SELECTION OF ELECTRICITY TARIFF DESIGNS FOR DISTRIBUTION NETWORKS USING ANALYTIC NETWORK PROCESS

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ABSTRACT

In electricity distribution networks, tariff designs set the interface between the users and network operators or service providers. Tariff designs provide the reference base for tariff schedules covering multiple categories of network users. It is widely accepted that electric utility rate designs have subjective and objective multi-criteria dependencies. Based on utility rate making literature, subcriteria for selection of tariff designs can be listed under the economic, technological, and social criteria. In this study, two widely used electricity tariff designs, volumetric or energy charges and capacity or demand charges are considered. In addition, real-time pricing and a hybrid tariff design that combines energy and capacity charges with critical peak pricing are also included in the comparison. Performance evaluation of these tariff designs on quantifiable parameters relating to economic aspects is carried out using the Tariff Design and Analysis Tool. Literature on electricity tariff designs and pricing provides the metadata on performance relating to qualitative criteria covering mainly the technological and social aspects. A synthesis of the quantitative and qualitative criteria evaluations was done by developing a Benefits-Opportunities-Costs-Risks (BOCR) model in the Analytic Network Process (ANP), a Multi-Criteria Decision Making methodology. A quantitative assessment of inconsistencies in evaluation and synthesis of the model using a consistency index shows that the developed ANP framework for tariff design selection is a valid approach. The developed BOCR model in ANP shows that the hybrid tariff design of Energy and Capacity charges with Coincident Peak Pricing is the best alternative. A sensitivity analysis shows that the ranking is variable when the BOCR priorities change.

Keywords: Analytic Network Process; capacity charges; Coincident Peak Pricing; electricity tariff; Real Time Pricing; volumetric charges

1. Introduction

Electricity pricing is a perennial problem for regulatory bodies trying to balance consumer expectations and service provider gains. The complexity of the issue primarily

ISSN 1936-6744https://doi.org/10.13033/ijahp.v15i2.1052

stems from the long-held position of electricity as a common utility good while modern power markets at the bulk level operate on demand-based costing (Kirschen & Strbac, 2018).Another layer of complexity for the pricing issue involves network technology migration to Smart Grids (SG) and Microgrids (MG) which continues to change the industry in fundamental ways (Widergren et al., 2019). Sustainability issues are forcing fossil fuel power plants out of operation while alternative sources of energy from the renewable portfolio have economic limitations when taken in totality. In the traditional electricity grid model followed until the 1990s, there is a top-down hierarchy of control and coordination with distinct Generation-Transmission-Distribution separation. The formulation of intelligent grid architecture with Smart Metering and Distributed Control is now changing the structure of the electricity network. Further, generation is not centrally controlled as more and more renewable energy systems are being added at the distribution level. An interesting aspect of the introduction of renewable energy systems at the electricity distribution level is the presence of prosumers. Of particular interest to policy makers is the economic impact on service providers under such dynamic role transitions. Structure of distribution electricity tariffs applicable to consumers and generators is a prime factor influencing integration of distributed energy resources in the low voltage grid (Picciariello et al., 2015). Due to the need for wider accessibility of electricity, regulators in developing economies are finding it difficult to develop pricing schemes that incentivize technology growth while avoiding under-realization by the service provider (Gencer, Larsen & van Ackere, 2020). Appropriate pricing of electricity through well-designed tariff mechanisms is required in the electricity sector of countries to aid in the technology development and show cost-reflectivity for electrical energy use.

The long-held position of electricity networks as natural monopolies with characteristics of a public good has guided the establishment of electricity tariffs until recently. Revenue requirement, fair apportioning of costs and economic efficiency have been the main regulatory principles for proposing electricity tariffs (Bonbright et al., 1961). An acceptable tariff structure needs to be economically efficient from both the producer's perspective and the consumer's perspective. There are also well accepted ancillary principles of rate making which are general in nature – transparency, additivity, stability, consistency and simplicity. From the point of view of equitable sharing of a near monopoly good, regulators attempt to enforce the principle of universal service worldwide (Anderson, 2009). The central role of tariff design as an interface between the users and the utility is recognized and current approaches follow an accounting approach rather than basic principles of utility tariff design (Reneses et al., 2014). For example, if the principle of equitable resource sharing is to be applied then the principle of economic efficiency will have to be compromised. Since purchasing power across all categories of consumers is not the same, some cross-subsidy mechanism will invariably need to be put in place to create equity. Subjective criteria like transparency and simplicity are incorporated through arbitrary procedural interventions rather than by following standard methodologies (Rábago &Valova, 2018). Such overriding interventions in the decision making process for tariff design selection are unacceptable under the evolving grid paradigms (Brown & Faruqui, 2014). Identification of a decision making methodology that will be able to support regulators in making informed decisions on tariff designs is extremely important in the transitioning electricity sector. Multi-Criteria Decision Making (MCDM) methods have not been used much to explore electricity tariff design selection although such methods have been applied to a wide variety of problems including energy portfolio management, site selection etc. (Bohra &Anvari-Moghaddam, 2022).

The present practice for deciding on the tariff design or structure is to consider ease of application and the type of consumer groups as a basic requirement. Over time, this has led to de-facto cross-subsidization, arbitrary division of incurred costs and unbalanced cost-recovery as highlighted in Foster and Witte (2020). For example, a question like whether volumetric design should be applied to residential consumers or if a capacity – demand type of design should be used are determined not through reasoned decision processes but by a combination of historical precedent and ad-hoc decisions. To complicate matters, in many economies the electricity sector has been opened to competition, and market-driven energy management at the transmission level is practiced even though the retail distribution level is not fully market driven. Services like system reserves required for reliable electricity supply are now opened up for small and marginal prosumers which complicates network energy management (Woo et al., 2014). The question of how renewable energy systems are impacting service providers also needs to be explored in the context of tariff designs rather than merely as an issue of energy cost (Sioshansi, 2016). In the immediate future, interaction between service providers and consumers or prosumers will need tariff structures that are built on tariff designs selected through a Multi-Criteria Decision Making (MCDM) approach (Ayo-Vaughan, 2022). The research question (RQ) addressed in this work is whether an MCDM methodology can be developed that utilizes the literature on independent tariff designs to select the most appropriate tariff design. Criteria from literature on electricity tariff design show interdependencies; hence, the ANP should be particularly suited for the context.

RQ: Can an ANP-based framework be developed to select the most appropriate tariff design from the set of commonly used tariff designs considering both qualitative and quantitative criteria from the literature?

The current work investigates the relevance of applying multi-criteria decision making using the ANP to select the most appropriate tariff design framework. This will help incorporate qualitative criteria like transparency, stability of tariff designs under different scenarios, simplicity and equity in addition to the quantitative criteria assessed through technical and accounting methods. The inclusion of quantitative criteria like cost recovery, revenue requirement and economic efficiency along with qualitative criteria is made possible by using a MCDM method like the Analytic Network Process (ANP) as it allows interdependencies of criteria to be built into the decision model (Saaty & Vargas, 2006). Four basic tariff designs that have been used in different forms by utilities all over the world are compared using the ANP. MCDM as a major research area covers a number of methods and approaches to problems spanning fields like infrastructure planning, renewable energy and business economics (Kumar et al., 2017).Some of these methods are only able to deal with linear constraints for model building. The ANP is unique in that it is a non-linear method well-suited for interdependencies of constraints in practical applications. In ANP formulation as given in Saaty and Vargas (2006), components made of elements are connected in subnetworks and networks which allow propagation of influences between the components and elements. A well-developed decision process framework is relevant to regulatory bodies in all countries tasked with setting operational standards and revenue models for electricity utilities using, producing or trading electricity.

2. Methodology

In this paper, an ANP framework for selecting tariff designs for electricity distribution networks is developed. The ANP requires listing factors as well as pair-wise comparison covering all the factors. Data available in the literature about different tariff designs was used to provide the factor dependencies as well as relative comparisons. The following methodology was used.

Step 1: List the basic tariff designs forming the set of possible solutions.
Step 2: Using modified Bonbright principles of utility rate making, identify the comparison criteria as main criteria and subcriteria following a hierarchy.
Step 3: Validate the proposed tariff design selection factors/criteria through discussion with a group of experts.
Step 4: Generate quantitative assessment data for the identified basic tariff designs following Steps 5a – 5c.
Step 5a – Step 5c:
  a: Select representative tariffs under each type of tariff design that has been used by electric utilities in Australia within the last five years as it has a mature electricity market mechanism.
  b: In the case of Real Time Pricing, use openly available energy trading data from the Australian Energy Market Operator aligned with the time period during which the tariffs in Step 4a were applicable.
  c: Evaluate the representative tariffs with respect to energy use, demand on network, peak demand, coincident demand and total charges.
Step 6: Identify the qualitative strengths and weaknesses of the listed tariff designs by performing a literature search using key terms relating to the qualitative subcriteria listed in Step 2
Step 7: Identify relevant studies from the literature on the representative tariff designs through a targeted keyword search in databases like IEEE Xplore, Google Scholar, Web of Science, etc.
Step 8: Prepare the Benefits-Opportunities-Costs-Risks (BOCR) model of the ANP from the criteria and subcriteria relationships identified in Steps 3 - 4. Set the basic tariff designs being compared as alternatives in the BOCR model.
Step 9: Carry out pairwise comparison of the ANP network clusters and alternatives. Data provided by research reported in the literature is used to prepare the pairwise criteria comparisons, both qualitative and quantitative. The quantitative comparisons from Step 5 supplement the comparison under energy charges, demand charges and correlation to energy use by consumers
Step9: Apply the consistency check to the ANP-BOCR model and validate the model.
Step 10: Run the validated BOCR model and generate the synthesized ranking of the tariff designs.
Step11: Perform a sensitivity analysis to understand the variability of rankings under changes to the merit ratings which will show the impacts.

