculating the CoS for aviation and lift irrigation categories.

From time-to-time, various SERCs/JERCs have been making observations/giving directions to distribution utilities to conduct studies to mainstream the required data for determining the CoS at each voltage level as directed by APTEL. Observations/directions of various SERCs/JERC are presented in Table 4.

Table 4: Observations/directions of SERCs/JERCs to distribution utilities in regard to CoS calculation methodology

Sl No.	State/UT	Tariff Order and Reference	Commissions' Observations/Directives
1	Andhra Pradesh	Retail supply tariff order 2019–20, Chapter VII and Point 353	"It can be inferred that Embedded Cost Approach which is being followed by the AP DISCOMs is a more detailed approach for cost allocation to different categories of consumers and reflects the true nature of costs incurred by the utility to supply single unit (INR/kWh) to each and every category of consumers depending on their voltage of use and purpose of use."
2	Arunachal Pradesh	Retail tariff order for FY 2018–19, Clause 8.1.3	Arunachal Pradesh Department of Power (AP-DOP) has not furnished the voltage-wise network cost due to which the Commission was unable to lay down the road map for reduction of cross-subsidy. The Commission has gone on the basis of the average cost of supply in the absence of relevant data for working out the consumer category-wise cost of supply.

Sl No.	State/UT	Tariff Order and Reference	Commissions' Observations/Directives
3	Assam	Tariff order for 2019–20 for APDCL, Clause 8.3.8	The Commission directed APDCL to complete the metering at 33 kV, 11 kV level, and LT level for arriving at the voltage-wise losses. The Commission also directed APDCL to expedite the energy audit exercise which shall give the correct picture for voltage wise cost of supply.
4	Bihar	Tariff order for FY 2019–20, Clause 11.2.8	The Commission has observed that the DISCOMs are calculating the voltage-wise cost of supply based on assumed technical losses for 33kV, 11kV, and LT voltage level without actually making any study as required. BERC directed the DISCOMs to take urgent action to complete the preparation of fixed Asset Register.
5	Chhattisgarh	Tariff order for FY 2019–20, Clause 8.2	The Commission notes that presently the voltage-wise losses are computed on the basis of assumptions and the actual losses would only be known after metered data at all distribution systems are properly captured. In view of the above, the Commission had no other option but to determine the voltage-wise cost of supply on the basis of available data.
6	Goa	Tariff order for FY 2019–20, Clause 7.4.1 (1[b])	The Commission strongly believes that determination of category-wise cost of supply is essential to ensure cost reflectivity in tariffs fixed for different categories. However, the Commission stated that in order to carry out the exercise of computing category-wise CoS, a lot of field -level information would be required. Therefore, in absence of the same, the Commission was unable to determine the category-wise CoS and has directed the Petitioner to start maintaining this data and to submit the same in the tariff proceedings of next year.
7	Gujarat	Tariff order for FY 2019–20 (All DISCOMs), Clause 7.2.(77)	In order to promote supply at higher voltages, the DISCOMs were directed to carry out a detailed study to work out the cost of supply at EHV level, reduction in technical loss for supplying electricity at higher voltages, and submit it to the Commission on or before 30 June 2019.

Sl No.	State/UT	Tariff Order and Reference	Commissions' Observations/Directives
8	Haryana	Retail tariff order for FY 2019–20, Clause 2.2.3 (8[a])	The Commission was of the considered view that a scientific methodology needs to be developed to calculate voltage-wise and category-wise losses so that the CoS of respective category could be calculated precisely.
9	Himachal Pradesh	MYT tariff order for the fourth control period (FY 2019–20 to FY 2023–24), Clause 9.2.4 and 9.2.5	HPERC computed the CoS under VCoS (Embedded) method only for indicative purposes and for assessing the trends and not for fixing the tariffs. In the absence of authentic information regarding voltage- level costs and losses, the Commission has computed the average cost of supply for purpose of fixation of tariff for various categories of consumers.
10	Jammu and Kashmir (including Ladakh)	MYT order for 2nd control period from FY 2016–17 to FY 2020–21 for JKPDD, Clause 3.189 and 3.190	Objections were received to calculate the voltage-wise cost of supply. However, for an accurate voltage-wise cost of supply study, energy accounting at all voltage level is necessary (not just 11 kV and above), which is only possible when energy meters are installed at every interface. Thus, in the absence of data on the status and results of the energy accounting process, and in the interest of establishment of regulatory discipline (in a scenario of less than 100% metering), the Commission, vide its Tariff Orders, has been determining tariffs based on the average cost of supply across all consumer categories, while allowing only the justified/prudent distribution costs, and not burdening the consumers with the inefficiencies of the Petitioner.
11	Jharkhand	Tariff order for FY 2019–20 for JBVNL, Clause 9.42 and 16.16	The Commission directed the utility to carry out a detailed technical study on voltage wise losses on distribution network and furnish a report within 3 months from the date of issuance of the Tariff Order for FY 2019–20.

Sl No.	State/UT	Tariff Order and Reference	Commissions' Observations/Directives
12	Maharashtra	MYT order on mid-term review for revised projections of ARR for FY2018–19 and 2019–20 for MSEDCL, Clause 9.18.8	MSEDCL has worked out the VCoS by adopting Embedded Cost approach, the ACoS so derived was also based on the certain assumptions considered by MSEDCL, as they do not maintain any voltage-wise costs details.
13	Uttarakhand	UPCL MYT tariff order for 3rd control period (FY 2019–20 to FY 2021–22), Clause 2.33.1.3	The Commission has taken note of the concerns raised by the stakeholders and further directed UPCL to compute the voltage-wise losses for each category of consumers and submit the data on voltage-wise losses along with their next tariff petitions.
14	Union territories - Chandigarh, Dadra and Nagar Haveli, Daman and Diu, Puducherry	Tariff order for FY 2019–20, Clause 6.4.1 (1[b])	The Commission strongly believes that determination of category-wise cost of supply is essential to ensure cost reflectivity in tariffs fixed for different categories. However, the Commission stated that in order to carry out this exercise, a lot of field-level information would be required.

