IMPACT OF SAUDI ENERGY MARKET RESTRUCTURING ON BUILDINGS' ENERGY CONSUMPTION & GENERATION PROSPECTS

BY

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To my parents and children and all friends who supported me to write this master thesis

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LIST OF ABBREVIATIONS

SEC: Saudi Electricity Company

EEM: Energy Efficiency Measures

EUI: Energy Utilization Index

ECRA: Electricity & Cogeneration Regulatory Authority

MOE: Ministry of Energy

IPP: Independent Power Producers

PPA: Power Purchase Agreement

RMU: Ring Main Unit

PV: Photovoltaic

ISO: Independent System Operator

KAPSARC: King Abdullah Petroleum Studies and Research Center

LF: Load Factor

TOU: Time of Use Tariff

LOCE: Levelized Cost of Energy

DCF: Discounted Cash Flow

EOA: Eastern Operating Area

DOA: Dammam Operating Area

ABSTRACT

Full Name : [Ayedh S. Al Fardan]

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This thesis discusses the impact of energy market restructuring on building energy performance. The new regulations and initiatives to liberalize the electricity market in Saudi Arabia will entail changes in consumer behavior and building energy consumption. The thesis focuses on building sector since it consumes about 80% of electricity in Saudi Arabia. The assessment of the impact will calculate the factors affecting the energy performance pertaining to buildings. A market model is developed to anticipate impacts and study the economic and environmental values gained. Also, such model will be able to correlate and study the impact of the electricity market restructuring on energy performance of buildings with respect to costs and consumption.

In order to establish a link between electricity markets restructuring and building energy performance, a model is established. The model will have inputs that affect directly the building energy performance. The model will predict the future consumption of electricity, cost of consumption and Energy Use Index (EUI) based on different scenarios. It is evident from the analysis and data gathered that for an increase of 3% in tariff, there will be a decrease in demand for 1% in Saudi Arabia electricity market. The implementation of PV net metering in buildings will have positive impacts as it will enhance energy performance of the buildings and will gain benefits for both consumers and the country.

The economic impact is based on different scenarios. From customer perspective if the aim is to gain independent energy supply from PV systems, the business case is not positive while if the aim is to avoid increasing cost for the future tariff when the subsidies are lift, the business case is positive for the consumer. On the other hand, the business case from the Kingdom of Saudi Arabia is positive due to the savings in oil consumption, costs avoided for generation, transmission and distribution networks. In addition, significant CO_2 emissions reductions are obtained. However, significant energy poverty occurs at 16% of the households and expected to increase for future tariff prices.

ملخص الرسالة

الاسم الكامل: عائض سالم عائض ال فردان

عنوان الرسالة: تأثير إعادة هيكلة سوق الطاقة في المملكة العربية السعودية على استهلاك المباني من الكهرباء وتوليدها للطاقة

التخصص: هندسة معمارية

تاريخ الدرجة العلمية: يونيو 2018 م

الدراسة تحقق في الأثر على استهلاك الطاقة في قطاع المباني في المملكة العربية السعودية وعن أثر التغييرات الهيكلية في قطاع الطاقة على الاستهلاك. وتم تطوير نموذج لعمل السوق الكهربائي وكيف يستطيع هذا النموذج محاكاة الآثار الاقتصادية والبيئية للتغييرات الهيكلية . غرض البحث الأساسي انشاء نموذج محاكاة لأثر التغيرات التي تحصل في سوق الكهرباء في السعودية والتي سيتم فيها رفع الدعم المقدم على شكل وقود رخيص وسيتم إعادة هيكلة السوق ورفع كفاءته ليكون سوقاً تنافسيا ودراسة أثر ذلك على أداء الطاقة في مجال المباني الذي يستهلك ما يقارب 80% من الطاقة المنتجة في السعودية. الدراسة تستعرض اللاعبين الرئيسيين في السوق وكيف سيكون سوقاً تنافسيا للكهرباء وما هي التكاليف للإنتاد بحيث يعمل السوق بدون دعم حكومي .

الدراسة توصلت إلى وجود علاقة مباشرة بين أداء المباني في الطاقة والتغييرات الهيكلية التي تحدث في سوق الكهرباء وتم التطرق إلى نموذج إدخال الخلايا الشمسية وكيفية احتساب أثرها في التكاليف والإستهلاك على مستوى الوحدات وعلى مستوى وطني. الدراسة توصلت إلى أن لكل زيادة في رفع قيمة التعرفة بـ 3% سينتج عنه خفض في الإستهلاك 1% وذلك لعينة من المنازل التي تم اختيارها للدراسة وتم دراسة الأثر بوجود خلايا شمسية وعدم وجود خلايا شمسية ووجد أن أفضل سيناريو للإستهلاك هو في وجود خلايا شمسية حيث رغم أن التعرفة سيتم رفعها إلا أن التوفير الحاصل من الخلايا سيكون مفيداً للمستهلك وللمملكة على حد سواء.

كما توصلت الدراسة إلى أن الآثار الإقتصادية على المستهلك ستكون عالية حيث أن سعر السوق التنافسي للكهرباء سيكون 39 هللة / ك.و.س مما يجعل من استخدام الخلايا الشمسية ذا عائد اقتصادي مجدي للمستهلك عند تطبيق صافي استهلاك الطاقة ومن جهة أخرى فإن الآثار الإقتصادية للملكة ستكون ايجابية من ناحية التوفير في الوقود وبناء محطات توليد جديدة وخطوط نقل طاقة وتوزيع وأيضاً التقليل من انبعاثات ثاني أكسيد الكربون لكن في عينة الدراسة سترتفع نسبة الإحتياج للطاقة أو ما يعرف بفقر الطاقة الذي بلغ في 2018 ما يقارب 16% من المستهليكن مما يحتم إعادة إصلاح منظومة الدعم للشرائح المستفيدة ورفع طفاءة استخدام الطاقة بالشكل الأمثل

CHAPTER 1

INTRODUCTION

1.1 Background

Electricity market changes due to external factors affecting the socioeconomics and environment in many countries. With the new environmental regulations worldwide and with the advent of smart technologies, the electricity market has become more agile to the new challenges. Moreover, this thesis discusses in detail the impact of energy market restructuring on buildings energy performance. The goal is to develop a market model that encompasses all necessary elements to have efficient and competitive energy market that can provide energy to consumers in efficient and reliable fashion while the prices are advantageous to both producers and consumers. The market design should enable the sustainability in the long run and provide more liberalization to prices.

The existing electricity market is vertically integrated which means that generation, transmission and distribution are solely or partially owned by one entity. Buildings in return consume more than 80 % of electricity generated in Saudi Arabia [17]. Moreover, the residential sector consumes more than half of Saudi Electricity Company transmitted and distributed electrical energy. In the current market, prices are subsidized heavily by government with a very low oil prices. Such fact has driven the demand for electricity to be significantly higher than in most countries. Such growth cannot be sustained for the long term and will squander the scare resources of the kingdom. By the same token, the tendency for consumers is to consume more of energy due to low prices. When the market is restructured, such inefficiencies can be eliminated. The energy performance of buildings is expected to improve and such performance can be measured through different KPI's one of which is EUI (Energy Use Index) or energy use intensity. The electricity market will yield a production cost of electricity that will impact the tariff prices which will affect the consumption of energy in buildings and entice consumers to respond in different ways.

1.2 Statement of the Research Problem

The problem that this thesis is trying to solve is that there has not been a model sufficient to study the impact of electricity market restructuring on buildings energy performance. Furthermore, the model will study the impact of the market restructuring on the residential buildings in particular. The reason for that is that residential buildings consume more than half of the energy in Saudi Arabia and the consumption behavior can be predicted over large portion of buildings. The desired electricity marked will impact buildings energy performance through legislations and production cost of energy that the consumers will bear at the end. In addition, this thesis will study the behavior of the consumer response to the increase of tariff prices through lessening electricity consumption and selecting cheaper alternatives through employing PV panels to be used for net metering. Such response will entail economic, social and environmental impacts that are going to be evaluated.

The new electricity market is explained showing how each player is functioning towards having competitive and balanced market. The new market will unbundle the vertically integrated and monopoly market that exists currently in Saudi Arabia. New actors like Independent System Operator (ISO) and Principle Buyer are discussed in details showing their roles as market governing entities. At the same time, generation, transmission and distribution business lines are discussed in the context of having independent and competitive standalone units. In addition, the consumer will have the chance to respond through net metering where consumers can generate energy in their buildings and sell it to the market. Such changes will make buildings energy generation units.

1.3 Significance of the Research

The significance of this research lies in the fact that Saudi Arabia is moving towards having sustainable and more efficient electricity market. Such transition needs to be studied in order to capture the benefits for the Kingdom. Also, the impact of such transition is important for both energy producers and consumers. For the first time ever, Saudi electricity market will be driven by competition and efficiency while it used to be a tool for social welfare to sustain the livelihoods of citizens. The impact will be in changing the tariff cost and introduce new regulations permitting consumers to generate power at the premises. The thesis will establish the link between the electricity market performance and building energy performance through a model.

This model will can be utilized in future to study the impact on building energy performance in other markets. In addition, this thesis will predict the production cost and the tariff cost of the new electricity market and will choose a sample of houses in order to study the impact of the new regulations and outcomes of the electricity market on them. At the same time, data from Saudi Electricity Company (SEC) is provided to substantiate the prediction of the future energy consumption in the sampled houses. Also, the economic impact is studied for both the consumers and the Kingdome. Two major scenarios are developed: scenario for consumers and scenario for the Kingdom. Each scenario is studied based on different tariff costs and PV options. The method used through Discounted Cash Flow (DCF) shows the significance and value of such transition. In addition, environmental and social impacts are laid out. The concept of energy poverty is introduced and the segment of consumers who will be energy poor is calculated and laid out.