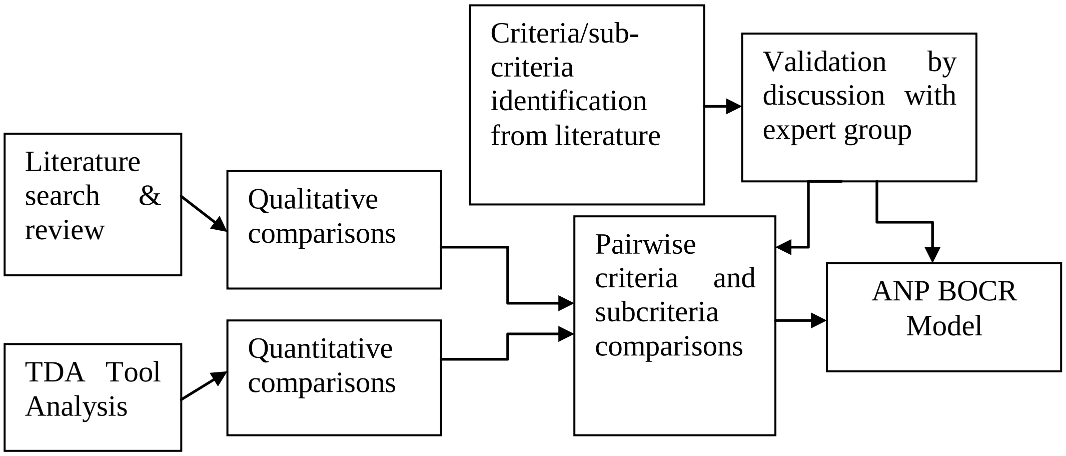

Figure 1 Sequence of workflow in pre-processing for applying the ANP

The qualitative pairwise comparisons underlying the BOCR model are derived from reported studies on tariff designs in the literature. The articles were identified using keyword searches covering the tariff design alternatives - “electricity tariff”, “business models, electricity networks”, and “electricity tariff design”. The databases used in the search were Google Scholar and IEEE Xplore as well as specific journal collections - Science Direct, Taylor and Francis, Wiley and Springer Nature based on initial search. The articles, after being screened for applicability, are listed in Table 6. For assessing the economic aspects of the different tariff designs, representative tariffs from Australia corresponding to the energy and capacity tariff designs and applicable to users at distribution-level were selected. For equitable comparison, the tariff schedule corresponding to real time pricing was compiled using data from the Australian Energy Market Operator. In the case of hybrid tariff design, a tariff structure built by modifying a tariff schedule from an Australian distribution service provider was used in the quantitative evaluations.

3. Tariff structure and designs

Even though there are numerous tariff designs in use all over the world covering multiple classes of consumers, types of service etc., the basic tariff designs are either static or dynamic. Of these, block energy tariffs and simple capacity tariffs are static, while marginal or spot prices as well as different forms of Time of Use tariffs are dynamic tariff designs. In the current work, the representative tariff designs considered are as follows:

1. Energy charges in the form of volumetric charges,
2. Capacity charges as demand-based charges,
3. Short Range Marginal Cost (SRMC) pricing or Real Time Pricing (RTP)
4. Energy and capacity charges with coincident peak pricing.

Coincident Peak Pricing (CPP) in itself is a dynamic tariff design coming under the Time-of-Use design, while energy and simple capacity tariff designs are static in nature. Setting an electricity tariff is a three-step process under the traditional regulatory or policy approach:

1. Determine the cost function for providing electricity and grid services for each group of entities with similar energy characteristics in the generation and distribution segments.
2. Apportion the cost of energy and ancillary services and an allowed surplus for the service provider to each group.
3. Prepare a tariff structure after selecting a design. Tariff designs can be any one or a combination of energy charges, capacity charges, network use charges etc.

Many regulatory bodies select tariff designs by following historic trends rather than by synthesis of design elements with defining constraints in a decision making framework. At the present stage of evolution of the electricity markets, only in a few countries and regions like the U.S, EU and Australia have there been consistent efforts towards competitive electricity markets covering retail energy business. Therefore, electricity pricing is a highly contentious and debated decision making process which should be addressed using rational decision making methodologies (Faruqui & Bourbonnais, 2020). The four tariff designs considered in this article to elucidate the method of selecting tariff designs using the ANP are described next. Note that one of the designs is a proposed tariff design for electricity pricing in countries that are facing challenges in moving to fully deregulated electricity markets.

3.1 Tariff designs

Energy or Volumetric charges: Volumetric charges are flat rate charges for the consumer arrived at by multiplying the quantum of energy used and an average price per unit of energy consumed or generated. The average cost per unit of energy is made up of the cost of energy purchased by the utility, a fixed distribution loss component and the distribution network operating cost as in Equation 1. Specific tax components are not considered here for the sake of simplicity.

$$W_v = \left(\sum_{p=1}^{m} C_p \,/\, \sum_{p=1}^{m} U_p\right) + \left[\left(C_{dnw} + C_{tnw}\right) / \sum_{p=1}^{m} U_p\right] + \left(C_{oh} \,/ \sum_{p=1}^{m} U_p\right) \tag{1}$$

W_v : volumetric price per unit to consumer
C_p : total cost of bought energy from source p
C_{tnw} : aggregate transmission network use charges
C_{dnw} : aggregate distribution network use charges
C_{oh} : operation, maintenance and administrative overheads
U_p : aggregate energy units bought by the Utility in control period

Volumetric tariff design, a simple but equitable distribution of costs across customer groups with varied characteristics, is not easy. With volumetric tariff design, the Distribution System Operator (DSO) or Utility will face lower recoveries when Distributed Energy Resources (DERs) are added to the network. A strictly volumetric design will lead to under-pricing, as the peak capacity of the grid should be retained for meeting peak time energy demands of the consumers when DERs are not supplying power. It offers undue advantage to prosumers, as there is no charge when self-generation and consumption occurs while the network needs to be designed to meet the peak demand. Cost reflectivity is thus very difficult to achieve.

Capacity or demand charges: As a network is supplying a varied set of network connected entities (NCE), it is the aggregate demand that decides the peak capacity requirement on the network rather than the individual volumetric consumption. In such a case, charges can be computed for usage of the network by apportioning the network capacity costs including the operational expenses to maintain the network capacity, across the consumer base. Long-term investment costs are included in this approach allowing the utility to plan capacity additions within a time horizon. However it is not an equitable tariff design for small consumers. Of the several ways of dividing the total capacity built into the network, one simple variation is given in Equation 2:

$$W_c = \sum_{i=1}^{n} (C_{wa,i} + C_{am,i}) \,/\, \sum_{j=1}^{m} n_j \qquad (2)$$

W_c : capacity price for consumer per unit
$C_{wa,i}$: weighted asset costs (time value)
$C_{am,i}$: asset management costs
n_j : number of consumers assuming single group for simplicity

In practice, calculation methods used by regulatory bodies follow accounting principles for the asset values and will include depreciation, asset grouping, segregating consumers into tariff groups, using weightage for such groups, etc. For the present discussion, the simplified basis will be sufficient to understand the cost recovery aspects and implementation.

Short Range Marginal Cost (SRMC): Economic theory posits that it is the incremental cost in meeting demand that most clearly reflects the additional economic cost incurred on the supply side to meet each additional unit of demand. Application of marginal cost concept in electricity tariff design selection will get consumers to respond systematically and rationally to the real-time cost of electricity consumption at a particular point of operation (Kaye & Outhred, 1989). By definition, SRMC is the incremental cost of supply for additional energy supplied, as in Equation 3, under the assumption that the network *status quo* is maintained. This is also called Real Time Pricing (RTP).

$$\text{SRMC} = M_{cp,t} \qquad (3)$$

$M_{cp,t}$: Market clearing price, a function of demand, supply, time and location.

Following RTP should bring in elasticity of demand which can contribute to demand management and reduce system costs. Modern electrical networks with reliable communication links between the consumers and aggregators are required as the energy market price will fluctuate in real time. Another shortcoming of the SRMC due to the random variability in prices is the unpredictability of long-term surplus for the service provider. It is clear that in an electricity market following spot pricing, the locational (x) and temporal (t) dependencies imply that the prices are dynamic and cost-responsive. Prices are arrived at following complex calculation and settlement methods, usually auction-based, which are not feasible in distribution networks under transition. In almost all deregulated markets, electricity markets function with averaged spot prices instead of pure locational pricing to avoid complexities in transactions.

Energy and Demand Charges with Coincident Peak Pricing: A realignment of the hierarchical building blocks of electricity networks providing generation, transmission and distribution functions are altering the command and control strategies of electricity networks (Ratnam, Palaniswamy & Yang, 2020). A tariff with an energy charge component and a coincident network demand component should provide a cost-reflective and cost recovery-oriented operational design for tariffs as in Equation 4:

$$C_{elec} = (C_{capacity} + C_{energy})|_{(x,t)} \qquad (4)$$

C_{elec} is the cost of electricity at time (t) in the spatial location (x)
$C_{capacity}$ is the cost for building and maintaining capacity with x, t dependencies
C_{energy} is the cost of supplying energy to location x, at time t.

In the time-dependent energy and capacity tariff, the location dependency can be averaged over a small area of service using appropriate loss factors rather than very large geographic spreads which is the norm in today's networks. Such a tariff design will be especially applicable in limited area electricity networks like microgrids. The growing relevance of microgrids show that limited area networks, as shown in Figure 2, will play a key role in the further development of electricity grids (Lenhart & Araujo, 2021; Cagnano, De Tuglie & Mancarella, 2020).The capacity charge component is arrived at by summing demand profiles (daily or any set period) of load agglomerations over the service area. The hybrid tariff design is dynamic in nature as it has a time-of-use element in the Critical Peak Pricing component of the tariff.