It is noted that the State Commissions/JERC find lack of complete metering and fixed asset registers in most of the distribution utilities in India to be the main bottleneck in providing accurate data about voltage-wise costs and losses. Consequently, the Commissions have been resorting to computation of cost of supply using Simplified/Average CoS approach and are also not in a position to lay down a road map for reduction of cross subsidies. Cognisant of the need for reflection of cost of supply in tariff, Commissions have given directions to respective DISCOMs as mentioned in Table 4. The directions include maintaining authentic field-level data through 100% metering, fixed asset registers, and energy accounting, etc.

APPROACH ADOPTED BY DISCOMs (STATE/REGION-WISE) AND ASSOCIATED CHALLENGES: DISCUSSIONS DURING 4TH DUF STAKEHOLDER MEETING

The present study covered six DISCOMs across the country (covering all the grid regions) in order to understand the approach/methodology followed by them for computation of CoS, to understand their views on different approaches and to identify the key issues and challenges faced by them in estimating the category-wise/voltage-wise cost of supply. The DISCOMs were selected based on variance in consumer tariff from CoS, method of calculating CoS, and the tariff for various consumer categories.

4.1 Assam Power Distribution Corporation Limited

Assam Power Distribution Corporation Limited (APDCL) is the sole distribution company in Assam, with a consumer base of approximately 5.4 million. There are numerous consumer categories in APDCL however, the bulk of consumers, i.e., 5 million (93%) fall under the domestic category. These 5 million domestic consumers represent 54% share in electricity consumption and contribute 39% in DISCOM's revenue. APDCL follows the ACoS method for computing the cost of supply. However, the Commission has directed APDCL to firm up the data required to calculate the voltage-wise cost of supply (VCoS).

For FY2019–20, Assam Electricity Regulatory Commission (AERC) approved a revenue requirement of INR 5593 crore from the sale of 7930 million units (MU) of energy to its consumers with the average cost of supply at INR 7.06/unit.

APDCL officials pointed out that the major challenges in using the Embedded approach to calculate CoS are:

1. APDCL was facing shortage of funds required for feeder segregation and feeder metering. Out of 14,032 feeders, only around 6000 feeder meters are installed and functional as of now; APDCL received funds to install the meters on left out feeders recently.
2. The energy accounting procedure is further exacerbated by the increase in household connections under the SAUBHAGYA scheme.
3. Distribution asset allocation on the basis of consumer category/voltage level is an important parameter required under ECoS approach. Although, APDCL's asset register is available, the assets have not been categorized voltage-wise and category-wise in the absence of an Enterprise Resource Planning (ERP) system.
4. APDCL is also facing a challenge in terms of data recording, data connectivity, and integration of data received from various locations due to dilapidated network infrastructure.

APDCL is expediting metering among various voltage levels (33 kV, 11 kV, and LT levels) for computing the voltage-wise cost of supply, as directed by the state regulator.

4.2 Bangalore Electricity Supply Company Limited

Bangalore Electricity Supply Company Limited (BESCOM) is one of the distribution licensees responsible for purchase of power, distribution and retail supply of electricity in Karnataka. BESCOM serves nearly 11.24 million consumers, out of which 7.4 million are domestic consumers that represent 26% share in electricity consumption and contribute 23% in DISCOM revenue. High-Tension (HT) consumers represent 32% share in electricity consumption and contribute to 44% share in revenue.

BESCOM follows the ACoS method for calculating the cost of supply. Recently, in ARR for FY2019–20, BESCOM proposed voltage-wise calculation of CoS. In the absence of actual data on voltage-wise cost, the bifurcation of cost

has been carried out on the basis of assumptions in line with the APTEL order using the simplified approach. The standalone voltage-wise CoS for 2019–20 is shown in the Table 5.

Table 5: Voltage-wise Cost of Supply by Bangalore Electricity Supply Company Limited, FY2019-20[9]

Voltage level	CoS (INR/kWh)
EHT (66 kV and above)	7.32
HT level (22 and/or 11 kV)	7.75
LT level	8.40
Total	**8.19**

BESCOM officials mentioned that the major challenges in using the Embedded approach to calculate CoS are:

1. BESCOM, like other DISCOMs, also faces lack of complete DT metering as one of the major challenges in the adoption of ECoS. Non-availability of adequate data is the key issue in estimating the CoS using embedded approach.
2. Category-wise asset allocation is also a hurdle due to the unavailability of an ERP system in place.

4.3 Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Limited

Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Limited (MPMKVVCL) is one of the distribution licensees responsible for purchase of power, distribution and retail supply of electricity in Madhya Pradesh. MPMKVVCL serves nearly 5.5 million consumers with about 4.5 million domestic residential (83.3%), 0.6 million agricultural (10.7%), 0.3 million commercial (5.1%) and 0.03 million industrial consumers (0.6%). MPMKVVCL follows the ACoS method for calculating the cost of supply. Adopting the methodology suggested in APTEL order, MPMKVVCL determined the voltage-wise cost of supply[10] for FY2018–19 using the following steps:

1. After taking into account the sales and losses at EHT, 33kV and 11kV + LT levels, the net energy input is calculated at these three voltage levels.
2. For the break-up of commercial and technical losses, 50% of the total loss at 11 KV + LT system is assumed as technical loss and the remaining 50% is treated as commercial loss. The 50% commercial loss is further split into three parts, i.e., for EHT system, 33 kV system, and 11 kV + LT system in the ratio of sales in the respective voltage level. In this way, the net energy loss (MU) at three different voltage levels is calculated. Adding this calculated loss to the sales at different voltage levels gives the net energy input at three voltage levels.
3. Further, total power purchase cost is allocated in the ratio of energy input at different voltage levels. Also, the cost other than power purchase cost is also segregated for three different voltage levels in the same way as for the power purchase cost.
4. In this way, the total cost at different voltage levels is arrived. Dividing this cost by the sales, the voltage-wise cost of supply is arrived. Detailed VCoS estimation using the simplified approach is given in Table 6:

MPMKVVCL officials pointed out that the challenges in using the Embedded approach to calculate CoS are:

1. Incomplete feeder segregation and non-metering of feeders leading to the non-availability of category-wise data.

[9] Bangalore Electricity Supply Company Limited (BESCOM). 2020. Determination of tariff for FY–20, Chapter 8. Government of Karnataka. Details available at https://www.karnataka.gov.in/kerc/Tarifforders2019/2-Bescom/Chapter-8_Determination%20of%20tariff.pdf, last accessed on 4 November 2019

[10] Madhya Pradesh Electricity Regulatory Commission. 2018. Aggregate revenue requirement and retail supply tariff order for FY2018–19; p. 121. Details available at http://164.100.60.27/030518-PNo-03-2018-Tariff.pdf, last accessed on 26 March 2020

Table 6: Voltage-wise Cost of Supply, FY2018–19[11]

Sl No.	Particulars	UOM	EHT System (66 kV and above)	33 KV System	11 KV + LT System	Total
A	Technical and commercial losses submitted by the petitioner	%	4.9%	5.9%	13.1%	20.2%
B	Energy input submitted	MU	3278	7312	56,860	67,449
C	Energy input admitted	MU	3205	7131	55,514	65,851
D	Sales	MU	3117	6543	42,991	52,652
E	Energy loss admitted (technical loss up to 33kV and 11 kV + LT– technical and commercial losses) (C – D)	MU	88	588	12,523	13,199
F	Commercial loss assumed as 50% of 11kV and LT overall losses (technical loss for 11kV + LT)	MU			6261	6261
G	Balance 50% commercial losses for all voltage levels in proportion to sales	MU	371	778	5113	6261
H	Net energy loss admitted	MU	459	1366	11,374	13,199
I	Net energy input (D+H)	MU	3576	7909	54,365	65,851
J	Power purchase costs – allocated based on net energy input	INR Cr	1305	2952	20,192	24,449
K	Other costs – allocated based on voltage-wise sales	INR Cr	438	856	5712	7005
L	Less: Other income – allocated based on voltage-wise sales	INR Cr	36	74	481	591
M	Recoveries of past	INR Cr	55	114	734	903
N	Total costs (ARR requirement) (J+K–L+M)	INR Cr	1762	3848	26,156	31,767
O	Voltage-wise cost of supply (N/C)	INR/unit	5.65	5.88	6.08	6.03

2. Unavailability of the ERP system, which is used for proper indexing of asset costs into various category-wise cost centres.

4.4 Maharashtra State Electricity Distribution Company Limited

Maharashtra State Electricity Distribution Limited (MSEDCL) is one of the distribution licensees responsible for purchase of power, distribution and retail supply of electricity in Maharashtra. MSEDCL serves nearly 25 million consumers with about 18 million domestic residential (72.4%), 4 million agricultural (16%), 1.7 million commercial (7%), and 0.35 million industrial consumers (1.8%).

[11] Madhya Pradesh Electricity Regulatory Commission. 2018. Aggregate revenue requirement and retail supply tariff order for FY2018–19; p. 123. Details available at http://164.100.60.27/030518-PNo-03-2018-Tariff.pdf, last accessed on 26 March 2020

Currently, CoS is being calculated by using the ACoS approach. However, on MERC's directive, MSEDCL calculated the VCoS for FY2019–20 using the Embedded CoS approach and submitted the study to the Commission in the mid-term review of FY2016 to FY2020.

The total costs for generation, transmission, and distribution have been classified into demand, supply and customer-related cost categories depending upon the nature of cost – fixed and variable. Demand-related costs, fixed power purchase cost, distribution asset cost, etc., have been allocated too and are presented in Table 7. In this study various allocation factors have been devised based on the following:

» **Demand-related costs**: These costs are worked based on the percentage contribution of non-coincident demand, average demand, and excess demand in the respective demand component.

» **Energy-related costs**: These allocation factors are derived based on the ratio of energy input at a particular voltage level. (Energy Input = Energy Sales + Losses).

» **Customer-related costs**: To address the variance in service cost across voltage levels, voltage level-wise weightages have been derived to determine the allocation factors for customer-related costs.

As per MSEDCL officials, the major challenges faced while estimating VCoS/ECoS using Embedded approach are:

1. In the absence of category-wise segregation of assets, the voltage-wise demand cost allocation has been carried out on the basis of demand share allocation.
2. Only agricultural feeders are segregated; the other feeders remain mixed. A voltage-wise/category-wise loss estimation is therefore, not possible.
3. Load research has not been carried out for the utility. Detailed data related to demand profile, losses, coincidental peak, and non-coincidental peak composi tion, etc., are not available (MSEDCL considered 19th EPS load factor to estimate the voltage-wise share allocation).

Table 7: Category wise total cost of service for FY 2019–20, considered by MERC[12]

Voltage level	Sales (MU)	Allocation (%)	Demand - related (INR Cr)	Demand (INR/ unit)	Allocation (%)	Energy-related (INR Cr)	Energy (INR/ unit)	Allocation (%)	Customer-related (INR Cr)	Customer (INR/unit)	Total (INR/ unit)
EHV (66 kV & above)	8549	0.07	2624	3.07	0.07	2222	2.60	0.00	5	0.01	5.67
HT Level (33 kV)	9495	0.09	3721	3.92	0.08	2743	2.89	0.01	29	0.03	6.84
HT Level (22/ or 11 kV)	18,160	0.17	6668	3.67	0.17	5467	3.01	0.11	284	0.16	6.84
LT Level	72,166	0.67	26,619	3.69	0.68	22,595	3.13	0.87	2207	0.31	7.13
MSEDCL Total	**1,08,369**	**1.00**	**39,632**	**3.66**	**1.00**	**33,103**	**3.05**	**1.00**	**2 525**	**0.23**	**6.94**

[12] Maharashtra Electricity Regulatory Commission (MERC). 2018. Mid-Term Review Order for MSEDCL for FY 2016–17 to FY 2019–20, case no 195; p. 457. Maharashtra. Details available at https://www.merc.gov.in/mercweb/faces/merc/common/outputClient.xhtml, last accessed on 26 March 2020

With the recent adoption of an ERP system, MSEDCL hopes to overcome the challenge of category-wise segregation of assets in the coming years.