1.4 Research Objectives

The aim and objectives of this thesis can be summarized as follows:

1- Examine the key features of the energy market restructuring in Saudi Arabia
2- Investigate the impact on building energy consumption due to the new market restructuring and the prospects of turning buildings into energy generating units
3- Study the economic and environmental aspects of the potential changes in the energy consumption and generation prospects of buildings
4- Study the impact on the energy market as a result of the building sector response in the new market environment.

1.5 Scope & Limitations

The scope of this research will cover the pre and post electricity market restructuring and will focus only on buildings mainly residential buildings. The area selected for the study is in Dhahran city but certain generalizations can be made to the whole of the kingdom. The buildings selected for study are 30 buildings and will be taken as a case study to examine and generate accurate assumptions and pricing models. In addition, the scope will examine the building energy performance through measuring EUI (Energy Use Index) as a major KPI to indicate how much savings can be obtained. The scope will examine the generation production cost at pre and post electricity market restructuring but will not discuss the cost of generation for different types of power plants. The limitations of the research can be described as its inability to model the whole market since it is out of scope and it will not specify the energy performance of buildings with Energy Efficiency Measures (EEM) such as enhancement in buildings structure, orientation, façade, HVAC systems, lighting and etc. The scope will examine existing energy performance and future energy performance in order to capture the impact and study the benefits and such restructuring.

1.6 Research Methodology

Although the market design for electricity in Saudi Arabia has not been designed fully but the conceptual framework is laid out as depicted in Figure 1. The market will be dependent on the existence of principle buyer for energy trading and compensation for capacity buildings in generation power plants. The key component is to determine the impact of such market design on buildings energy consumption taking into consideration that the buildings themselves are becoming electricity generating units contributing more to the system and may lower future demand. The general assumptions for the design will take into account a market design that is regulated to provide fair dispatching among generation companies but at the same time provide reliable services. Furthermore, the methodology as explain in Figure 2 will start by selecting planning zone at distribution level which is a zone that bounded by 13.8 kV transformers. Sample data of the buildings selected which are 30 buildings within the area will be collected making sure that buildings are conforming to standardized buildings where their energy performance is within the range of the national level and the measurement will use EUI kWh/m2/year . Then, the energy consumption of each building along with its major loads (breaker size, total floor area and peak capacity) will be laid out and then studied in order to calculate the EUI based on the existing electricity market. On the other hand, the new market structure will be laid out and the study of the energy performance will entail using modeling software to model the impact of using net metering where such buildings will be able to install Solar PV as regulated by ECRA (Electricity and Co Generation Regulatory Authority). Such assessment will be aggregated to larger level at the distribution network where the whole impact will studied.

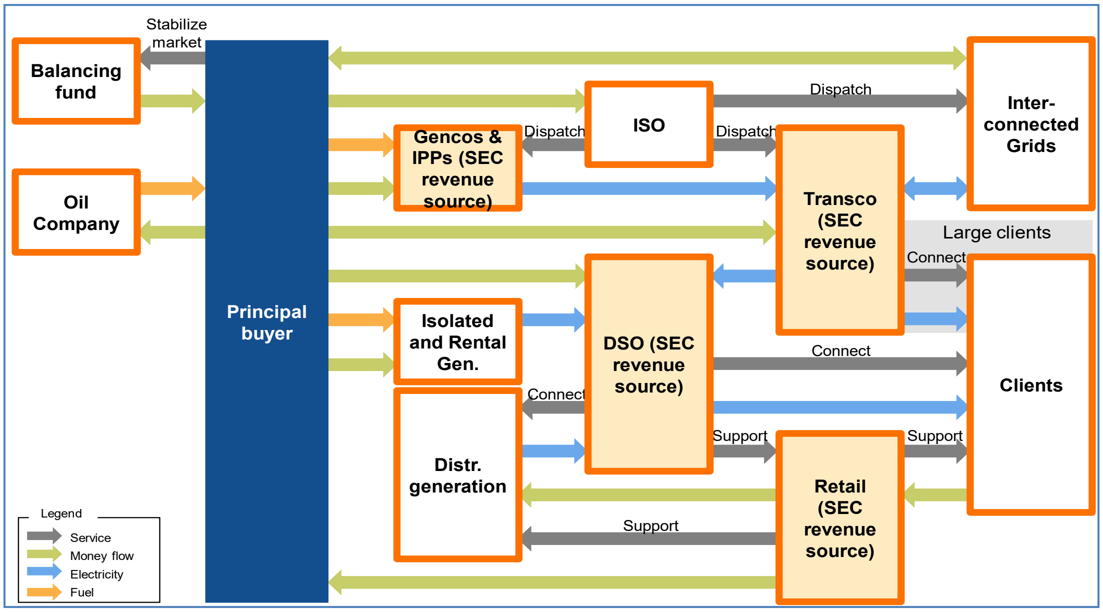


Figure 1: Electricity Market General Framework

In the existing market , the relationship between tariff price, consumption cost paid by consumer and electricity consumption will be established when comparing set of data before and after tariff increase and examine the correlation using R2 regression methodology. Such will enable us to establish a prediction for the future market after determining the future production cost of electricity and tariff. The EUI for the existing market is calculated for each building and the average can be derived and compared to previous studies and international benchmarking as laid out by EIA (Energy Information Administration) in the United States. On the other hand, the cost of production of generation after the restructuring will be discussed and calculated according to study using Nash Equilibrium and Carnot Model. Such production cost will be used and added to the cost of transmission and distribution to come up with the final cost of production upon which the market will compete. By using prediction, the future consumption, future cost of consumption can be estimated while using 2 scenarios: with PV net metering and without PV net metering. In both scenarios the EUI is calculated and compared with post market. Then, derivation of benefits for the consumers and for the kingdom is evaluated and discussed.

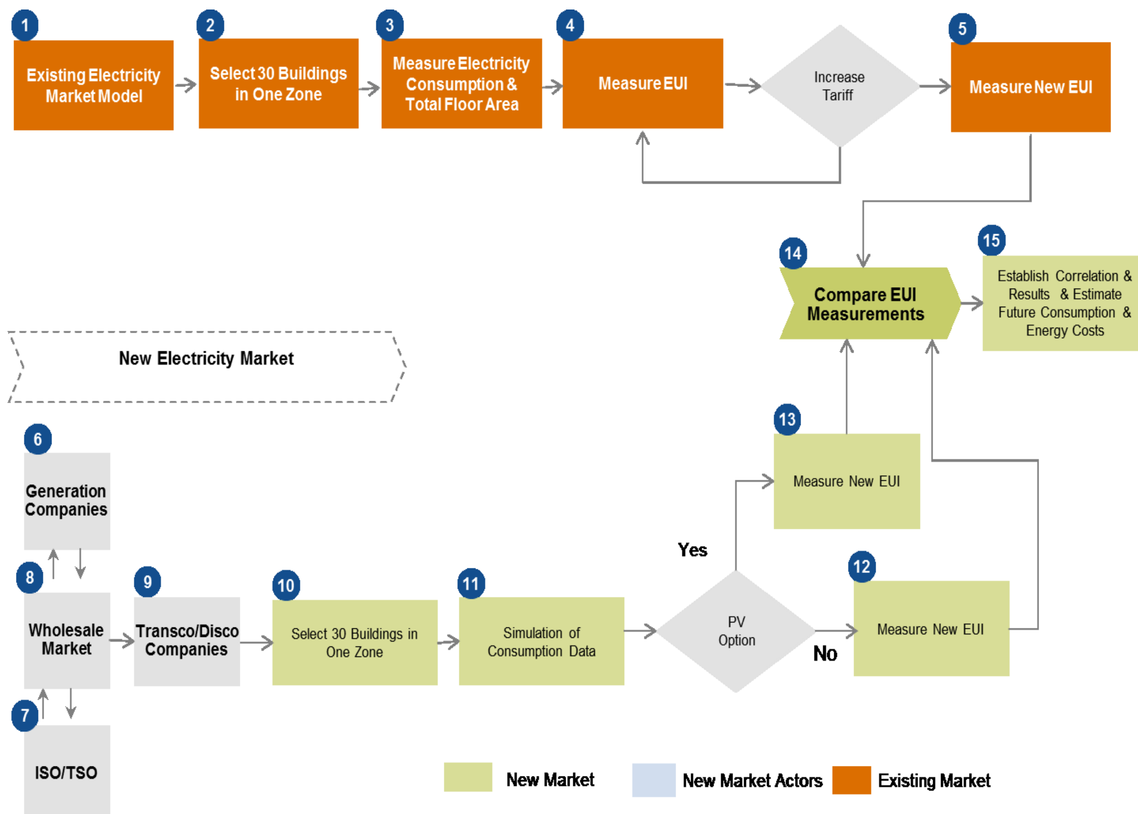


Figure 2: Research Methodology to Capture the Impact of Electricity Market Restructuring on Building Energy Performance.

Figure 2 explains the flow chart for the methodology used in the study. Such methodology is used to govern the study and ensure the building energy performance is calculated and examined. By working through this mechanism, an established link between electricity market and building energy performance can be obtained. Such model is laid out in the subsequent chapters.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the conventional electricity markets that have existed long before the advent of new electricity markets. It discusses the framework of such markets and kinds of inefficiencies associated with them. Also, this chapter discusses the new liberalized electricity markets in Europe, Americas and Asia to learn of other countries experiences. Furthermore, a focus on the evolution of Saudi Arabia electricity market and set of challenges it faces is detailed. The aim is to have a good review of what has been accomplished in electricity market restructuring and the impact on performance and energy prices to the consumers.

2.1 Conventional Electricity Markets

Conventional electricity system or what is being described as power system is composed of generation capacity mostly power plants which types or technologies are dependent on the type of fuel used, transmission system and distribution network [1]. Furthermore, the power system has evolved into more complex system encompassing three sub systems: physical, cyber and decision making where the whole system is controlled and can communicate through means of power system control equipment and communication systems [4]. Such evolution has leaded the progress into new power system that is classified as smart system. The most important qualities of functional power system are that it is reliable and can deliver quality energy meeting customers growing demand.