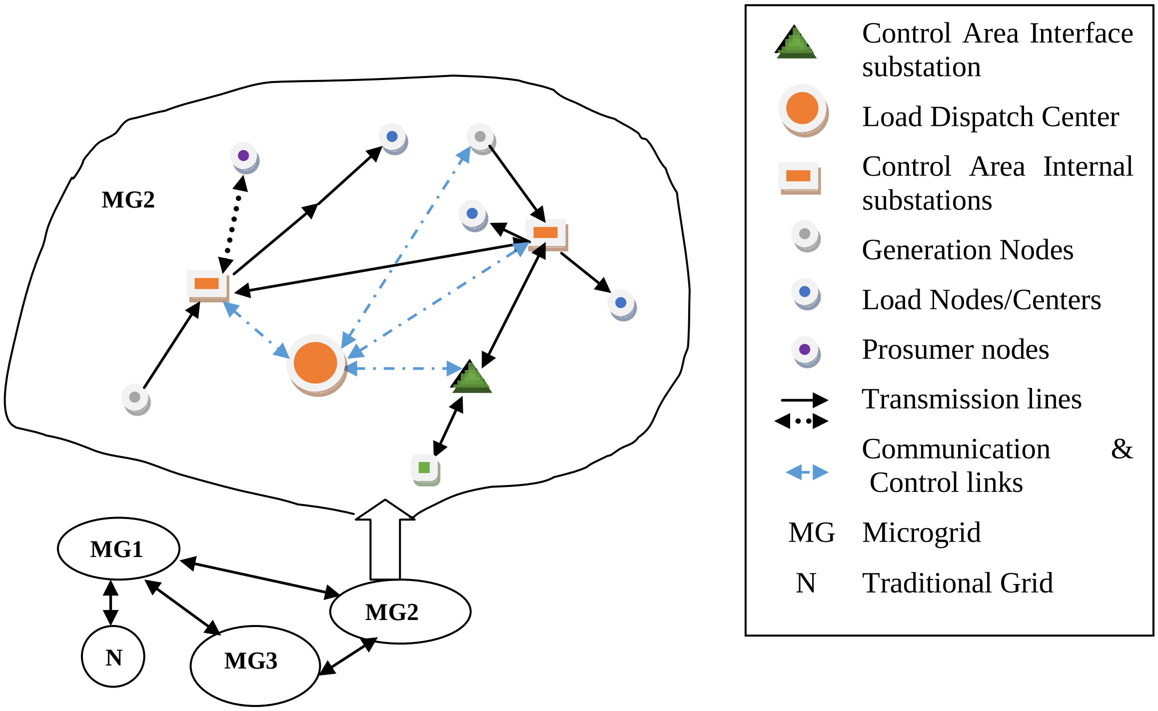

Figure 2 Limited area networks as sub-networks in the electricity grid

With a large increase of Distributed Generation in distribution networks, tariff designs should be able to meet certain conditions.

1. They should be cost reflective of services used by network connected entities (NCE). The cost of electricity as in Equations 5 and 6 have multiple components:

   $$\text{DUoS} + \text{TUoS} + \text{tax components} = \text{NUoS} \quad (5)$$

   $$\text{EC} + \text{NUoS} = \text{Total cost of electricity to the connected entity} \quad (6)$$

   DUoS - Distribution Network Use of System charges
   TUoS - Transmission Network Use of System charges
   NUoS - Network Use of System charges
   EC - Energy costs
2. Tariffs should provide economic signals to control demand variations. In the proposed CPP tariff design, the time-of-use pricing structure provides the consumer with price signals based on when the consumer demand is coincident with network aggregate demand (coincident peak).
3. When net metering is used, the prosumer is remunerated for energy fed into the grid at the same rate fixed for consumption so as to bring about parity.
4. Tariff design for Network Connected Entities (NCE) with self-generation in the distribution network should also contribute to recovering the distribution network investments of DSO/Utility under the cost causative principle. This is necessary since prosumers usually retain full capacity connections and utilize these whenever self-generation is either not there or is insufficient. Coincident demand billing allows the DSO to be remunerated for network capacity provisions.
5. Grid ancillary services like voltage control and frequency regulation are still needed even under the condition that feed-in from distributed generation to grid is positive.
6. Complexity should be minimized by avoiding too many interdependent constraints like multiple time slots of use and also by having clarity of price components.

Even in fully deregulated energy markets where one-to-one trading between producers and consumers of energy is allowed, capacity additions are necessary in the long term. Volumetric charges alone are not sufficient to meet these long-term investment needs. Peak demand pricing with network capacity charges on a proportional basis can be applied to all customers and generators so that network costs are recovered from the users including prosumers, improving the allocation efficiency. Many studies have shown that providing correct price signals across the network to consumers and generators will improve the utilization efficiency. Time of Use charges in the CPP mode will have a salutary effect on consumer response including more efficient capacity utilization through peak shifting and peak spreading (Passey et al., 2017).

3.2 Factors in tariff design and strategic criteria

In order to develop a methodological framework to evaluate tariff designs, the basic principles of electricity rate making need to be understood in the context of modern electric networks. In Brown and Faruqui (2014), the Bonbright principles were amended for use in the case of modern electric grids. These are economic efficiency equity, revenue stability, bill stability and customer satisfaction (Faruqui & Bourbonnis, 2020).

Combining revenue stability and bill stability under the revenue model is feasible as it is the selected revenue model which will ensure revenue stability for utilities and bill stability for network connected entities. A study on the volatility of electricity pricing using a MCDM method, the interval-valued intuitionist hesitant fuzzy sets method, establishes pricing dependency on two aggregating factors – Economic and Political, and Environmental and Technological (Wang et al., 2020). Universal access to electricity, one of the Sustainable Developmental Goals of the U.N., requires innovations in related technological and economic or financial aspects as well as operational aspects (Cantarero, 2020; Glachant, 2021). Considering these, the following three aspects are identified as classifiers in the ANP model:

a. Technological aspects: Electric network security and stability control which have been centralized functions until now will become increasingly distributed and require a robust communication backbone with an extensive data analytics infrastructure (Ghorbanian et al., 2019). Grid management functions at transmission level like frequency control and voltage stability will be converted as value adding services in the new scenario (Burger & Luke, 2017). More interestingly, technological advancements are enabling participative energy management programs in new grid topologies thereby extending business value capture modes to new services (Hamwi, Lizarralde & Legardeur, 2021).
b. Operational aspect: Distributed generation (DG) and renewable energy sourcing, when combined with the defining requirements for intelligent and resilient grids, opens up new business value streams for the entities in the electricity sector (Bai, Yang & Zhang, 2016). Reactive power management, for example, has long been included in service providers' reliability control portfolio, but increasing amounts of DG make it a value-sharing business stream if pricing is done through an appropriate tariff design (Satchwell & Cappers, 2018). This requires a regulatory mandate. As the value of electricity and energy services shifts rapidly in a renewable rich energy market, new business models should convert the utility to a digital, resilient utility (Vijay et al., 2017). A number of identified independent business entities are in this framework developed on the basis of value creation, delivery and value capture (De Martini, 2019). Similarly, microgrids provide value streams in areas like Demand Response (DR), energy markets and improved resiliency (Stadler et al., 2016). Energy-attribute dependent characteristics of Smart Cities can be harnessed through business model innovation by energy utilities to tap the emerging economic opportunities in new electricity networks (Masera et al., 2018).
c. Financial aspect: Social welfare takes a hit when traditional tariff designs are used under an increasing prosumer presence (Pollitt, 2018). Energy poverty and tariff impacts due to increasing renewable support programs will have regressive effects on society as a whole if proper tariff designs are not chosen (Mastropietro, 2019).Regulatory control and policy guidelines are needed to convert the opportunity for low-cost renewable energy into a societal good (Bogdanov et al., 2021).

3.3 Quantitative comparisons of representative tariff designs

In investigating the impact of standard tariff designs, representative tariffs from the Australian electricity sector were used. The choice of Australian tariffs was driven by the following reasons:

a. The Australian energy market has reached a high maturity level so that studying impacts of tariffs and the interactions of an energy market under variable supply and demand conditions is useful for transitioning regions or countries.
b. Australian electricity supply network tariffs with tariff schedules under multiple design structures are available in the open domain along with related data. A number of studies have been conducted, primarily on residential electricity services, to determine the impact of tariffs and their changes on consumer behavior (Passey et al., 2017).
c. Availability of data (AEMO, 2017; AEMO, 2019) in the public domain makes it particularly attractive to base this study on an analysis of the Australian electricity sector which has an established and extensive market operation under the Australian Energy Market Operator (AEMO) at the transmission level.
d. There are a large number of energy service providers at the retail level which source energy from a wide mix while operating under the Independent System Operator (ISO) mandated control for a secure and reliable grid.
e. It is of note that Australian residential solar PV systems generated around 9000 GWh of electricity in 2017 (AEC, 2018). Since then, there has been an even more accelerated increase in the distributed generation.

The Australian case study is thus representative of transitioning electricity networks that are moving from traditional to new architectures. Quantitative criteria relate mainly to economic efficiency and revenue model ratings. The Tariff Design and Analysis (TDA) Tool from CEEM, University of New South Wales was used to evaluate the quantified economic impacts when different tariff designs are applied to different types of connected entities (CEEM, 2017). The TDA tool contains sets of actual residential consumer data from energy management projects in Australia like the AusGrid 300 project and Smart Grid Smart City. The tariff designs used for analysis are shown in Table 1 with further details in Appendix 1A. In the case of SRMC pricing, data (Appendix 1B) from the Australian Energy Market Operator (AEMO) and the load data from the AusGrid 300/SGSC data sets in the TDA Tool database were used after developing a tariff structure consistent with half hourly AEMO prices (Ausgrid, 2020). In order to render the comparisons meaningful, annualized charges were converted to a per day basis, since spot prices vary over the minimum pricing periods in the course of a day.