4.5 Punjab State Power Corporation Limited

Punjab State Power Corporation Limited (PSPCL) is the sole distribution licensee responsible for purchase of power, distribution, and retail supply of electricity in Punjab. PSPCL has a consumer base of 9.3 million and an asset value of INR 26,950 Cr. There are about 7.8 million domestic residential (83.5%), 1.4 million agricultural (15%), and 0.14 million industrial consumers (1.5%) in PSPCL.

Punjab is one of the few states in the country which follows the ECoS methodology to determine the voltage-wise/consumer-wise cost of supply. Punjab State Electricity Regulatory Commission (PSERC) approved two methodologies under EoS based on the power supply situation. Methodology I must be used in power surplus scenario and Methodology II is to be used in a power deficit scenario. The main difference between these two methodologies is in the cost classification step followed by the respective change in the cost allocation step.

PSPCL officials described the major challenges in using the Embedded approach to calculate the CoS as under:

» PSPCL has been following Methodology II[13] which is used in a power deficit situation; whereas PSPCL is in a power surplus situation for the past 2 years. The need for changing the methodology has been identified by PSPCL and the Commission's directions in this regard are awaited.

» The values of demand factor indicated in PSERC (Supply Code and Related Matters) Regulations, 2007 for different consumer categories, which forms the base for demand allocation and asset apportionment, has been the same since 2007. As the demand patterns change over a period of time, it is necessary that demand factors are reviewed periodically.

» Category-wise losses across the same voltage level are taken to be equal. However, losses in LT–industrial can be significantly different from losses in LT–domestic. Hence, an accurate assumption in estimating category-wise losses would make the estimation of the ECoS more cost reflective.

4.6 West Bengal State Electricity Distribution Company

WBSEDCL is the largest distribution company in West Bengal, with approximately 19 million consumers. There are numerous consumer categories (more than 30) in WBSEDCL. Bulk of the consumers, i.e., 17 million (90%), fall under the residential category. WBSEDCL follows the ACoS method for calculating the cost of supply.

For the FY2017–18, West Bengal Electricity Regulatory Commission (WBERC) approved ACoS of INR 6.89/unit as against INR 7.55/unit projected by WBSEDCL. An internal exercise was carried out by WBSEDCL to compute the voltage-wise/category-wise CoS with various costs and technical assumptions. The results of the exercise indicated a reversal of tariff charged, that is, industrial consumers and HV consumers who are generally charged a higher tariff of INR 8/unit, have CoS of INR 5.5/unit and agriculture/LT consumers, who are generally charged in the range of INR 4–6/unit have CoS of INR 9/unit. The exercise ended with

[13] TERI. 2012. Voltage Wise – Consumer Category wise Cost of Supply, prepared for PSPCL. Details available at https://www.pspcl.in/wp-content/uploads/2017/05/arr_petition_2013_14_cost_supply.pdf, last accessed on 26 March 2020

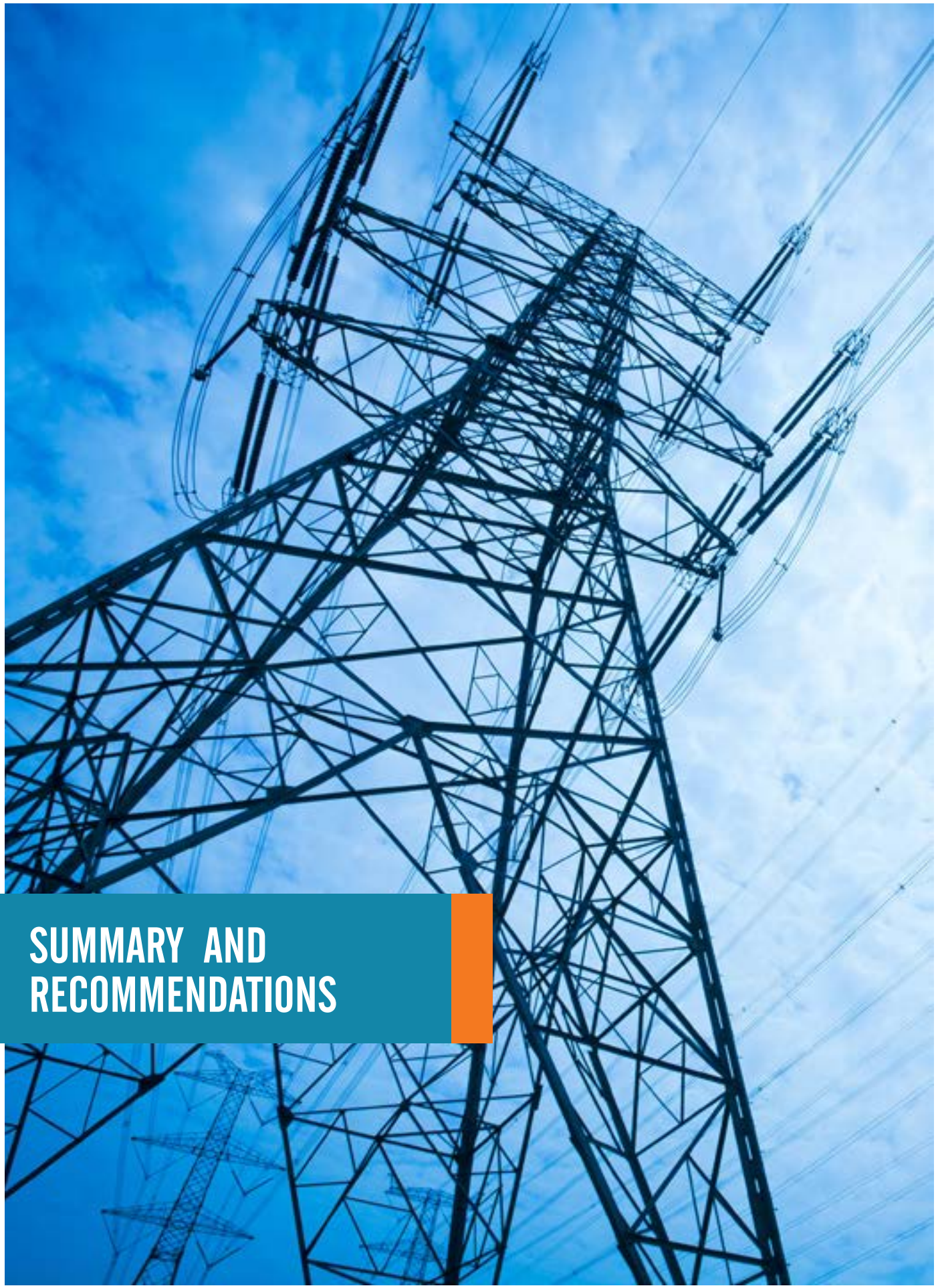
the conclusion that imposition of these estimated CoS will create a tariff shock to LT consumers, unless subsidized.