Because of it is extreme high capital cost, most of the value chain components in power system like power plants, transmission lines, substations and many sub systems used for control and communications are owned and subsidized by governments and large investment companies. At the same time, the duty of operating and maintaining such large systems has led to a monopoly market where consumers have little options to have competitive prices or request improved services [2].

Moreover, conventional electricity markets are marked by monopoly and or oligopoly where few large utilities control the whole market. Also, the price determination is not calculated based on actual costs causing more capital and operational inefficacies leading to more production costs [3]. Another reason for heavily regulated and centralized power systems is to ensure the reliability of supply and balancing the energy transfer from power generation to consumers [5]. Such fact has caused utilities to rely on central planning for future demands where reliability is the top factor which in retrospect has added unnecessary large investments in the grid that could have been used otherwise. Electricity market represents a convoluted system where electricity market actors like producers, operators, traders and consumers play the role to supply and consume electric energy accordance to standards by which the market is designed to be fair and balanced [6]. Electricity markets can be classified into three distinctive types: centralized, decentralized and integrated [7]. In centralized markets the transmission and distribution is a monopoly and generation can be in some cases a competition where as in decentralized the whole system actors are competition to provide the optimum price. On the other hand, in the integrated system the whole market or most of it is controlled by one utility like the case in Saudi Arabia cannot provide dynamic interaction where consumers have the ability to choose and demand quality service which is at the end might endanger the quality of services provided.

2.2 International Experiences in Electricity Markets Restructuring

In Europe, the electricity market was oligopoly dominated by state owned utilities and there were little independent utilities if existed [2]. However, in some countries there existed some local distribution companies to provide services to remote customers. In the United States, the electricity market is divided into 3 main sub regional systems: eastern interconnection, western interconnection and Texas interconnection [3]. Although existing in one country but the whole system is not synchronized and there is not much power trading existed between the sub systems. Most utilities are vertically integrated [8]. The pricing for the system was based on the production costs which have caused spikes in prices [9]. Prices also reflect an important objective to provide electricity prices with future incentives to invest more in utilities [12]. In Mexico, the centralized utilities control the market and prices are set so that there is a cap not to be exceeded [10]. Such market is interconnected except for some isolated areas and priorities for the grid expansion is centrally planned causing inefficiency in setting plans and satisfying consumers especially large ones in commercial and industrial [10]. In addition, the power system in South America can be described heavily subsidized and have inefficiencies that caused inflation in prices and delayed unbundling [24]. Furthermore, the Chinese utility was more efficient and prices were reasonable to customers but such had required a lot of investments to expand the grid and maintain the reliability which in return has caused sever high demand on power because of the economic development in the country [29].

During the 80s, market liberalization was the trend in order to improve efficiency and boost stagnant economies. Utilities were no exception. The wave started in electricity markets in order to provide competitive prices and more reliable services. As a matter of fact, when the liberalization started, the market saw improvement in the efficiencies in utilities [5] but not so in the impact on prices [8]. In most scenarios, some initiatives pertaining liberalization have been enacted. Such initiatives involved establishing the principle buyer which acts as the balancing actor in the market and allow energy trading between companies [13]. Also, there had been establishment of many utilities across the value chain in generation, transmission, distribution and retail [20]. The efficiency and asset utilization were improved but the prices came under uncertainty where they could spike involuntarily due to lack of market fair competition and lack of strong regulation[30] [23]. In addition, no significant decrease in production costs for the kwh but the efficiency for Independent Power Producers (IPPs) improved from 1.6% annually to 35% by 2012 [26]. In addition, for transmission the losses were within the acceptable rages of 2.5 % -4.5% [28]. In addition, such competition in the market has resulted in adopting new technologies in order to improve efficiencies and reduce the production cost. For example, adoption of new smart equipment and sophisticated dispatching systems and in some cases using some of the artificial intelligence by employing advanced algorithms to operate the network can be noticed [1].

Also, the liberalization of power market has led to diversify the portfolio of generation mix. For example, the types of the portfolio for generation companies in the United States have added to traditional utilities: investors' purely owned and power marketers leading the United States to have over 3,292 utilities [3]. By the virtue of existing of smart grid, renewables can be utilized in the generation mix leading to more diversification and less reliance on a single source for generation [4]. Also, such liberalization has led to more stable market where the gaol is to design a fair and balanced market to deliver quality service with efficient prices for both consumers and producers [12].

Each electricity market has a model by which it functions. The model takes into consideration related factors as to the level of competition, grid maturity and readiness of frameworks and regulations for the market. In most market models , Independent System Operator (ISO) or Transmission System Operator (TSO) plays the significant role of maintaining the fair and equal dispatching between all electricity producers [2][5]. The market structure can be established based on either one of the following concepts: mathematical model, engineering model or economic model [6]. Each model assumes point of equalizing and maximum efficiency a market can reach. Furthermore, in some countries, the market can be deregulated where there are many producers across the electricity value chain and each producer can linger for best gains [7]. In all market models, the power exchange can be evaluated through real time contracts, hour ahead or day ahead markets where prices can be negotiated or announced [11]. The role of regulations hence is to maintain fair competition between all actors and ensure the longer sustainability of the market for foreseen future. In addition, the market model has to capture how much value added, how much income redistributed from producers and consumers and the economics of growth contribution of the electricity [14]. Any market model has to balance the security of supply with environmental and competitiveness requirements for a country [14]. Since the consumer is very concerned about consumption of energy, many factors need to be studied upon the design of the structure of the electricity market to ensure that consumers pay fair price and ensure prices do not spike out of control [15].

2.3 Electricity Market Evolution in Saudi Arabia

In Saudi Arabia, the challenges for electricity market are more daunting. With a very high growth ranges from 6-8 % annually and a consumption of energy that has exceeded 330 Twh (SEC: 2016) which requires new installed capacity of 4.2 MW annually and more than 60 Billion SAR in annual spending (SEC: 2017) [18]. Moreover, it is accepted estimation that each 15 years, Saudi Arabia has to double its capacity to match the load growth. It is expected the total Capex USD 500 billion over the next 10 years [18] [25]. The energy sector in Saudi Arabia is highly subsidized at a rate of 77.3% [25] making it among the highest subsidized in the world. The generation mix in Saudi Arabia is highly dependent on hydrocarbon (59% on oil and 41% on Gas) with more LNG coming as the base fuel in future generation projects with expected installed capacity of 120 GW by 2032 [25]. Furthermore, the electricity consumption in Saudi Arabia is one of the highest in the world estimated at 5.7% per capita and 25% of oil is burned to generate electricity [27]. With such facts, the cost of production of electricity for Saudi Arabia load profile where there is around 500 hours of annual peak and with a low load factor (65%) requires large investments and high costs of production per kWh generated [32]. Some of the challenges seen in Saudi Arabia have been witnessed in countries like the US, UK, China and Russia before restructuring electricity markets [31]. The expected structural shifts will occur to electricity market in Saudi Arabia in both sides: supply and demand.

Moreover, on the supply side: ample increase in renewables in energy mix due to the falling prices of PVs and COP21 requirements for environment [16]. On the demand side: consumers will change behaviour due to liberalized tariff structure and more options to have smart homes and appliances. Also, consumers will be able to generate electricity and trade it in wholesale market as anticipated by instating the net metering by ECRA (Electricity and Cogeneration Regulatory Authority) [16].

Building sector in Saudi Arabia consumes more than 70% - 80% of electricity generated where in fact more than 65% of load is cooling load to the clime in the country [16][25]. Also, for more than 5 million consumers who are residential, the building sector constitutes the biggest area where improvements in consumption can occur. In a new wave of reforms, ECRA has issued a new set of regulations to establish net metering for small consumers (below 1 MW) to buy and sell energy to the grid. Net metering experience in Saudi Arabia is totally new [33]. There are many drivers for such decision. One of which is that the load growth in Saudi Arabia is one of the highest in the world [34]. Also, almost most of generation power plants in the kingdom depend on oil and gas as primary fuels which will hinder the kingdom ability to export oil as it is the primary source for income for the government and the country. Such drivers have expedited the process to authorize net metering. Moreover, according to Saudi Arabia vision 2030 and national transformation program 2020 (NTP) : all subsidies will be lifted by year 2020 and that means the end user will bear the cost of electricity paving the way for net metering to be more economically viable.

ECRA has issued what it has described as Small Scare Solar PV Systems Regulations document in 2017 laying the ground for using Solar PV in small scale application. The main reasons for focusing primarily on solar energy is that the kingdom itself can make use of staggering insolation levels in the kingdom (6400 wh/m2). The regulation focuses mainly on three stakeholders: the utility (Saudi Electricity Company), the consumer and consultants/contractors. For each stakeholder the regulation specifies the roles and responsibilities in order to have efficient and reliable energy trading system.

The regulation hence focus on setting terms , conditions , requirements and process by which small scale soar PV systems can be managed and regulated. In order for a consumer to benefit from, he/she has to satisfy the following conditions:

a) Should comply with the allowed rated capacity as specified under the regulations;

b) Must be located within the consumer housing premises;

c) Should not exceed a capacity of 1 MW in one Premise;

d) Should not exceed a capacity of 5 MW in the area of supply at any distribution zone for a city; and

e) Should not be less than 1 kW.

f) Should connect and operate safely with the Distribution System. [17]

The distribution company should provide the net metering service and such arrangement has to comply with Saudi Distribution Code laid out by ECRA. Furthermore, the net metering should be available to all customers regardless of their property type: residential, commercial, governmental or agricultural. Also, the net metering must be provided in such an arrangement where there is only one exit to the grid. The meters should be bidirectional and Distribution Company will bear the cost for meters up to 100 kW but the customer will bear the cost for higher energy requirements.