Table 1
Tariff designs and components under consideration for comparison

DSO	Tariff type/ Pricing method	Tariff identification	Method	Remarks
Energex, Australia	Volumetric energy/flat rate	Residential Flat NTC 8400 2017-18	Supply charge + Usage charge	Supply charge to be excluded when treating design as energy charge tariff
	Capacity/demand	Residential Demand NTC 7000 2017-18	Supply charge + usage charge + demand charge	Supply, usage charges to be excluded to consider tariff design as pure capacity tariff
NA	SRMC	Spot pricing in AEMO	Usage charges under marginal pricing	Loss factor calculations provide use of system / capacity component
NA	Energy and capacity charges with coincident peak pricing	Modified NTC7000 (with coincident peak pricing)	Usage charge + capacity charge + dynamic demand charge	The coincident network peak component makes the demand charge dynamic.

In comparisons using the TDA Tool, appropriate changes in the selected Energex tariff designs were made to make them representative of energy charges or capacity charges, respectively (see Table 1). In generating the spot pricing schedule, spot price data for two dates from the summer and winter seasons were selected from the AEMO spot prices database from the year 2017. A time-of-use tariff template was used to develop two pricing schedules for comparison. The loss factors involved in transferring energy bought on the national energy market through transmission network set at an average of 1.10 as an upper bound were used with these spot prices (AEMO, 2017). As it is represented in terms of $/kWh units, it was considered to represent the pay-out under TUoS to system operator. The proposed hybrid tariff design is a modified Energex 7000 Demand Tariff 2017-18 with peak pricing aligned to network peak. Such a coincident peak pricing method will show whether the network capacities are used by consumers in tandem. Significantly, it is this peak demand that necessitates the need for investments in network capacity by the DSO. Prosumers who can reduce electricity sourcing from the network at peak hours will benefit more under such coincident peak pricing. For the utility, the problem of maintaining a high level of unutilized network capacity for peak load use can be minimized while the prosumer is charged for the network capacity maintained. The network prosumers considered are the AusGrid 300 Solar Home project residential units having their own solar generation with metering data from 2011 to 2013 (Ausgrid, 2020).

In the TDA Tool, the gross metering and net metering options are provided with this data set enabling the consideration of consumer-prosumer behavior variability. The influence of network load profile when prosumers in aggregate start using storage solutions coupled with self-generation from solar power was studied in a simplified form by applying tariff analysis to an aggregate time-shifted profile of network load by 4 hours.

For comparative purposes, this is sufficient as it can be interpreted as use of stored energy during a designated grid peak time rather than the afternoon peak of solar generation. Three cases were considered when estimating the impact of tariff design on the bill for different load profiles. However, it should be noted that prosumer incentives are not considered here as the objective is to assess the basis of the tariff design in general.

Case 1: AusGrid 300 Solar Homes load group excluding solar generation using the gross metering data.
Case 2: AusGrid 300 Solar Homes load group including solar generation using the net metering data.
Case 3: AusGrid 300 Solar Homes load group including solar generation and shifting the aggregate load/network load profile by 4 hours. This is equivalent to energy storage being used during network peak time defined to be from 16:00 hrs to 20:00 hrs.

The three cases are shown in Figure 3.

For the Network Connected Entity (NCE), the favorable shift in outgo for different bill components is clear – the coincident energy and capacity tariff design provides the optimal fit. Modified tariff design Energex 7000 with coincident network peak proves better when prosumers with energy storage are considered. The net shifted consumption evaluation was done with a shift of load pattern by 4 hours to simulate use of storage in the peak period. The Modified 7000 tariff design was shown to be better for gross-metered consumers because of the absence of a “Daily charges” component. For the utility, the apparent loss of surplus when moving to coincident peak pricing need not really be so as network capacity costs get shared by all connected users depending on the capacity use. Furthermore, it is a more equitable design from the cost reflective point of view. By considering the component charges of a tariff design as functions of parameters like consumption, demand and network coincident peaks, it is possible to determine how these are correlated. Unitized bill value computed according to Passey et al. (2017) helps in the visualization of the correlation between network costs and what the customer pays. Unitized bill is the weighted average kW consumed in a month for which the consumer is charged.

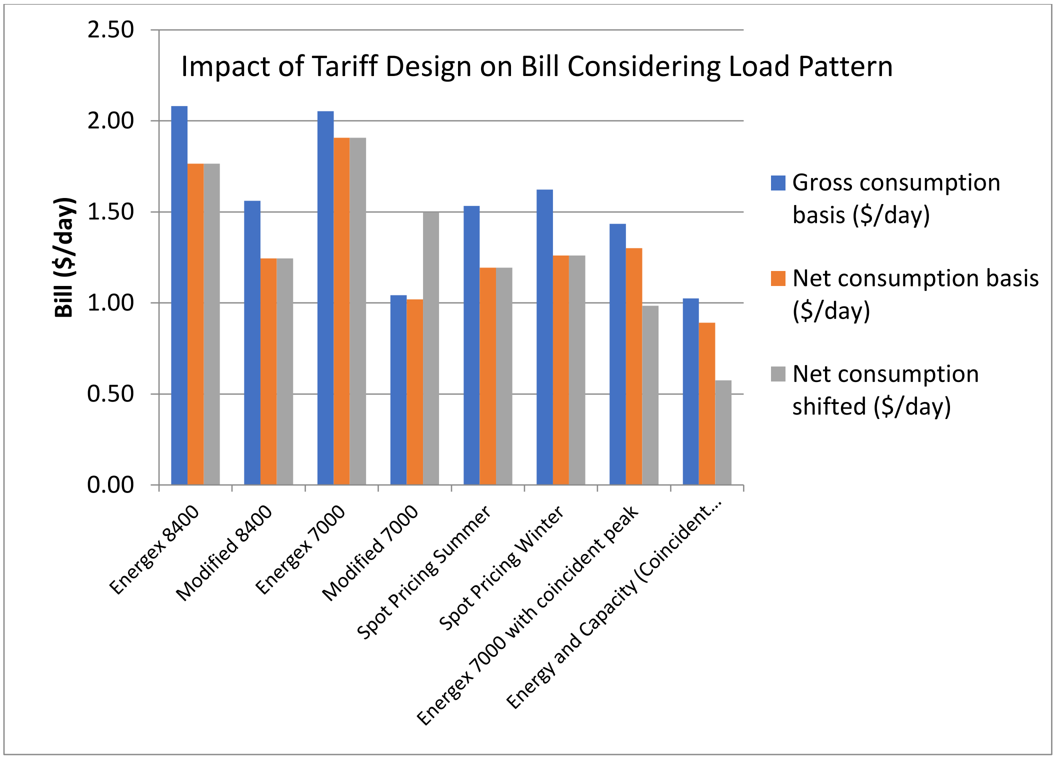

Figure 3 Comparison of NCE / user bills under different tariff designs

Pearson correlation coefficients for the relationship between a unitized bill and identified parameters were calculated for the load derived data using the TDA Tool. These are shown in Figure 4 for the tariff designs under consideration. When self-generation is considered the calculations were redone and the results are shown in Figure 5. Note the strong correlation with the energy use pattern as well as peak capacity use shown by the hybrid tariff designs – Energex 7000 with CPP, Energy and Capacity (CPP). It is of note that perfect correlation is non-existent for any of these tariff designs. The graphical representations show how well tariff designs track the connected load usage patterns in terms of energy use, capacity and peak demand under the conditions with and without self-generation. A flat energy tariff provides direct correlation to average daily energy usage as do spot pricing modes. Network capacity charges under demand tariffs provide better correlation with average demand and network peaks. The hybrid coincident peak tariff designs with energy and capacity charges achieve better correlation when all the parameters are considered. The graphical representations show how well tariff designs track the connected load usage patterns in terms of energy use, capacity and peak demand under the conditions with and without self-generation. A flat energy tariff provides direct correlation to average daily energy usage as do spot pricing modes.