According to WBSEDCL officials, the major challenges in using the Embedded approach to calculate CoS are:

1. Non-availability of DT/feeder meters and non-completion of feeder segregation are the key reasons for not having appropriate data to calculate the voltage-wise/category-wise embedded CoS. According to WBSEDCL, 33 kV and 11 kV feeder/DT level metering was completed recently in 2018–19. Below 11 kV, only 50% DTs are metered.
2. Determination and apportioning of actual cost and distribution loss for each voltage level is difficult as consumers of different categories (more than 30) are fed through the same voltage feeders using the same infrastructure and manpower. With the consumer categories being over 30, existing calculations are quite complex. The complexity would increase further with likely addition of consumer categories. WBSEDCL is planning to add EV charging as another category (as per commercial rate, other than domestic connection). Even small airports under UDAN scheme, government schools and temples, are also demanding a separate category for themselves.

4.7 Other Observations

» Other DISCOMs/utilities such as Tata Power Delhi Distribution Limited (TPDDL), CESC Limited, Grid Corporation of Odisha (GRIDCO), also highlighted their concerns over data unavailability due to the absence of meters at various feeders and DTs as the primary challenge in the estimation of ECoS.



SUMMARY AND RECOMMENDATIONS

Electricity Act, 2003 stipulates that the retail tariff for electricity should progressively reflects cost of supply and cross subsidies should be reduced in the manner specified by Appropriate Commission. The National Electricity Policy and Tariff Policy have, from time to time, made provisions in furtherance of aforesaid statutory provisions. Policy prescriptions in many of the States have however not been followed to required extent, primarily due to concerns of likely tariff shocks and lack of requisite data.

This report presents legal and policy provisions as a backdrop and also approach/methodology adopted by a few DISCOMs in India for computing the CoS to different consumer categories based on the regulatory provisions/directions in respective states. The report also brings out key issues and challenges coming in the way of their graduating from the prevailing approaches and methodologies to one which reflects cost of supply to various consumer categories at various voltage levels in a more realistic manner. Regulatory approaches to Cost of Supply across a wide cross section of DISCOMs under the prevailing conditions are also presented in the report. The report also presents approach and practices followed by utilities in a few developing and developed countries for estimating the cost of supply of electricity to consumers with a view to serve as a guide and learning for the DISCOMs in the country.

The approaches followed in India could be classified into two categories, namely Simplified/Average Cost of Supply and Embedded Cost of Supply. Majority of the DISCOMs in the country follow Average Cost of Supply Approach as mentioned in the section 3.1.1 of the report. APTEL has suggested a simple formulation which would take in to account major cost elements without waiting indefinitely for availability of entire data. Though some of these DISCOMs calculate Voltage wise Cost of Supply (Section 3.1.2), Average CoS is followed for tariff determination, primarily due to lack of data or its reliability and robustness of energy accounting methodology. DISCOMs in Punjab and Telangana follow Embedded CoS Approach with certain assumptions. MSEDCL and DISCOMs in Andhra Pradesh have initiated transition to Embedded Cost of Supply on the directions of respective SERCs. APSERC has also observed that Embedded Cost of Supply is a more detailed approach for cost allocation and reflects true nature of costs. The observations of State Commissions and JERC bring out the reasoning behind the computational approach being followed and the difficulties as mentioned in Section-3 in switching from simplified approach to a more detailed approach for computation of CoS. State Commissions and JERC have also given directions to concerned DISCOMs/ power departments for capturing and maintaining data in respect of asset costs and losses at various voltage levels, developing a scientific/robust methodology for computation of CoS and energy accounting, carrying out technical studies for assessment of losses in the absence of requisite metering, etc. Therefore, ECoS approach is best suited to Indian DISCOMs.

The major limitations coming in the way of computation of cost of supply based on ECoS approach, as explained above are lack of metering infrastructure, limited digitized data base and inadequate data on load patterns. In this context, following steps are considered necessary.

Complete distribution transformer (DT) and feeder-level metering:

One hundred per cent metering at feeder, DT and consumer levels has been mandated by Government of India. Government has also been providing budgetary support from time to time for the same. Though most of the DISCOMs have achieved almost 100% feeder metering, DT level metering is still too less, more so in

the rural areas. Further, the feeder meters not being AMR meters, inaccuracies in manual reading and recording of meters cannot be ruled out. As brought out in Table 8, data on current level of urban and rural level DT metering in 7 DISCOMs (whose approach for computation of CoS has been discussed in the study) shows the need for approximations and assumptions which may be required in computing cost of supply realistically.

Table 8: DT metering status of consulted DISCOMs

State	DISCOM	DT metering status (%)		Status as on
		Urban	Rural	
Madhya Pradesh	MPMKVVCL	76%	44%	March 2019
Maharashtra	MSEDCL	31%	19%	December 2019
Punjab	PSPCL	63%	1%	December 2019
Karnataka	BESCOM	100%	62%	December 2019
Assam	APDCL	100%	38%	September 2019
Telangana*	TSSPDCL	100%	100%	December 2019
Andhra Pradesh*	APSPDCL	100%	54%	December 2019

** DISCOMs following ECoS approach*

Source: UDAY portal

Directions by SERCs to respective DISCOMs to expedite DT and feeder level metering as well as monitoring of compliance by SERCs would help in developing robust energy accounting.