The PV capacity should not exceed 15% of the rated capacity of the distribution transformers and should be connected at low voltage level. Such technical requirements will ensure the network is not jeopardized and the voltage quality is maintained. All other extra technical requirements have not been furnished yet. ECRA indicates that all remaining technical information shall be provided later [17].

The process of having small scale PV connection employing net metering consists of the following steps:

1- Choosing of solar PV certified consultants/ contractor
2- Making enquiry about PV installation to distribution company (SEC)
3- Obtaining municipality approval for civil and environmental works
4- Design approved by distribution company
5- Inspection and energization after the approval from the distribution company

Such process will ensure all technical and commercial requirements are met. Independent consultants will help in developing the business more towards having more customers using net metering [17].

ECRA has insisted that all bills issued to customers by Distribution Company must include the number of energy units exported and imported, accumulated of energy units due to surplus or credit and how much credits are earned. In this way, the regulator wants to insure transparent relationship between the retailers and customers. Also, the regulator insists that the distribution company must make sure to provide to public all the information required, pros and cons of net metering and public awareness sessions [17].

CHAPTER 3

ELECTRICITY MARKET FRAMEWORK

The existing electricity market is vertically integrated where Generation, Transmission and Distribution is owned solely or partially by one company (Saudi Electricity Company). Furthermore, as per strategic plans, the electricity market which is a monopoly suffers from large inefficiencies and higher consumption by consumers is expected which squanders the kingdom resources [18]. More of the existing market is explained in next chapter.

In order to have efficient net metering service where prosumers can have fair and balanced trading of energy, the electricity market must be designed in a way to encourage competition and enhance quality. Saudi Arabia has been traditionally relying in providing electricity prices at very low prices as a subsidy to its citizens. Such approach has drain out the resources and would potentially pose grave danger to the sustainability to such approach. Therefore, liberalization of the market is underway [34] in order to liberalize the energy market certain steps must be undertaken, one of which is to have an energy market that can make energy trading possible. The scheme explained in this part is suggested based on the unique structure of Saudi Energy market and certain challenges it faces. Furthermore, Saudi energy market faces several challenges one of which is the absence of legal framework that governs the relationship between all stakeholders. The suggested structure as depicted in figure 3 refer to important pillars where the principle buyer plays the significant role in balancing the market needs. The general framework which is planned as per SEC (Saudi Electricity Company) for Saudi Electricity Market stems from the fact that the principal buyer's function is to efficiently operate a reliable electricity market. As it may converge in the future, the principal buyer structure must regulate the market electricity trading; however, it is proposed that this be structured along three parts:

- Trading
- IPP and renewable energy
- Fuel supply and agreements

These will function as shown in Figure 3 below, including impact on revenues.

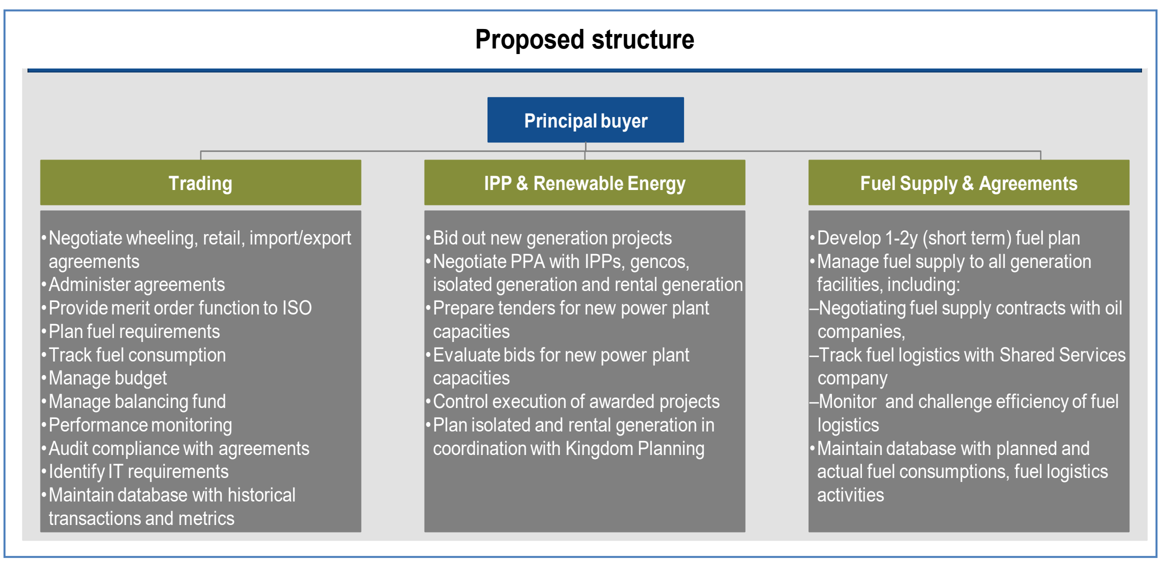


Figure 3: Proposed structure of the principal buyer

The trading pillar will focus on the negotiation of wheeling, retail, import and export agreements with different electricity companies. The wheeling charges are the charges that transmission incur in order to carry electric energy. The principle buyer (and can be called single buyer) will compensate the national grid which is a monopoly owned by the government on how much energy it will wheel. Such contract is vital to the system to ensure higher reliability and fair dispatching and competition between producers. On the other hand, principle buyer will ensure fair trading with neighboring countries for import/export. Also, for trading part, the principle buyer will provide merit order to the Independent System Operator (ISO) and sometimes can be called Transmission System Operator (TSO). Such function is important to ensure fair dispatching and ensure lower costs among all electricity producers. At the same time, principle buyer will ensure efficient supply of fuel mix which is in the case of Saudi Arabia oil and gas in all power plants although few renewable energy resources are underway [35]. All information and trading transactions management should be kept under the supervision of the principle buyer. Fuel planning is an important function that must be taken seriously in order to supply fuel to power plants and Independent Power Producers with minimum costs possible.

Second major role for principle buyer is the relationship with Saudi Electricity Company (SEC) and other IPPs which produce electricity from their power plants. New power plants competition will be organized by principle buyer in order to ensure huge investments are management efficiently. Each company will bid for new required capacity and the least bid will win according to set of rules and regulations that must be fulfilled. In this manner, the country resources can be devised wisely and efficiently. And each company to compete to provide more cost-effective power plants. At the same time, principle buyer will ensure that new power plants are built according to the market needs taking into consideration possible reduction in loads due to the use of renewable resources.

Third part of the function of principle buyer is the role it acts with respect to fuel supply. Principle buyer will negotiate with oil and gas companies to ensure obtaining competitive prices and ensure short and long-term fuel supply plans. In this manner, the principle buyer should obtain competitive fuel prices from suppliers and can ensure such prices will reflect the real cost of fuel when calculating the total costs.

SEC (Saudi Electricity Company) which controls most of the generation capacity and 100% of transmission and distribution revenue will come from five sources in the future:

- Sale of generated power and capacity
- Distribution services
- Retail services
- Transmission operation services (at least on the short-term, long-term might involve services companies)
- Kingdom planning services (at least on the short-term, long-term must be managed by government in order to ensure neutrality).

Payment transactions will be primarily with the principal buyer as per Figure 4. That Kingdom planning services will be structured into an independent non-profit company and will be under the wing of energy ministry.

The general framework will involve defining the mechanism by which generation; transmission; distribution and retail services can be organized. Such mechanism as laid out must ensure taking into consideration all stakeholders fair participation and benefits. The stakeholders are the Generation companies & IPPs, ISO, Transmission Company, International customers, clients, retailers, distribution system operator (DSO), Distributed Generation companies, oil & gas companies and the principle buyer. A balancing fund can be arranged in order to balance the market due to sudden changes in prices due to different economic climates that might occur.

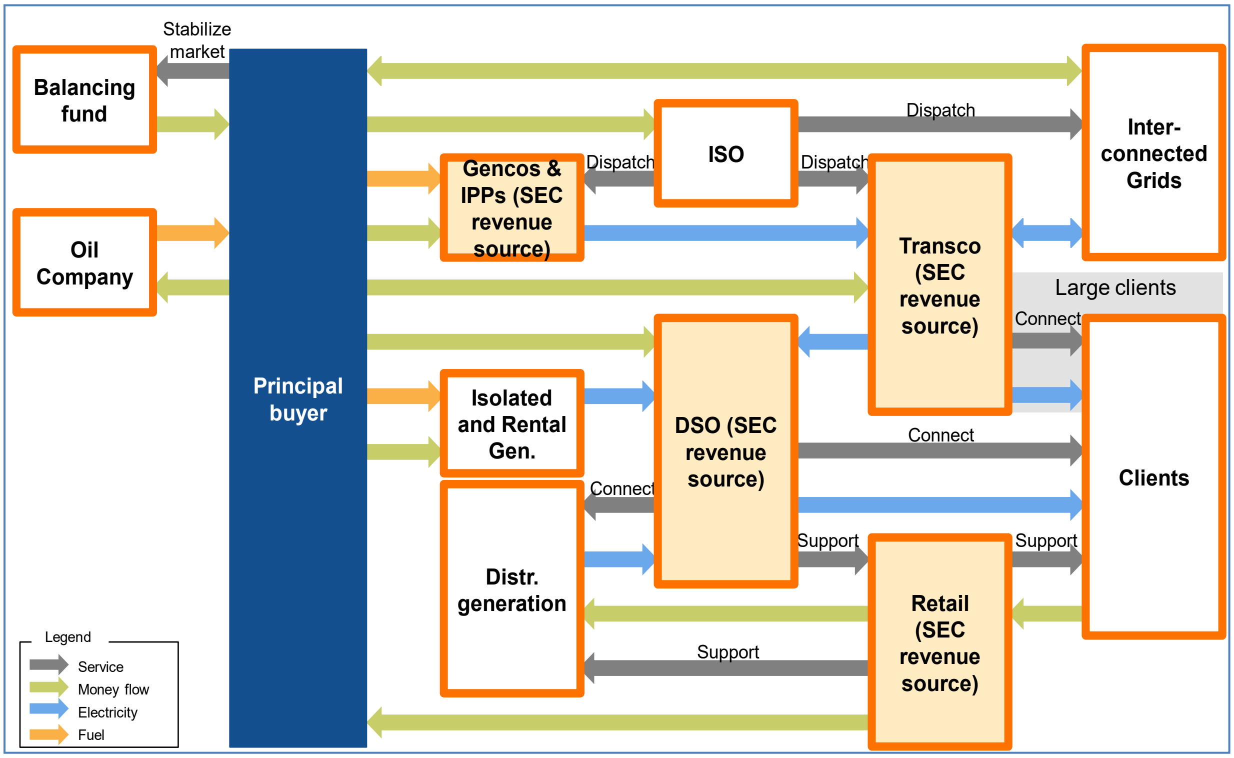


Figure 4: SEC (Saudi Electricity Company) revenue flows [47]

3.1 Sale of Generated Power and Capacity

Sale of generated power will be driven by expected load (set by the ISO/independent system operator) as an input, and contracts will be concluded with the principal buyer. Payment will be made by the principal buyer for fuel transformation/electricity production as per Figure5. Revenue planning will therefore have to forecast principal buyer payment (contract) levels. In addition, a fixed capacity fee will be paid by the principal buyer.