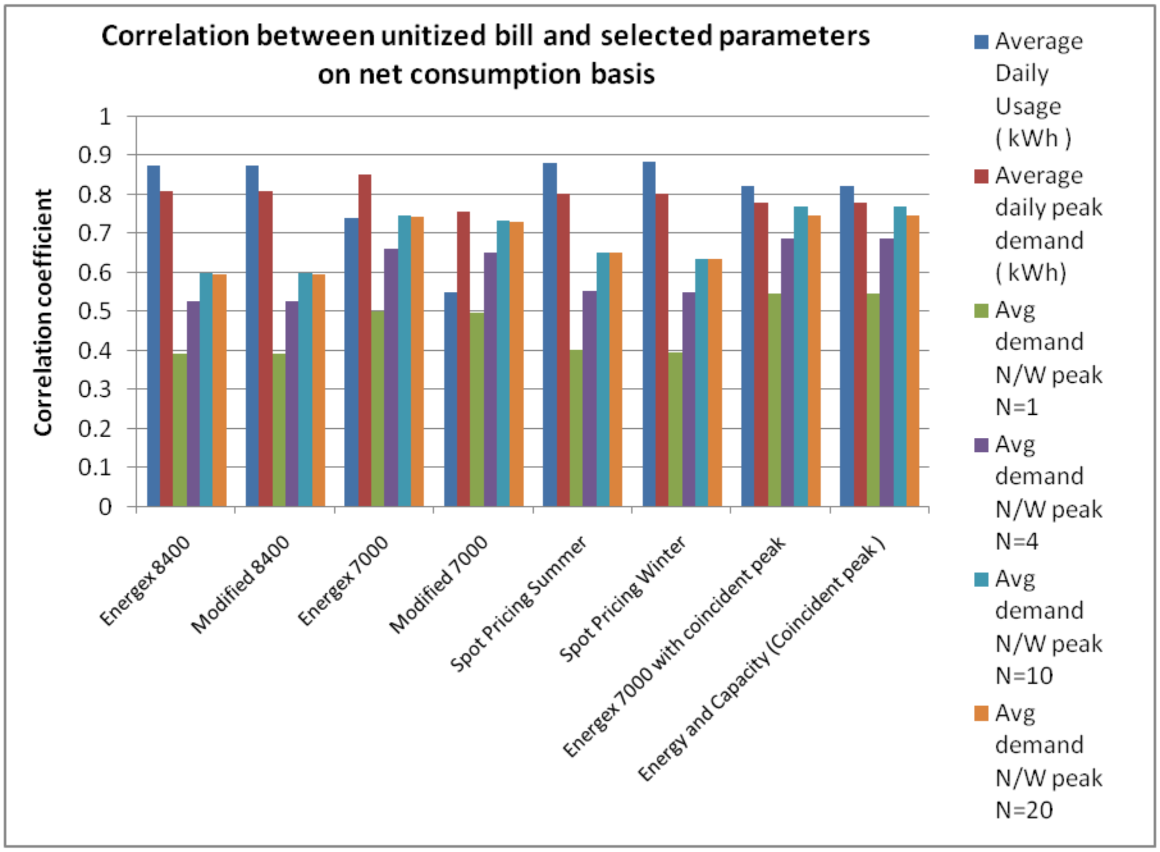

Figure 4 Correlation between the bill value and energy usage by a connected entity under different tariff designs (number of critical peak pricing periods (N) can be set and three samples are shown with N = 1, 3 and 10)

Network capacity charges under demand tariffs provide better correlation with average demand and network peaks. The hybrid coincident peak tariff designs with energy and capacity charges achieve better correlation when all the parameters are considered.

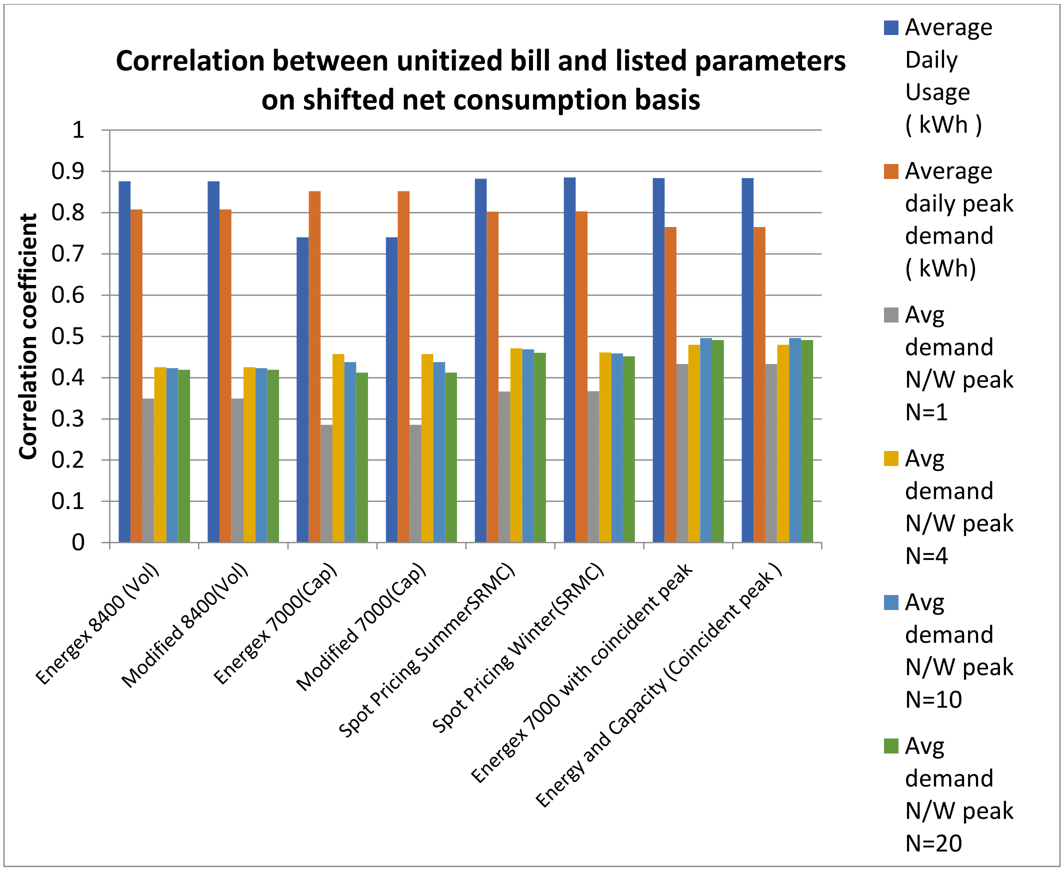

Figure 5 Correlation of unitized bill and consumption related parameters with self-generation

4. Analytic Network Process and tariff design

When decision variables show interdependencies which cannot be removed, the Analytic Network Process (ANP) that uses weighted matrix ranking of priorities between decision variables can be used. The underlying theory of supermatrix ranking of priorities requires the pairwise comparison of all the decision variables entering the solution set on an absolute measurement scale (Saaty & Vargas, 2006). In complex decision making through the ANP, the weights have an associated inconsistency. Inconsistency can be visualized as an enlargement of the solution space resulting from the set of pairwise comparisons being at variance with each other to some extent. An inconsistency index (C.I) is defined as in Equation 7 to track the level of inconsistency entering the decision making process.

$$C.I = \frac{(\lambda_{max} - 1)}{(n-1)} \qquad (7)$$

λ_{max}: maximum eigenvalue of comparison matrix A of order n.

According to Saaty & Vargas (2006) a figure of 10% or a ratio of 0.10 is acceptable as a sufficient upper limit for a consistency ratio. Elements of the ANP model constituting the clusters contribute to the Benefits, Opportunities, Costs and Risks (BOCR) sub-networks to meet the primary goal set for decision. These sub-networks build upon the interactions of the elements for the chosen set of alternatives which form the solution set. The strategic criteria and the sub-criteria are shown in the Figure 6.

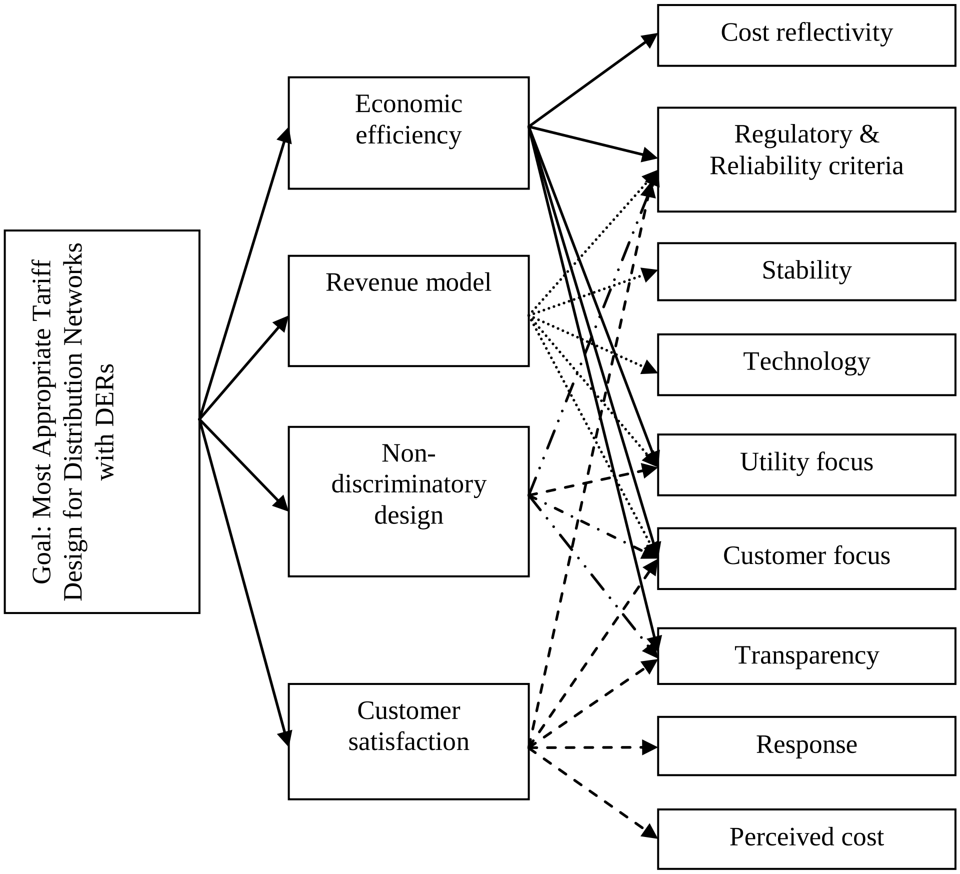

Figure 6 Strategic criteria and subcriteria for evaluation of tariff designs

The strategic criteria and subcriteria were developed in concordance with the literature on electricity tariffs (Brown & Faruqui, 2014; Faruqui & Bourbonnis, 2020).The impact of changes in the generation and use of electricity is also affecting the tariff design requirements and constraints as seen in Cantarero (2020), Glachant (2021), Satchwell and Cappers (2018) and De Martini (2019). The regulatory guidance aspects should be aligned to meet the goals of access and affordability under changes in the hierarchies of control (Mastropietro, 2019; Bogdanov et al., 2021) which are included as subcriteria under "Regulatory and Reliability criteria" as well as "Non-discriminatory design". Further aspects on developing the hierarchy of criteria are discussed in Section 3.2.