» **Implementation of enterprise resource planning (ERP) tools:**

The implementation of a centralized ERP system in each DISCOM is a pre-requisite for allocating asset cost among different consumer categories and voltage levels. An ERP would help in the proper indexing of distribution assets and costs associated with it at various voltage levels and for different consumer categories. This would enable utilities to design cost-reflective tariff through the Embedded Cost approach. The benefits gained through an ERP system would outweigh its cost. Recently, a few Indian utilities, such as PSPSCL, BRPL and MSEDCL have implemented or are in the process of implementing ERP system. Most of the DISCOMs in the country, however, need to give priority to it. SERCs interventions and directions to respective DISCOMs in regard to this would help in giving required thrust to this.

» **Periodic load research of utility:**

The pattern of the load curves has been changing over the years due to several factors such as changing usage patterns including impacts of DSM and energy efficiency, penetration of solar rooftop systems, increasing rural household electrification, deployment of electric vehicles, etc. Thus, it becomes pertinent to periodically (say once in 2–3 years) capture the changes in these demand profiles by conducting a comprehensive load research. Insights regarding changing consumption patterns, peak coincidence, and contribution by different consumer categories in the utility peak would help utilities in computing realistic cost incurred in catering to different consumer categories.

Way Forward

While actions, interventions and measures suggested in the preceding section would provide a technically sound automated system, which would enable the DISCOMs to follow ECoS approach in true sense. Pending implementation of these measures, a simple formulation like the one suggested by the APTEL is recommended as a practical way forward for transition to ECoS approach.

Table 9: Way forward for transition to ECoS computation (parameters and requisite data for computation of ECoS)

Sl No.	Parameter	Cost Classification (Demand/Energy/ Customer-Related)	Suggested approach in the absence of data
1	Asset base	Demand	» In absence of break-up of total asset cost in various categories and voltage levels, total asset cost can be allocated to various voltage levels utilizing log sheet based asset data available at divisional/ sub-divisional level.
2	Connected load	Demand/customer-related	» Available with the DISCOMs
3	Energy sales	Energy and customer-related	
4	Technical loss of distribution system	Energy	» Technical loss at various voltage levels can be computed through simulation studies » Commercial loss can be computed from AT&C loss and technical loss can be determined through simulation studies.
5	Transmission loss	Energy	» Voltage-wise losses are available in tariff order issued by SERC/JERC.
6	Power purchase cost (including inter-state transmission charges)		» Available with DISCOMs
6a	**Fixed cost** ROE Interest on loan Interest on working capital Depreciation Tax O&M expenses	Demand cost	» Costs are available with DISCOMs with classification of fixed cost and variable cost.
6b	**Variable cost** – Fuel cost	Energy	
6c	Power purchase expenses – Other costs	Energy	
7	Distribution cost	Demand/Energy/ customer-related	» Available with the DISCOMs
8	Transmission cost (intra-state)	Demand cost	
9	Transmission cost (inter-state)	Demand cost	
10	POSOCO charges		
11	SLDC charges	Demand cost	
12	Coincidental peak demand (CPD)	Demand	» It could be drawn from feeder-level load research using sample predominant feeders.
13	Non-coincidental peak demand (NCPD)	Demand	
14	Load factor	Demand	
15	Number of consumers	Customer-related	» Available with the DISCOMs

Different parameters constituting CoS, their classification in to demand, energy and customer-related costs along with a practical approach for each parameter are recommended (Table 9).

It would also be of interest in this context to explore the ways and means for reducing overall CoS keeping in mind the consumer interests. A few key points that merit consideration in this regard are as follows:

1. Implementation of Integrated resource planning ensuring inter alia realistic demand forecast and adopting optimal power procurement strategies

2. Electricity sector is one of the sectors wherein domestic and agriculture consumer categories are heavily subsidized. During the DUF meeting, a number of DISCOMs suggested that these consumer categories are required to be sensitized about the subsidy they are provided; one way of doing so is by highlighting the Actual Cost of Supply (ACoS) in the bill itself (like in case of Philippines) and mentioning the difference between ACoS and the tariff billed. Building on this, consumers can be requested for voluntary withdrawal of subsidies as has been done in the case of LPG cylinders through the "Give It Up" scheme in India. Schemes like "Paani Bachao, Paise Kamao" scheme, based on direct benefit transfer of electricity (DBTE), introduced among agriculture consumers in Punjab could also be introduced across various states and consumer categories to reduce cross-subsidy levels.

ANNEXURE 1

INTERNATIONAL PRACTICES – OVERVIEW OF CoS APPROACH FOLLOWED BY A FEW COUNTRIES

New Zealand

New Zealand follows two different methodologies for electricity pricing—

a. Grid Exit Point (GXP) methodology for its western region which can be considered a wholesale delivery model and
b. Installation Control Point (ICP) methodology[14] for its eastern region which is a retail delivery model.

Both methodologies are checked against a cost of supply model to ensure that prices recover the cost of supply. In New Zealand, the role of the CoS methodology is not to set price but to compare the realisation of revenue from the current price structure so that the prices are readjusted to avoid price shocks.

A step-by-step incremental cost approach of cost of supply methodology of New Zealand is as follows:

» Calculate total costs for the relevant period; these include transmission costs (including ACOT – avoided cost of transmission), capital costs, operating costs, maintenance costs and administration costs;
» Determine the key drivers of network expenditure;
» Determine suitable groupings of connections across each network based on similarities of network and consumer characteristics such as geography, rural/urban connection density, mains size, protection rating and/or transformer capacity;
» Determine the allocation of costs (such as operating costs, transmission costs and cost of capital) across each network based on the asset utilization costs within each group.
» Subsequently, allocate the costs between different tariff categories in 80:20 weighted average of the contribution to regional coincident peak demand and Installation Control Point (ICP) numbers for each group.