Planning of generated power and capacity revenues is completed by the finance department with input from the Generation BU planning entity. Care must be taken that all assumptions made while planning revenues for generation and capacity correspond to assumptions made on the cost side of the planning process.

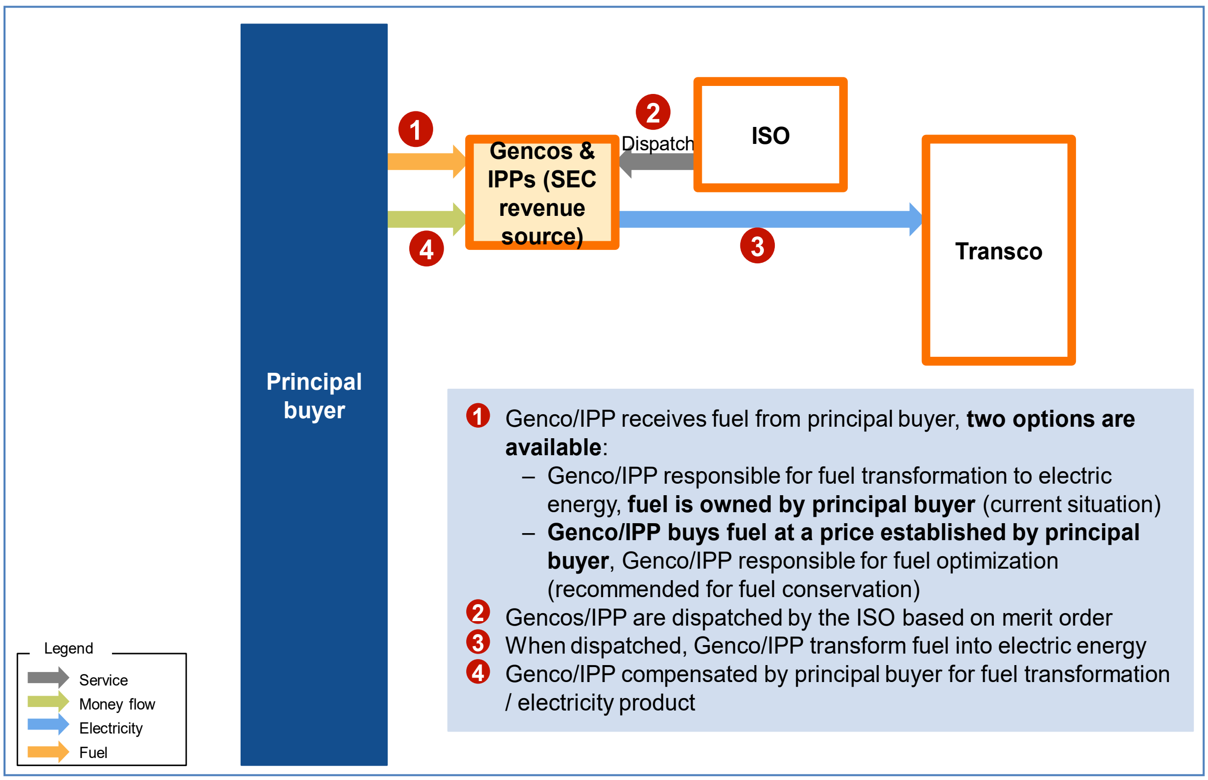


Figure 5: Generation revenues [47]

The principle buyer will have two options to provide fuel to Generation companies/IPPs. The first is through providing fuel and will be responsible to convert fuel to electric energy at certain heat rate and then compensate the generation companies based on the rate as per daily merit orders. The second is that the generation companies buy fuel and will be responsible to convert it to electric energy and this way is recommended to ensure more efficient fuel management. For large renewable energy producers, the principle buyer will compensate based on the daily merit order which might be unfavorable unless some governmental subsidies are devised for such producers since the competition with gas fired power plants will be difficult.

3.2 Distribution Services

The principal buyer will compensate distribution services. The mechanism of this has to be designed at maximizing the economic benefit for the country. It could be imagined that this would entail either an asset- or performance-based model. Asset based indicate that the distribution company will be compensated based on how much capacity it can deliver and therefore, it will be compensated based on such. Performance based will depend on the operation excellence and hence will be compensated from the principle buyer based on that. However, either will depend heavily on the final contract/regulatory structure between the principal buyer and the Distribution companies.

Planning of distribution services revenues is completed by the finance department with input from the DSO (distribution System Operator). Care must be taken that all assumptions made while planning revenues correspond to assumptions made on the cost side of the planning process. The core responsibility of distribution companies to connect to clients: retailers, distributed generation, rental generation and national grid for Medium Voltage to Low Voltage customers. Principle buyer should compensate distribution companies for wheeling. It can be imagined that distribution companies sell energy in bulk for certain retailers for discounted prices.

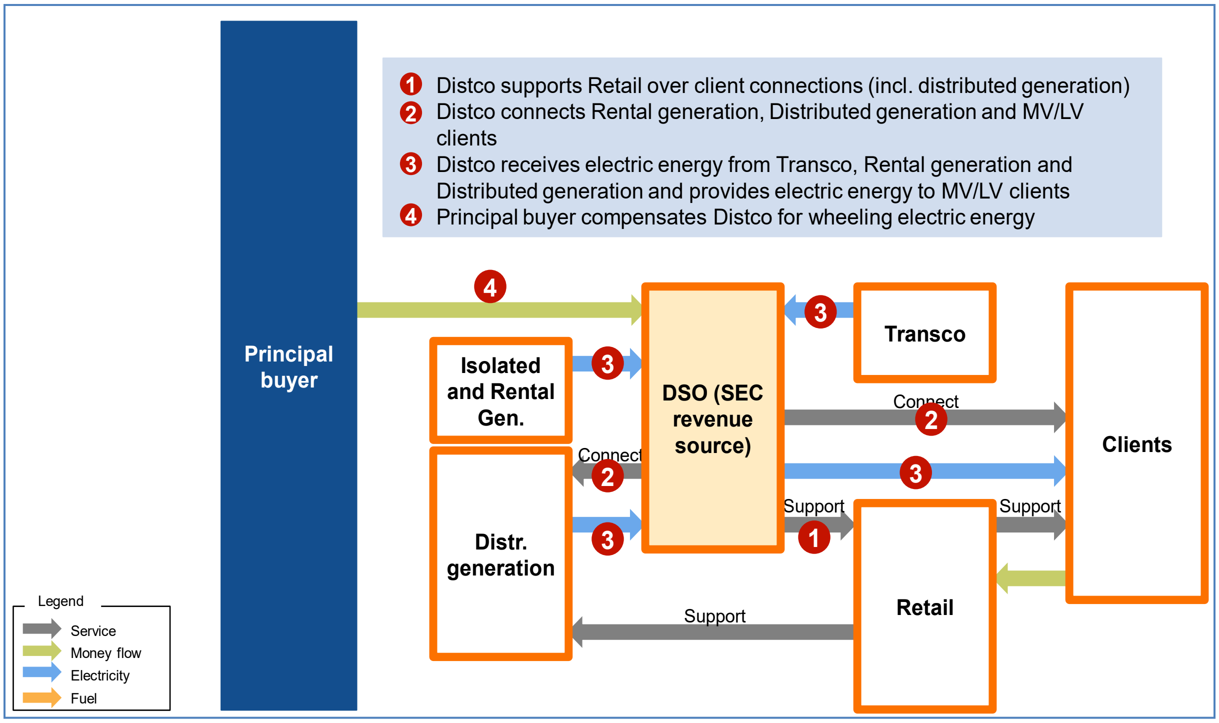


Figure 6: Distribution service revenues [47]

3.3 Retail Services

The principal buyer will compensate retail services. It could be imagined that this would entail a volume-based model, most likely linked to the number of clients or client types, as well as performance (e.g., in terms of collection/reading).

Planning of retail services revenues is completed by the finance department with input from the Retail BU planning entity. There are two options available for retailers. First, the retail is an agent that acts on behalf of the principle buyer and execute the retail activities such as billion collection and connection to new customers. Second, the retail operates independently where it buys energy from the principle buyer and selling it to clients which is recommended scenario in order to free tariff.

The retail must also support the coordinate with distribution and transmission to connect to customers. Also, retail will collect client bills and settles payments due to distributed generation opening the door for net metering option in Saudi Arabia. In addition, the retail will collect funds and energy prices to principle buyer.