Four tariff designs, namely volumetric, capacity-demand, SRMC/RTP as well as Energy and Capacity with Coincident Peak Pricing are taken as the alternatives in the ANP model formulation. These are compared under the five broad criteria listed which are themselves made up of subcriteria. Utilities and NCEs are the broad groups which are considered to form the clusters which are influenced by the alternatives under the control criteria. The clusters and control criteria are listed in Tables 2–5.

Table 2
Benefits merit and clusters

BOCR Merit	Control criteria	Clusters	Elements
Benefits	Financial	Utility related	Segregation of network costs and other costs
			Proper service identification and costing
		NCE related	New ancillary service identification
			Cost-to-system based bill
	Operational	Utility related	Ease of use
			Flexibility
			Network infrastructure optimization
		NCE related	Compatibility of usage pattern
			Simplicity of design
	Technological	Utility related	Demand management
			Technology support services
		NCE related	Self-generation adaptability
			Technology neutral design

Table 3
Opportunities merit and clusters

BOCR Merit	Control criteria	Clusters	Elements
Opportunities	Financial	Utility related	Improved asset financial management
			Better planning of modernization
		NCE related	Better control over bill
	Operational	Utility related	Wide Demand Side Management program
			Innovative billing practices
		NCE related	Coordinated response to capacity limitations of network
			Preference of energy storage for demand response
	Technological	Utility related	Better/robust network control
		NCE related	Wider integration of Distributed Energy Resources

Table 4 shows the cost merit and the relevant clusters that have an effect on the alternatives under consideration.

Table 4
Cost merit and clusters

BOCR Merit	Control criteria	Clusters	Elements
Costs	Financial	Utility related	New billing methods with IT support
			Training and development costs
		NCE related	Short-term costs for support services
			Loss of cross subsidization
	Operational	Utility related	Large-scale change in metering infrastructure
			Loss of revenue due to regulatory criteria
		NCE related	Recurring costs for metering and billing services
	Technological	Utility related	Customization cost of advanced technology
			Revenue loss due to technology limitations
		NCE related	Upgradation cost for tariff related technology migration

The risks subnet is listed in Table 5. Tariff designs will have risks associated with each design for both Utility and NCE.

Table 5
Risks merit and clusters

BOCR Merit	Control criteria	Clusters	Elements
Risks	Financial	Utility related	Risk of lower aggregate revenue realization
		NCE related	Risk of unstable bill
	Operational	Utility related	Customer opposition against migration to new operational procedures
		NCE related	Exclusion of vulnerable and marginal users
	Technological	Utility related	Technology for advanced ancillary services
		NCE related	Dependence on proprietary technology limiting customer choice

The BOCR model is shown in Figure 7. The strategic criteria were derived from the literature on electricity tariff design.

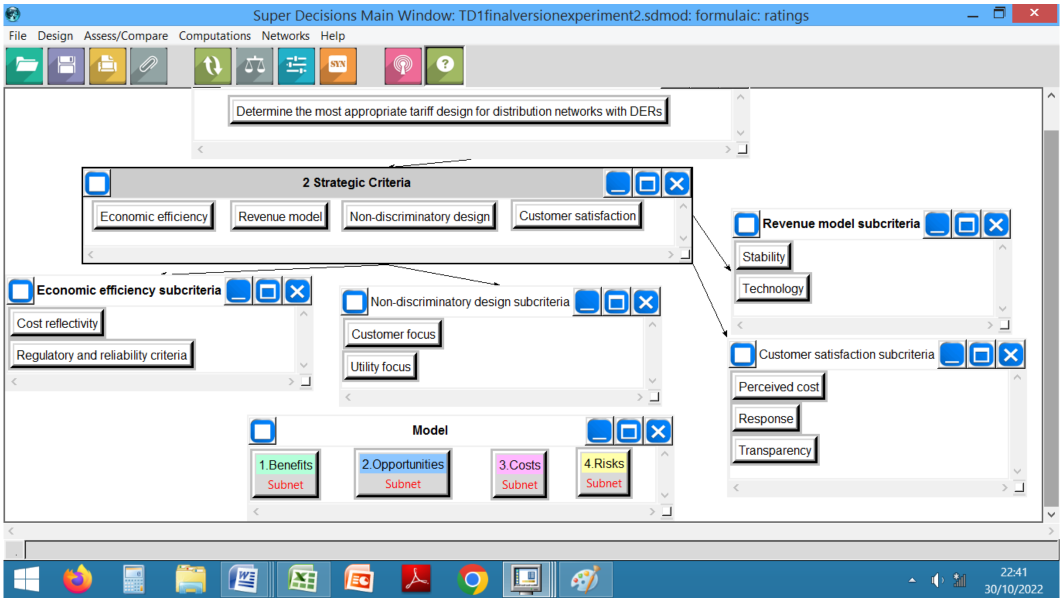

Figure 7 Screen view of the top level BOCR model

The model networks and sub-networks under each merit rating were configured. Three control criteria, namely Financial, Technological and Operational, were considered for all four ratings. Any tariff design will have financial implications for both the utility and the NCEs. To consider each control criteria and its impact on the goal or primary objective, other subcriteria were formed as clusters. For example, in the Benefits rating, under the Financial criteria, Utility related and NCE related are the clusters which represent the stakeholder-related factors. Technology has an important role in implementing tariff designs as some of the designs can be implemented with available technology while some need new technologies. Pairwise comparisons of the identified clusters and nodes should be based on expert opinions or studies if the ANP methodology is to provide valid results. Towards this end, a survey of the existing literature was found to provide significant inputs and this is tabulated in Table 6. This data was used to derive the pairwise comparisons in SuperDecisions® software. Of the five methods - graphical, verbal, matrix, questionnaire and direct - the questionnaire method with the Saaty scale of grading was utilized. This is because the inputs from the literature do not have a unique one-to-one correspondence across all the nodes or clusters. In the first place, combining these inputs is not possible in a simple additive fashion. In the proposed ANP framework model simulated in the SuperDecisions® software, the questionnaire mode was utilized to input the relative comparisons of the different tariff designs using the data in Table 6.

5. Simulation results and discussion

The quantitative assessments along with the qualitative guidance on tariff designs compiled from the reported literature was utilized to form the cross comparisons against each decision factor or node in the ANP model evaluating alternative tariff designs. The developed ANP model was created in SuperDecisions® software with the pairwise comparisons included in the influence matrices. The ANP model run generated a detailed analysis showing the control criteria, the clusters and nodes which are created through the network model under the BOCR framework. Figure 8 shows the priorities generated for each of the basic tariff designs listed as one of the alternatives. The limit priorities are given in Appendix 2.

The five strategic criteria were given equal weightage. In synthesizing the complete model, following the standard Additive approach (Saaty & Vargas, 2006), Benefits and Opportunities ratings were taken as positive priorities while Costs and Risks were negative priorities. The merit ratings were also given equal importance in the model evaluation initially. The overall rankings were computed using the standard subtractive formula given in Equation 8for multiple level networks in the ANP:

$$\text{Rank} = \text{Rank (Benefits)} + \text{Rank (Opportunities)} - \text{Rank (Costs)} - \text{Rank (Risks)} \qquad (8)$$

Table 6
Comparison of tariff designs in the literature

Comparison aspect	**Tariff design**	**Reference**	**Conclusion**
Lower recovery of system cost	Volumetric / flat, TOU without capacity charges	(Young, Bruce and MacGill, 2019)	Cost causation
Non-incentivization of self-generation	Tariff with capacity charges or fixed charges	(Young, Bruce and MacGill, 2019)	Affects self-generation
Network dependence and low self-generation	Multi-part tariffs with high capacity components	(Gunther, Schill and Zerralin, 2021)	Utility faces under recovery
	Feed-in tariffs improve self-generation		
Risk and equity in access	High base rate volumetric, Time-of-Use (TOU) and Coincident Peak Pricing(CPP)	(Jargstorf and Belman, 2015)	Responsive NCEs better placed
Preference for self-generation	Volumetric tariff , CPP		Positive for volumetric and negative for CPP
Demand management	TOU, CPP	(Faruqui and Sergici, 2010)	TOU: 3-6 % CPP:13-20%
Demand management with enabling technology	CPP	(Faruqui and Sergici, 2010)	CPP:27-44%
Preference for self-generation	Volumetric (export and import)	(Schittekatte, Momber and Meeus, 2018)	Net metering reduces cross subsidy
Nonlinear pricing		(Brown and Faruqui, 2014)	Better performance

Network supporting behavior by NCE	TOU / CPP	(Grunewald, Mckenna and Thomson, 2015)	High Distributed Energy Resource presence
Real time pricing	RTP /Ramsay methods	(Young, Bruce and MacGill, 2019)	Heterogeneity of NCEs not favorable
Multi-part tariffs	Volumetric and Capacity	(Apponen et al., 2017)	Cost causation based
Bill reduction	Time varying rates	(Darghouth, Barbose and Wiser,2011)	RTP and TOU/CPP are utility favorable but not prosumer friendly
Demand management	Dynamic pricing	(Jang et al., 2016)	Net demand should be used in tariffs
DER use	TOU/Demand tariffs	(Ansarin et al, 2020)	Volumetric designs not favourable
General rate design	Comparison of designs	(Revesz and Unel, 2020)	Regulatory guidance required
Rate designs	Comparison of selected tariffs	(Foster and Witte , 2020)	General comparison
Rate designs	Comparison of selected tariffs	(Schittekatte, Deschamps and Meus, 2021)	Regulatory guidance required
Cost reflective pricing	Tariff designs	(Hobman et al., 2016)	Acceptance of cost reflective tariffs

The priorities generated after comparison are shown in Figure 8. It is because of the high costs and the high risks invoved in switching to RTP that the overall ranking of the SRMC/RTP alternative is so low. Considering the current levels of technology and the user experiences, the most suitable tariff design is the hybrid design with Energy charges and Capacity charges with the coincident peak pricing component added. The improved communication technologies currently available are satisfactory for implementing the coincident peak pricing method integrated into the hybrid tariff design. As network costs are escalated by the increased standby capacity built into the networks for handling peak demand, coincident peak pricing provides an economic signal to the connected entities to respond to the dynamics of network energy flows. Significantly, it is the total peak demand that necessitates the need for investments in network capacity by the DSO. Prosumers that are able to reduce electricity sourcing from the network at peak hours will benefit more under such coincident peak pricing. Coincident Peak Pricing with Energy and Demand charges addresses three components of network management that have a direct bearing on the economics of operation – energy charges to meet peak energy requirement, infrastructure for meeting peak demand and providing self-generating consumers with full energy support in contingencies of failure in self-generation system.