During cost allocation, New Zealand allocates costs in such a way that it complies with the Electricity Authority's pricing principles. As per the New Zealand Electricity Authority, prices are to signal the economic costs of service provision, by being subsidy free (equal to or greater than incremental costs, and less than or equal to standalone costs), except where subsidies arise from compliance with legislation and/or other regulation.

In order to allocate the increment cost, New Zealand forecasts growth of network for the next ten years and the cost estimated would be distributed among those ten years. A marginal increase in O&M cost, overhead costs and transmission costs are considered in the treatment of capital contributions.

In this way, New Zealand follows the incremental cost approach methodology in arriving at component-wise costs and allocates the costs to different categories based on the asset utilization; thereafter, the tariff is fixed to reflect the cost of supply while limiting price shocks.

Australia

The Australian Energy Regulator mandated retail supply utilities to comply with pricing principles of pricing within standalone and avoidable costs and using long-run Marginal Cost of Supply approach for the computation of cost of supply.

[14] Powerco Limited. 2019. Electricity pricing methodology in New Zealand (effective 1 April 2019). Details available at https://www.powerco.co.nz/media/2063/powerco-electricity-pricing-methodology-2019-vf1.pdf, last accessed on 26 March 2020

As per the regulator,

1. For each tariff class, expected revenue to be recovered from customers must be between the standalone cost of serving those customers and the avoidable cost of not serving those customers.
1. Each tariff must be based on the long run marginal cost of serving those customers, with the method of calculation and its application determined with regard to the costs and benefits of that method, the costs of meeting the demand from those customers at peak network utilisation times, and customer locations. [15]

Australian utilities divide the utility revenue requirement into system access cost, energy cost and demand cost. Furthermore, all these costs are allocated to different tariff categories based on different factors, as explained below:

Network Access Charges (NACs)—NACs are fixed daily charges per National Metering Identifier (NMI) for connection to an electricity network. This is separate from the ACS metering charge, which is also a daily charge, but applied to the number of meters at the NMI.

Anytime Energy Charges—All the tariffs include an anytime energy charge based on a dollar per kWh ($/kWh), as measured by the customer's meter except for customers on the unmetered tariff. Customers on the unmetered tariff are charged an anytime energy charge in $/kWh, based on the device's assumed consumption profile.

Demand Charges—Demand charges encourage a reduction in the peak consumption. Peak consumption is a major driver of network expenditure. These charges are calculated based on Long Run Marginal Cost (LRMC).

Demand charges can only be applied to those customers with smart meters. Accumulation meters do not collect the required information. The demand charge is applied to the peak demand within a month, within the peak period.

Philippines

The Philippines utilities also follow the Embedded Cost of Supply approa ch[16] in order to determine their cost of service. Their cost components are similar to that of South Africa. Utilities in the Philippines also follow the same steps in determining their revenue requirement, cost functionalization, cost classification, and cost allocation. However, the uniqueness in the Philippines CoS is that the cost functionalization consists of generation, transmission, system loss, distribution and universal charges. A Philippines consumer's electricity bill clearly depicts all these components for a clearer understanding.

A brief explanation of each component in the below illustrated electricity bill of Philippines is, as follows[17].

Generation Charge refers to the cost of power generated and sold to the distribution utility by the National Power Corporation (NPC) as well as the Independent Power Producers (IPPs).

Transmission Charge refers to the regulated cost or charges for the use of a transmission system, which may include the availment of Ancillary Service.

System Loss Charge represents recovery of the cost of power lost due to technical and non-technical losses currently pegged at 9.5% for private distribution utilities

[15] AER. Essential Energy Prices Report. 2018–19. Details available at https://www.aer.gov.au/system/files/Att.6%20Essential%20Energy%20Annual%20Network%20Pricing%20Report%202018-19_0.pdf, last accessed on 26 March 2020

[16] Republic of the Philippines (Energy Regulatory Commission). Reference from Philippines' Knowing More My Unbundled. Details available at https://www.erc.gov.ph/ContentPage/21, last accessed on 26 March 2020.

[17] Reference from Philippines' Knowing More My Unbundled, Url: https://www.erc.gov.ph/ContentPage/21

JOWEL CANLOBO
(02) 2 LT LAWIN DR
ST. FRANCIS HOMES PH VI NIUGAN
CABUYAO
LAGUNA

MERALCO

Page 1 of 2

Service Info

Service ID Number	: 240725101-2
Rate	: General Service
Contract in the name of	: JOWEL CANLOBO
Service Address	: (02) 2 LT LAWIN DR
	ST. FRANCIS HOMES PH VI NIUGAN
	LAGUNA

Billing Info

Bill Date	: 18 AUG 2008
Billing Period	: 18 JUL 2008 to 18 AUG 2008
Due Date	: 27 AUG 2008
Total kWh	: 78
Total Current Amount	: ₱ 525.05
Other Unpaid Bills	: ₱ 496.40
TOTAL Amount Due	: ₱ 1,021.45

Billing Summary

BILL SUBGROUP	SUBTOTAL	PERCENTAGE
Generation	345.91	65.9%
Transmission	77.39	14.7%
System Loss	57.60	11.0%
Distribution (Meralco)	109.79	20.9%
Subsidies	(118.06)	(22.50)
Government Taxes	49.30	9.4%
Universal Charges	3.11	0.6%
Other Charges	0.00	0.0%
Total	525.05	100.0%

Typhoon Watch

Being prepared is the best defense against *typhoons*. BE PREPARED this typhoon season.

Before a typhoon, store water because service may be interrupted for days. Store food that do not need refrigeration like canned goods and noodles.

During a typhoon, tune in to TV and radio stations for emergency information. If your house is flooded, turn off the main switch and move your appliances to a higher area in your house.

After a typhoon, do not operate wet electrical appliances and have them checked by a qualified repairman.

Call the Meralco Call Center at **16211** or text **0917-5592824** or **0920-9292824** or give online feedback through the Meralco website to report power failure, damaged electrical facilities and flood.