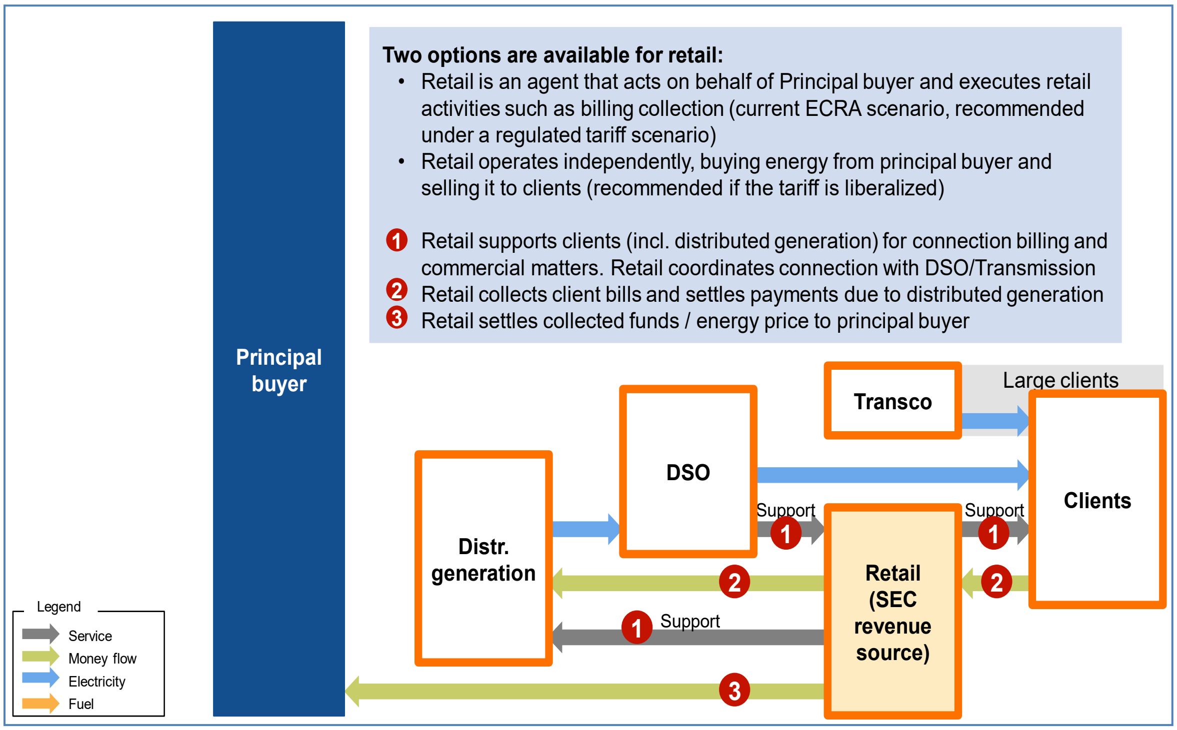


Figure 7: Retail service revenues [47]

3.4 Transmission Services (Short Term)

As for short term, it was unclear whether transmission services will be structured as an independent company; however, it will certainly remain within SEC for some time in the future. During this time, it will be a source of revenue and will have to be included in revenue planning. The transmission company will be the backbone of the system responsible to transmit energy between producers and consumers.

Payment will be made to the transmission company by the principal buyer as compensation for wheeling electricity. The payment mechanism will be based on assets and performance but will depend heavily on the final structure of the principal buyer and any bilateral contracts between the transmission company and the principal buyer.

Planning of transmission services revenues is completed by the finance department with input from the transmission company planning entity. The transmission company will support retail over high voltage HV client connection. Also, it will ensure the efficient and adequate connection of new power plants into the grid maintaining all reliability criteria. Transmission company will receive energy from power plants based on the fair dispatching performed by ISO and will transfer energy to High Voltage customers, distribution companies and international import/export points of connection. The principle buyer will compensate national grid or the transmission company for wheeling electric energy. In most likely scenario, Transmission Company will be fully owned by the government.

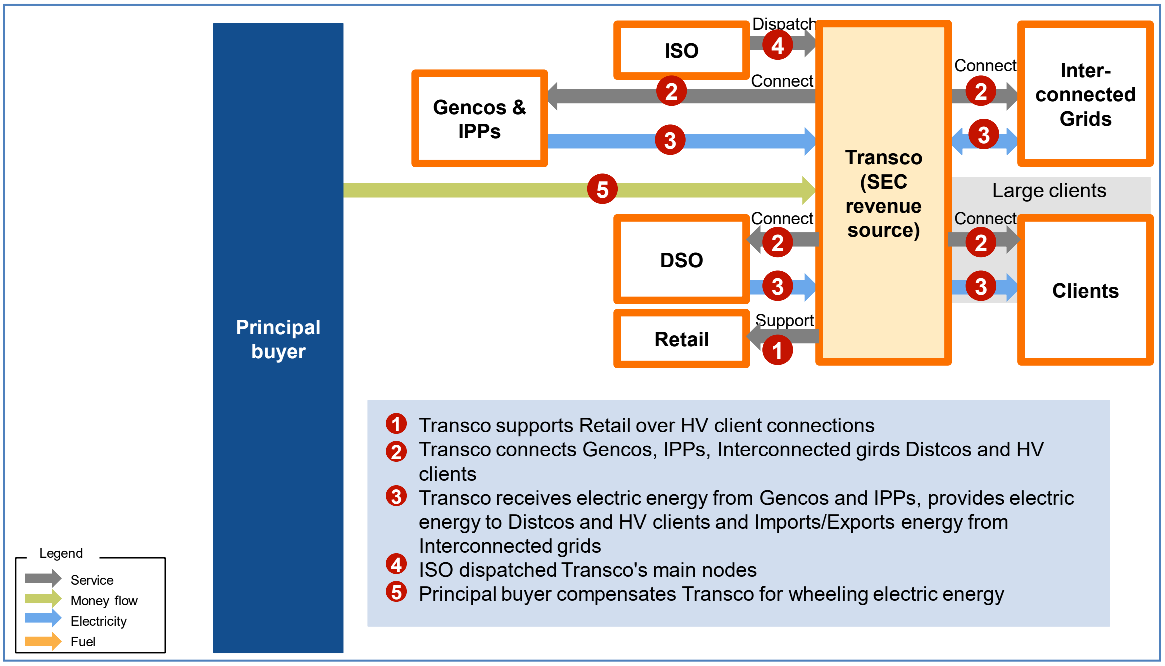


Figure 8: Transmission service revenues [47]

CHAPTER 4

PRE RESTRUCTURING ELECTRICITY MARKET

4.1 Background

Utilities used to be natural monopolies where such utilities provide power to customers and dictate the cost. This type of business model is known in strategy as vertically integrated model as depicted by Figure 9. The cost of production in generation and the wheeled power through transmission and distribution is passed to customers and in many cases the prices are subsidized either as fuel or enforcing low tariffs on the lower slabs of consumption. Furthermore, in Saudi Arabia , Saudi Electricity Company (SEC) is the monopoly that controls the transmission and distribution while controls more than 80% of the generation capacity allowing some Independent Power Producers (IPPs) to supply energy through Power Purchase Agreements (PPAs). The generation capacity in Saudi Electricity Market stands at 74 GW (SEC Data: 2017) while the peak demand is 64 GW during summer times due to heavy cooling requirements. The number of customers for SEC is 9 million adding 400,000 customers a year.

Such market is marked by growing demand that used to be 8% till 2015 (SEC Data: 2017) which requires to add 4.2 GW of capacity yearly. One of the reasons for such demand besides the economic activities is that the subsidies make it uneconomic for customers to enhance their energy conservation measures. Such growth has led to huge constrain on the network causing voltage overloading in many zones and can potentially lead to more load shedding. At the same time, the economic costs can be attributed to the fuel that is burned to generate electricity at low prices where the subsidies equal to $ 4 barrel of oil. Such growth with low return on assets will complicate the financial standing of SEC forcing it to gets more loans with uncertainty to pay. Such characteristics for the electricity market lead Saudi Electricity Company, Ministry of Energy and ECRA to devise a market restructuring in order to improve efficiency and lean off the dependency of crude oil and subsidized natural gas prices. At the consumer level, in natural monopoly, consumers have little freedom to negotiate prices, improve their energy efficiencies (no incentives).

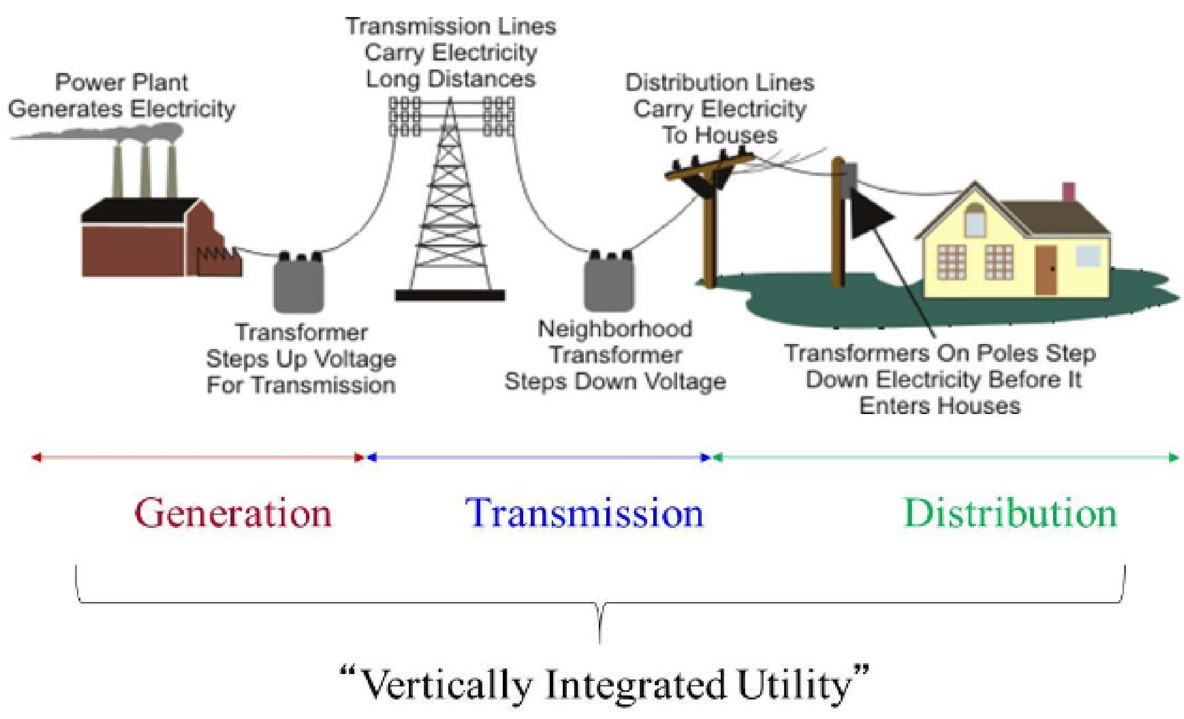


Figure 9: Vertically Integrated Utility [45]