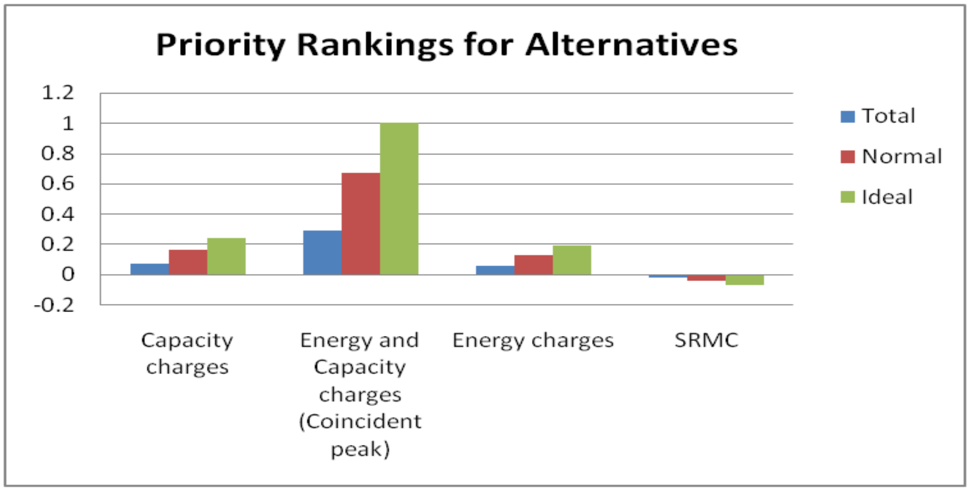

Figure 8 Priority rankings of the four tariff designs across Total,Normal and Ideal

The quantitative impacts of tariff design on the Network Connected Entity (NCE) are in Figures 3-5. The favorable shift in outgo for different bill components is clear; the Energy and Capacity charges with coincident peak pricing tariff design provides the optimal fit. For the utility, there is an apparent loss of surplus when moving to coincident peak pricing, but it will not persist as network capacity costs get shared by all connected users depending on the capacity used by each NCE-related to network peak energy requirement. Further, it is a more equitable design from the cost reflective point of view. It is also important to understand how the priority rankings of the alternatives are affeccted when the weightages of the priorities are changed. In order to to do, this four senstivity analyses were performed covering Benefits, Opportunities, Costs and Risks. The results are graphically shown in Figures 9-12.

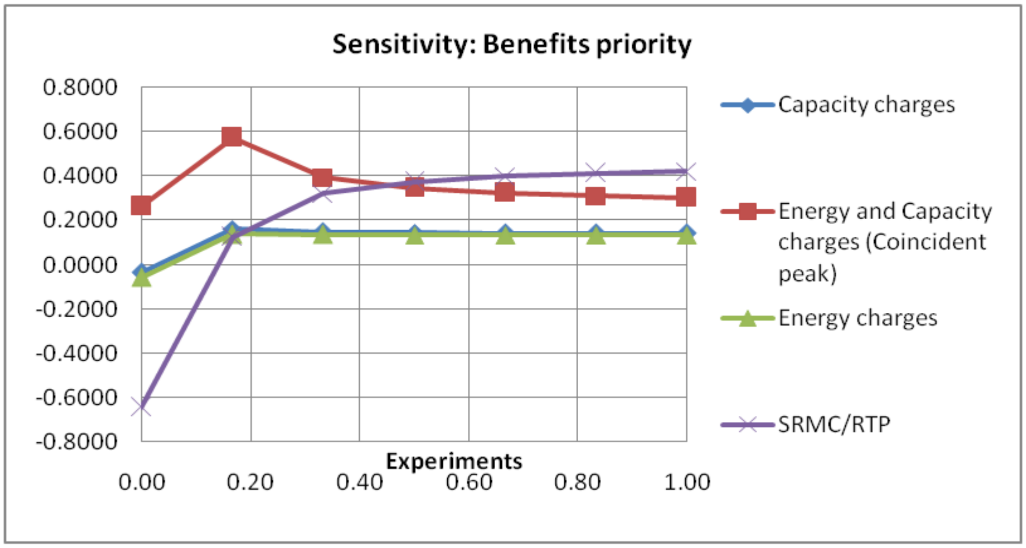

Figure 9 Sensitivity analysis of the Benefits merit (any combination of BOCR merits should add up to 1)

In the case of Opportunities, the sensitivity curves are shown in Figure 9. The hybrid design is preferred if opportunities under both the utility and NCE clusters are considered. However, as the weightage for opportunities is increased, RTP also becomes favorable along with the hybrid design.

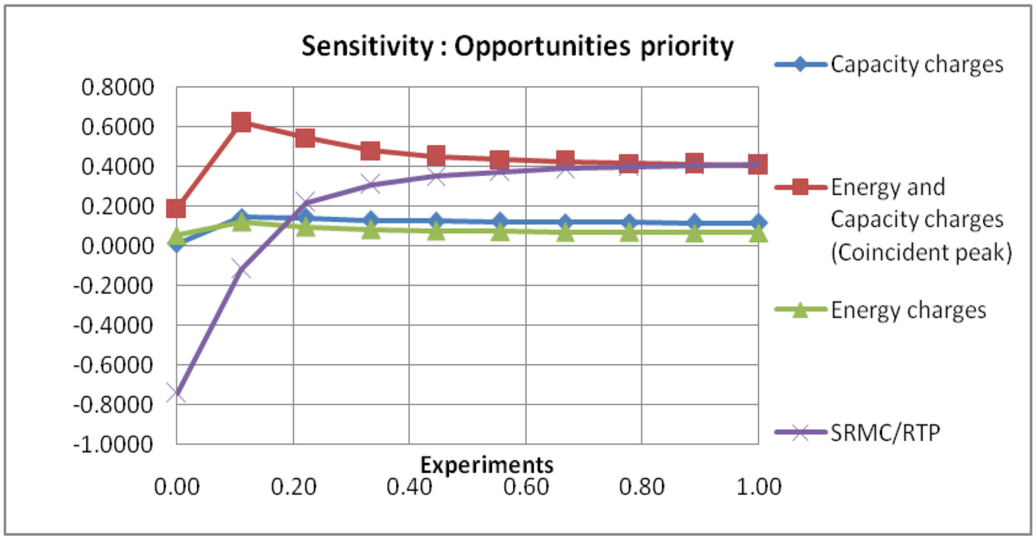

Figure 10 Sensitivity curve for Opportunities

The ANP framework shows that when the Costs merit is considered, the ranking changes from Energy and Capacity Charges with CPP tariff design to Energy charges tariff design beyond the 56% level. This is supported by the fact that cost of technology plays an important role in addition to the coincident peak pricing component increasingly contributing to the costs impact of the tariff design.

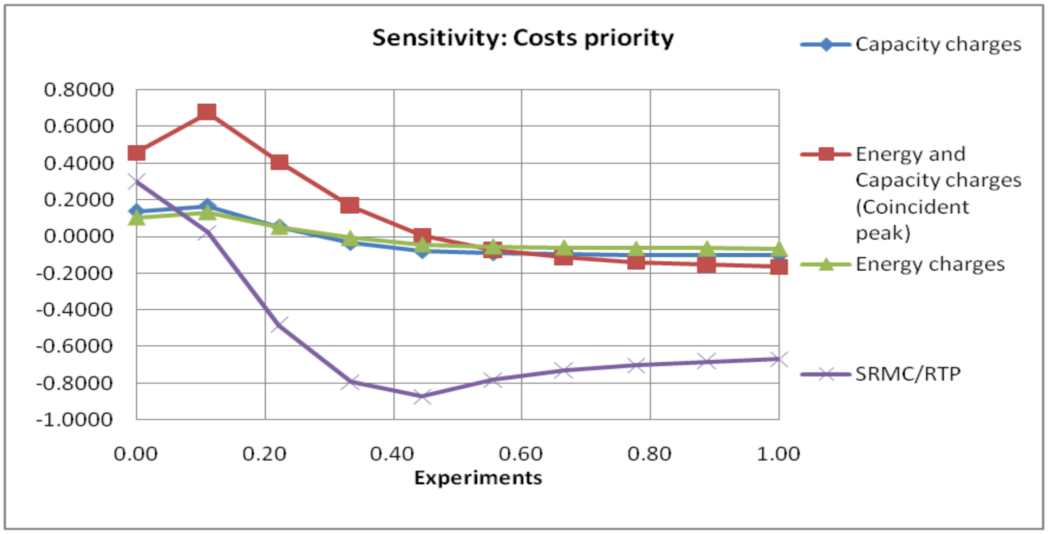

Figure 11 Costs priority weightage influencing the ranking

Energy and Capacity charges with CPP is the most favorable alternative when the priority weightage is less than 67%. Beyond this, the associated risks with the three tariff designs excluding SRMC are equally ranked. The risks with the SRMC RTP design are very high throughout.