For more information, log on to **www.meralco.com.ph**.
Typhoon Watch is a public service of Meralco.

Your monthly electricity consumption chart

4247-EC800136-20080926-1433594~ Total: 525.05

For authorized collecting agents

Account Name	Billing Address
JOWEL CANLOBO	(02) 2 LT LAWIN DR ST. FRANCIS HOMES PH VI NIUGAN CABUYAO LAGUNA

Service ID No. (S.I.N.)	ATM / Phone Reference No.	Meralco Reference No.	Total Current Amount
240725101-2	0 240725101 2 08183	0 240725101 2 080818 3 080831 02	₱ 525.05

A Philippines consumer's electricity bill

and 14% for electric cooperatives, including company used power.

Distribution Charge is the regulated cost of building, operating and maintaining the distribution system, which brings power from high voltage transmission grids, to commercial/ industrial establishments and to residential end-users. It also includes metering and billing costs.

Subsidies is a reduction in the bill of subsidized customer classes, specifically residential, small industrial, government hospitals and streetlight services, and an upward adjustment in the bill of subsidizing customer class.

Government taxes refers to the national and local franchise taxes which must be paid by private utility companies.

Universal Charge refers to the charge, if any, imposed for the recovery of stranded debts, stranded contract costs of NPC, and other mandated purposes. It is a non-bypassable charge, which shall be passed on and collected from all end-users on a monthly basis by the distribution utilities.

In this way, Philippines utilities are showing the breakdown of total cost of supply in the electricity bill of the consumers to make them aware of the actual component-wise costs and subsidies of electricity being supplied to them.

South Africa

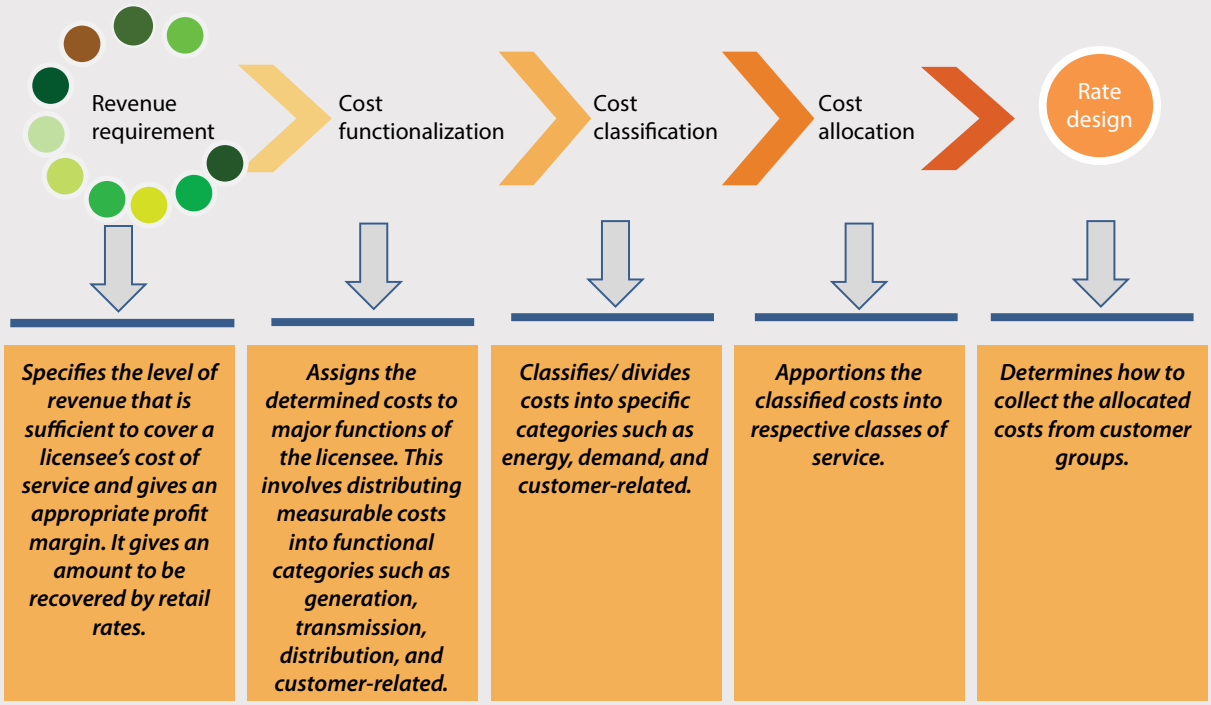
South Africa follows the Embedded Cost of Supply approach with a four-step process defined as revenue requirement, cost functionalization, cost classification and cost allocation.

South Africa adopted the cost-plus methodology to determine the revenue requirement which is further assigned to different functional groups, such as generation, transmission, distribution, and customer-related costs to facilitate in terms of which consumer groups are responsible for such costs. After the functional separation, these costs are classified into cost components.

Cost classification is a two-step process. First, functionalised costs are classified as either fixed or variable costs. Then, fixed and variable costs are classified as demand, usage or energy and customer-related. The sum of these three types of costs within a given class is the cost to serve that class. The cost drivers and classification are indicated in the tables, as given below.

Cost Drivers

Cost Driver	Characteristics
Demand	Triggered by peak demand and fixed in nature
Energy	Vary with volume of energy utilized
Customer-related cost	Depends on the number and type of consumer served



South Africa's Cost of Supply 4-step process[18]

Cost Functions and Classification

Function	Cost classification
Generation	Demand-related Energy-related
Transmission	Demand-related
Distribution	Demand-related Consumer-related

Further, energy costs are allocated based on the energy consumption in addition to the losses by each category. Demand costs are allocated based on Reduced Network Diagram (RND) and customer-related costs are allocated based on weighted customer numbers.

[18] National Energy Regulator of South Africa (2015) - Cost of Supply Framework for Licensed Electricity Distributors in South Africa http://www.nersa.org.za/Admin/Document/Editor/file/Electricity/Legislation/Methodologies%20and%20Guidelines/Cost%20of%20Supply%20Framework.pdf

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