4.2 Building Energy Performance in Pre Market Restructuring

In order to study the impact of the existing electricity market on building energy performance, one key KPI has been selected where it can be benchmarked and observed which the Energy Use Index (EUI) is or in some literature is called Energy Use Intensity which basically measures the consumption in kWh per m2 for a year. The selected buildings have been chosen so that they are located in one electricity zone as per figure 10. The reason for that is to ensure all buildings endure similar electricity performance so that data collected about consumption is not affected by different performances of the power system. The zone selected is in Dhahran area with collaboration from Saudi Electricity Company. The nature of the zone is heavily residential which is important to the research since residential segment behaves similar way as occupants live in the dwellings most of the time and have similar consumption behaviors. Industrial and commercial buildings are different in the sense that there are many hours they are empty and the loads can be controlled to cut on expenses. The residential sector constitutes more than 50 % of the electricity consumption in Saudi Arabia.

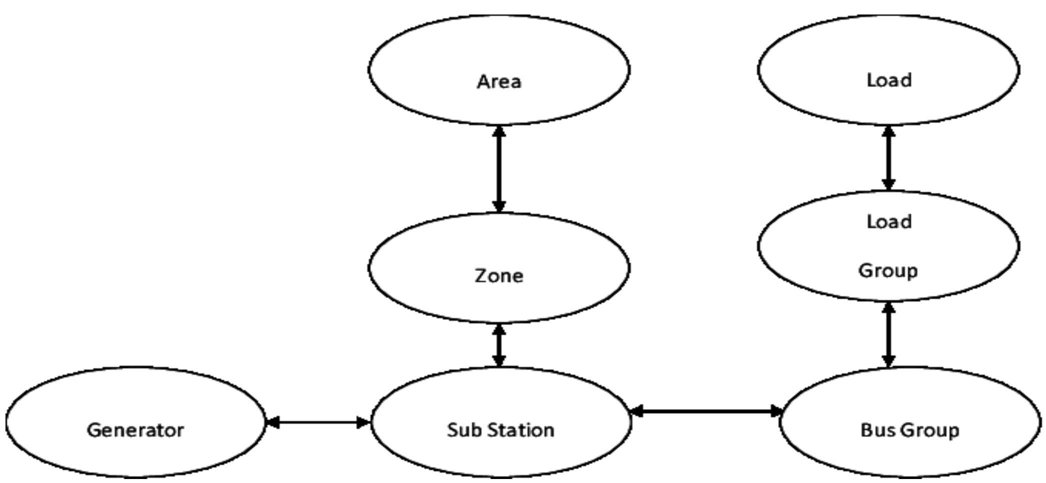


Figure 10: Definition of Planning Zone in Electricity

The zone is defined by feeders coming out of the nearest substation from the 13.8 kV going to the local Ring Main Units (RMU).

The selected buildings characteristics are laid out as per Table 1. The major determinant in designing the power demand for a house as per distribution standard and procedures is the total floor area. The area will determine the breaker size or the KVA needed by the building. The installed capacity represents the maximum power the house needs which is in theory very difficult to consume more than the peak for a typical house. At the same time, the power rating or the installed capacity as a feature of the existing market is determined as a quota for each building and with future expansions, the owner must ask for more power and has to pay for connection fees and monthly meter services which make the consumer in disadvantageous position.

The total floor area is the key feature of the buildings which will be used to measure the performance of the energy of buildings. In typical calculation, the EUI for larger buildings tend to be higher but the selection was made to take EUI for each building and then take the average for the whole zone. The typical load factor which compares the maximum demand of the load profile of a building (hourly loads in a year 8760 hours) is low in Saudi Arabia (around 65%: SEC data). And the reason for that are the climate nature and the load nature (cooling load) which is higher during summer time and low during winter making the utilization of assets for SEC harder.

Table 1: Selected Buildings in Dhahran Load Characteristics

Dhahran	Area (m*2)	Amper (A)	Installed Capacity (KW)	Annual Consumption (kWh) 2017 and before	Consumption Cost (SR) 2017 and Before Tariff
Building 1	120	60	22.8	55122	7260
Building 2	120	60	22.8	47740	5655
Building 3	120	60	22.8	30711	2729
Building 4	120	60	22.8	61131	8526
Building 5	120	60	22.8	15563	838
Building 6	120	60	22.8	24756	4126
Building 7	120	60	22.8	30156	2223
Building 8	120	60	22.8	14340	1051
Building 9	120	60	22.8	17327	1270
Building 10	120	60	22.8	20931	1500
Building 11	120	60	22.8	23718	1656
Building 12	120	60	22.8	10778	705
Building 13	220	100	38	40703	3563
Building 14	220	100	38	33189	2430
Building 15	220	100	38	36946	2900
Building 16	220	100	38	37544	3211
Building 17	220	100	38	33466	2454
Building 18	220	100	38	40255	3600
Building 19	320	150	57	33163	4025
Building 20	320	150	57	46252	4716
Building 21	320	150	57	38164	3300
Building 22	320	150	57	42200	3745
Building 23	320	150	57	39961	3570
Building 24	320	150	57	41777	3700
Building 25	550	200	76	43200	4152
Building 26	550	200	76	50211	5021
Building 27	550	200	76	51338	5133
Building 28	550	200	76	55388	6092
Building 29	711	250	95	68400	10690
Building 30	740	250	95	71321	11146

Table 1 indicates the consumption in kWh in a year for each building. Some of the buildings tend to have less consumption behavior inconsistent with their total floor area. However, such behavior is expected as some buildings are not occupied sometimes and others experiencing different consumer behavior. Generally, the higher the total floor area will be combined with higher consumption. In addition, the consumption cost is the cost paid by consumer to the utility for each month amounted per year as shown in the table. The numbers are worked out from the billing system for each building. It is not simply the multiplication of the tariff times the consumption since some of the amounts are due to other months and some consumers do not pay on time making accumulation of the amounts due. Therefore, the data was selected to make sure all the buildings pay the due amounts on regular basis for data consistency.

From Table 2 the Energy Use Index (EUI) is calculated by dividing the energy consumption in a year over the total floor area.

Table 2: Energy Use Index (EUI) for Study Buildings in Dharan before Tariff Increase in Dec 2017

Dhahran	Area (m*2)	Amper (A)	Installed Capacity (KW)	PV Installed Capacity (kW)	Annual Consumption (kWh) 2017 and before	EUI Before Tariff Increase (kWh/m2)
Building 1	120	60	22.8	4.2	55122	459.35
Building 2	120	60	22.8	4.2	47740	397.83
Building 3	120	60	22.8	4.2	30711	255.93
Building 4	120	60	22.8	4.2	61131	509.43
Building 5	120	60	22.8	4.2	15563	129.69
Building 6	120	60	22.8	4.2	24756	206.30
Building 7	120	60	22.8	4.2	30156	251.30
Building 8	120	60	22.8	4.2	14340	119.50
Building 9	120	60	22.8	4.2	17327	144.39
Building 10	120	60	22.8	4.2	20931	174.43
Building 11	120	60	22.8	4.2	23718	197.65
Building 12	120	60	22.8	4.2	10778	89.82
Building 13	220	100	38	7.7	40703	185.01
Building 14	220	100	38	7.7	33189	150.86
Building 15	220	100	38	7.7	36946	167.94
Building 16	220	100	38	7.7	37544	170.65
Building 17	220	100	38	7.7	33466	152.12
Building 18	220	100	38	7.7	40255	182.98
Building 19	320	150	57	11.2	33163	103.63
Building 20	320	150	57	11.2	46252	144.54
Building 21	320	150	57	11.2	38164	119.26
Building 22	320	150	57	11.2	42200	131.88
Building 23	320	150	57	11.2	39961	124.88
Building 24	320	150	57	11.2	41777	130.55
Building 25	550	200	76	9.625	43200	78.55
Building 26	550	200	76	9.625	50211	91.29
Building 27	550	200	76	9.625	51338	93.34
Building 28	550	200	76	9.625	55388	100.71
Building 29	711	250	95	12.4425	68400	96.20
Building 30	740	250	95	12.95	71321	96.38

From the table 2 the average EUI for the set of buildings chosen for the study = 175 kwh/m2/year. For each house, the total consumption of electricity in 2017 is divided by the total floor area in order to obtain EUI for each house. Such number in reality is less than what a study in Saudi Arabia has laid out [36] which is 156.8 kWh/m2/year; however, for some larger units the EUI can go up to 221.5 kWh/m2/year. Such data were collected for 2017 the year at which the weighted average of electricity tariff for residential was 14.5 halalah/kwh.