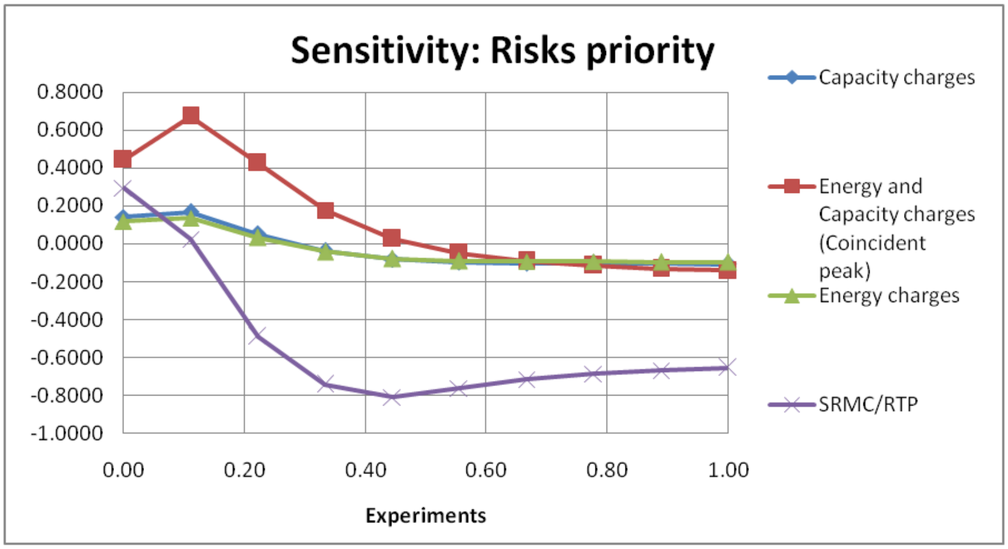

Figure12 Sensitivity of rankings to Opportunities weightage

All three designs, except RTP, are in use in one form or another in distribution networks all over the world, and many studies have confirmed that the risk elements attached to these are indeed low. The strength of the ANP methodology for selecting the appropriate tariff design lies in providing a logical basis to combine the conclusions of independent studies on tariff design impacts. A direct approach requires independent studies of qualitative factors (like equity of access) and quantitative factors (like cost-causation) which then need to be combined using some mechanism. These can then be used as the inputs to derive the influence matrix after formulating control criteria related to the BOCR merits. Even so, quantitative inputs on financial performance of utilities, customer costs and network upgradation are to be determined through requirement analysis and financial modeling. As an MCDM method, the ANP-based tariff design will supplement these methods by combining both qualitative and quantitative considerations in the selection of tariff design to meet multiple objectives.

6. Conclusion

The changes occurring in the electricity sector across technological, economic and social dimensions have impacted the business models of utilities. Electricity tariff design plays a key role as the interface between utilities and NCEs. Selection of tariff designs should depart from historical approaches such that selecting the most appropriate design takes into account the interdependencies of the guiding principles. The Analytic Network Process, an MCDM approach, is particularly suitable where interdependencies of decision factors exist and cannot be linearized realistically. The ANP method for tariff design selection was developed by building a BOCR model frame of reference. The clusters and elements making up the ANP networks as well as subnetworks were formed by referring to the five strategic criteria from the basic principles of tariff design. A relative ranking of four alternatives, the four tariff designs Volumetric, Capacity-Demand, SRMC or RTP and a hybrid Energy-capacity with CPP was completed. RTP requires a highly reliable communication backbone as well as a social environment that has a highly informed and active set of NCEs. This situation can be obtained in highly developed countries. A change in the merit weightages to match the realistic situation prevailing in transition economies characterized by low technology readiness and not too high levels of social development shows that wide application of tariff designs like RTP is not an acceptable solution. A sensitivity analysis with the four merit ratings of the BOCR model shows that the Energy and Capacity with Coincident Peak Pricing design is the preferred design. In transition economies, the technology readiness levels will not match that expected for RTP implementation partly because of the highly heterogeneous consumer group. Here, the Energy and Capacity with CPP (or Multi-part) design can be used as it has lower technological requirements and lower costs and risks. Utilities in such economies can implement progressive TOU tariff designs like CPP to take advantage of available technology infrastructure while introducing an economically preferable tariff design.

Application of the ANP methodology has limitations when considering solution alternatives exceeding four or five elements as the pairwise comparisons get unwieldy. Arriving at the appropriate strategic criteria and the identification of the right control criteria can happen only through informed and well-researched study of the underlying theoretical aspects. The implication is that the ANP cannot assure realistic solutions unless the model synthesis is done based on extant theory as well as practical considerations. Even so, the ANP is useful as a MCDM methodology given the correct prioritizing comparisons are used to determine which is the appropriate tariff design adapted to the social, economic and technological environment.

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APPENDICES

Appendix 1A
Detailed tariff rates from the Australia

Tariff	Daily Charges ($/day)			Energy ($/kWh)			Capacity/Demand ($/kW/month)			Remarks
	DUoS	**TUoS**	**NUoS**	**DUoS**	**TUoS**	**NUoS**	**DUoS**	**TUoS**	**NUoS**	
Energex 8400	0.4466	0.0715	0.5181	0.0862	0.0158	0.1020				A daily charge for additional DSO services included
Modified 8400				0.0862	0.0158	0.1020				Daily charges excluded
Energex 7000	0.4801	0	0.4081	0.035861	0.003432	0.039193	6.5879	2.1648	8.7527	Includes Daily and energy charges though tariff is called demand tariff.
Modified 7000							6.5879	2.1648	8.7527	Daily and energy charges excluded
Spot Pricing-summer day				Half-hour AEMO rates (3/1/17)	Loss factor for network added	Total energy cost				Tariff is marginal cost pricing
Spot Pricing-winter day				Half-hour AEMO rates (3/7/17)	Loss factor for network added	Total energy cost				Tariff is marginal cost pricing
Energex 7000 with Coincident peak pricing	0.4801	0	0.4081	0.035861	0.003432	0.039193	6.5879	2.1648	8.7527	Coincident network peak matching instead of fixed time interval
Energy & Capacity with Coincident peak pricing				0.035861	0.003432	0.039193	6.5879	2.1648	8.7527	Coincident network peak matching without daily charges

Appendix 1B

Spot prices from AEMO database adapted to basis ($/kWh)

	Time	RRP ($/kWh)		Time	RRP ($/kWh)
03/01/2017	00:00	0.06559	03/07/2017	00:00	0.06173
	00:30	0.04578		00:30	0.062
	01:00	0.04791		01:00	0.06115
	01:30	0.04504		01:30	0.06014
	02:00	0.04692		02:00	0.06121
	02:30	0.0446		02:30	0.07045
	03:00	0.04672		03:00	0.0648
	03:30	0.04327		03:30	0.06488
	04:00	0.04322		04:00	0.06486
	04:30	0.04383		04:30	0.06235
	05:00	0.05192		05:00	0.06481
	05:30	0.052		05:30	0.06485
	06:00	0.05095		06:00	0.05991
	06:30	0.06667		06:30	0.07534
	07:00	0.08191		07:00	0.19347
	07:30	0.06783		07:30	0.10446
	08:00	0.08981		08:00	0.10514
	08:30	0.09855		08:30	0.13599
	09:00	0.10579		09:00	0.11596
	09:30	0.09867		09:30	0.1583
	10:00	0.09779		10:00	0.10546
	10:30	0.09779		10:30	0.10373
	11:00	0.09893		11:00	0.10191
	11:30	0.10287		11:30	0.09584
	12:00	0.1001		12:00	0.10373
	12:30	0.11843		12:30	0.09206
	13:00	0.08602		13:00	0.09205
	13:30	0.09564		13:30	0.11023
	14:00	0.0968		14:00	0.10533
	14:30	0.0967		14:30	0.08706
	15:00	0.09073		15:00	0.08544

	15:30	0.09856		15:30	0.11501
	16:00	0.11502		16:00	0.10661
	16:30	0.10519		16:30	0.09753
	17:00	0.10394		17:00	0.09665
	17:30	0.09815		17:30	0.1038
03/01/2017	Time	RRP ($/kWh)	03/07/2017	Time	RRP ($/kWh)
	18:00	0.09329		18:00	0.14435
	18:30	0.08257		18:30	0.13659
	19:00	0.17494		19:00	0.10677
	19:30	0.20652		19:30	0.09881
	20:00	0.11429		20:00	0.09445
	20:30	0.08997		20:30	0.10373
	21:00	0.07917		21:00	0.10654
	21:30	0.0752		21:30	0.06789
	22:00	0.05162		22:00	0.06272
	22:30	0.08883		22:30	0.07271
	23:00	0.09142		23:00	0.06437
	23:30	0.07575		23:30	0.0639

Appendix 2
Priority and limiting priorities in the ANP criteria network

Criteria and sub-criteria	Normal priority	Limiting priority
Customer satisfaction	0.25	0.125
Economic efficiency	0.25	0.125
Non-discriminatory design	0.25	0.125
Revenue model	0.25	0.125
Perceived cost	0.11111	0.01389
Response	0.11111	0.01389
Transparency	0.77778	0.09722
Cost causation	0.125	0.02083
Regulatory and reliability criteria	0.875	0.14583
Customer focus	0.625	0.10417
Utility focus	0.375	0.0625
Stability	0.5	0.02083
Technology	0.5	0.02083