4.3 Establishing Correlation between Tariff Increase, Consumption Cost, Consumption Magnitude and EUI

There have been some studies which establish the correlation between the increase in tariff and the corresponding electricity consumption [37] [38] which indicate a linear relationship between increase in tariff and consumption. However, such relationship is not total elastic since consumer will remain in need for energy at levels that will give him thermal comfort. For example, in a study conducted in the USA [37] for a 10% increase in tariff, the consumption is reduced by 2%. In order to establish the relationship, the opportunity appeared when the Saudi government represented by ECRA allows an increase of tariff on Dec 1st 2017 to increase the tariff for residential segment from an average of 14.5 halalah/kwh to 18 halalah/ kWh for the first 6000 kWh and 30 halalah/kwh above 6001 kWh. Such increase can be observed in Table 3.

The data are collected after the increase as shown in Table 3. For 2017 both the consumption cost in Saudi Riyals and the consumption of electricity in kWh annually is represented. Also, the data for 2018 up to October is reflected while November and December are estimated through extrapolation. To establish the relationship between the consumption and consumer cost which is the amount paid by consumers to the utility, we need to take the difference between 2017 and 2018 readings for both consumption of electricity and cost of consumption taken into consideration that the tariff was increased from 14.5 halalah/kwh to 18 halalah/kwh for the lowest slabs. Such increase is calculated to be 24.14% increase.

From Table 3 we need to establish a correlation between the columns: difference in cost (SR) column and difference in consumption column (kWh). In order to do that, we need to find R2 for linear regression for 2 sets of data using excel. If R2 is significant enough, that will establish a correlation. Thereafter, and according to the literature, we can deduce the linear relationship between consumption cost and electricity consumption. For each column, we take average difference and evidently it turns out that for the increase of 41.25% in consumption cost, the electricity consumption drops by 8.19%.

Table 3: Establishing Relationship between Tariff Increase & Consumption & EUI

Dhahran	Area (m*2)	Annual Consumption (kWh) 2017 and before	Consumption Cost (SR) 2017 and Before Tariff	Annual Consumption (kWh) 2018 and after	Consumption Cost (SR) 2018 and After Tariff	Difference in Consumption (kWh)	Difference in Cost (SR)	EUI Before Tariff Increase (kWh/m2)	EUI After Tariff Increase (kWh)/m2
Building 1	120	55122	7260	37324	5886	-17798	-1374	459.35	311.03
Building 2	120	47740	5655	32714	5411	-15026	-244	397.83	272.62
Building 3	120	30711	2729	28995	4409	-1716	1680	255.93	241.63
Building 4	120	61131	8526	46419	7890	-14712	-636	509.43	386.83
Building 5	120	15563	838	15681	2577	118	1739	129.69	130.68
Building 6	120	24756	4126	14161	2814	-10595	-1312	206.30	118.01
Building 7	120	30156	2223	27139	4604	-3017	2381	251.30	226.16
Building 8	120	14340	1051	13700	2174	-640	1123	119.50	114.17
Building 9	120	17327	1270	17563	2787	236	1517	144.39	146.36
Building 10	120	20931	1500	8260	1250	-12671	-250	174.43	68.83
Building 11	120	23718	1656	15674	2591	-8044	935	197.65	130.62
Building 12	120	10778	705	14287	2298	3509	1593	89.82	119.06
Building 13	220	40703	3563	33024	5437	-7679	1874	185.01	150.11
Building 14	220	33189	2430	36561	6034	3372	3604	150.86	166.19
Building 15	220	36946	2900	34799	5220	-2147	2320	167.94	158.18
Building 16	220	37544	3211	36107	5416	-1437	2205	170.65	164.12
Building 17	220	33466	2454	32702	4905	-764	2451	152.12	148.65
Building 18	220	40255	3600	38966	5799	-1289	2199	182.98	177.12
Building 19	320	33163	4025	42315	7338	9152	3313	103.63	132.23
Building 20	320	46252	4716	50618	8905	4366	4189	144.54	158.18
Building 21	320	38164	3300	21921	3288	-16243	-12	119.26	68.50
Building 22	320	42200	3745	36344	5451	-5856	1706	131.88	113.58
Building 23	320	39961	3570	38654	5798	-1307	2228	124.88	120.79
Building 24	320	41777	3700	40100	6015	-1677	2315	130.55	125.31
Building 25	550	43200	4152	45320	6743	2120	2591	78.55	82.40
Building 26	550	50211	5021	48555	7283	-1656	2262	91.29	88.28
Building 27	550	51338	5133	52971	7945	1633	2812	93.34	96.31
Building 28	550	55388	6092	54766	8215	-622	2123	100.71	99.57
Building 29	711	68400	10690	74800	15316	6400	4626	96.20	105.20
Building 30	740	71321	11146	70654	11092	-667	-54	96.38	95.48

According the Figure 11, there is a strong relationship between Consumption cost and electricity consumption which is well established fact in the literature. The R2 = 0.72 pointing to strong correlation. However, such relationship has not been examined in Saudi Arabia where energy prices are low and consumers do not feel the necessity to conserve energy.

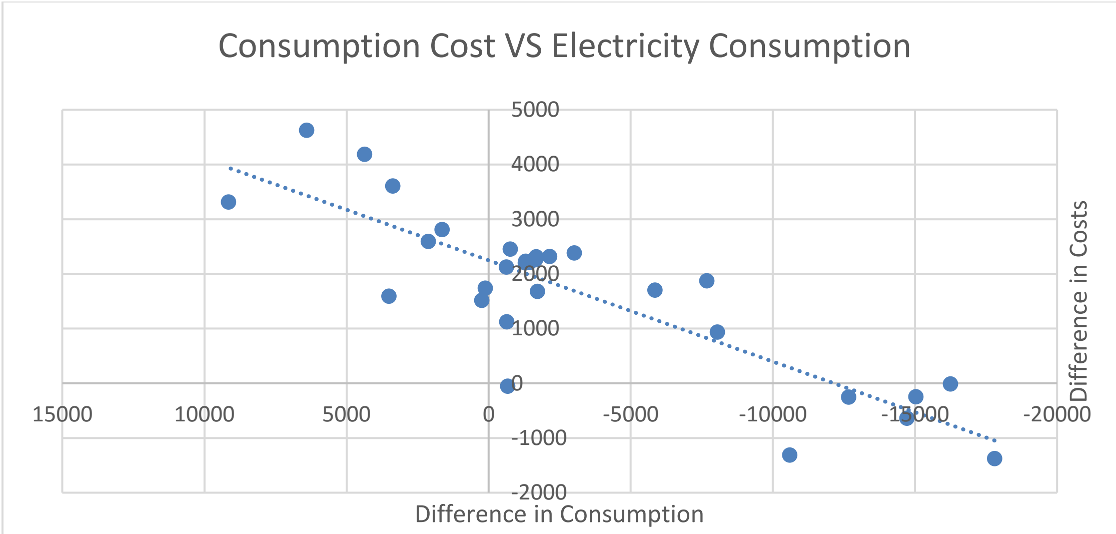


Figure 11: Correlation between Consumption Cost & Electricity Consumption

On the other hand, consumers in Saudi Arabia due to the nature of existing market do not have spare capacity due to economic feasibility to search for other means to reduce consumption and costs for electricity. Generally, factors contribute to energy consumption depends on:

- Electricity prices
- Income per capita
- Net imported energy
- Capital stock [38]

From the analysis of data and for existing Saudi electricity market, for a 5% increase in consumption cost paid by consumers, there is 1% drop in electricity consumption. Also, for an increase of 3% in tariff, the electricity consumption will drop by 1% and such relationship is linear till the demand becomes inelastic but in Saudi Arabia the demand and supply of electricity in abundant and the prices are not yet burden to consumer and that is why it takes 5% increase in consumption costs to have a 1% drop in electricity where in other countries for the USA for example, it takes only 3% increase in cost to have 1% drop in consumption.

In addition, Saudi Electricity Company (SEC) data for 2017 and 2018 as shown below in both appendixes A and B shows that for Eastern Operating Area (EOA) and for Dammam Operating Area (DOA) in particular where the 30 houses located , the consumption in MWh has decreased by 6.4% although the GDP in the kingdom has risen from -0.86% to 2.1% so that strengthen the argument that the reduction in consumption for the area is mainly due to price of tariffs which lead to less consumption of electricity (see appendix A for load growth details and for Dammam Operating Area (DOA)). At the same time, appendix B show that for the increase of the new tariff the whole kingdom electrical system for residential consumption shows a reduction of 9% which is very close to the sampled houses reduction in consumption. We need to take into consideration that the GDP growth and weather data show no change or growth for the two years of 2017 and 2018 while the tariff was the key factor that has increased by 24.5%.

For the EUI, the difference is calculated to be by comparing the difference between EUI at 2017 and EUI and 2018 and it turns to be -14% (decrease). Such indicates that energy performance of existing buildings has improved by increasing the tariff cost without having to introduce any Energy Efficiency Measures (EEMs) to the buildings.

CHAPTER 5

POST RESTRUCTURING ELECTRICITY MARKET

In this chapter the new electricity market is discussed with its major features and how such electricity market will have an impact on buildings consumption. A model to establish a link between building energy performance and electricity market performance is laid out in order to have comprehensive view and understanding of the dynamics of different factors affecting the electricity market. The model will provide two major options for buildings that will impact the energy performance and the electricity market which is the introduction of PV net metering service. In both scenarios the study and modeling will be carried out and the results from the model will be discussed. The need here is to compare the two scenarios: buildings with PV net metering and buildings without. It is expected to have difference in both building generation of electricity and consumption behavior. The building ability to generate power and send the excess to the network will have enormous impact in many aspects of the building energy performance. Homer software will be used to carry the analysis along with providing tables explaining the estimations of power generated, electricity consumed, cost of production and consumption and measure expected EUI values for both scenarios. The aim here is to validate the model that will enable us to calculate and estimate the benefits of such new electricity market and measure the impact on building energy performance.

5.1 New Electricity Market in Saudi Arabia

As laid out in Chapter 3, the new electricity market was explained from the standpoint of electricity major actors: generation companies, ISO (Independent System Operator), Principle Buyer, transmission company (National Grid) and transmission and distribution companies. However, the consumer will look at the market from different prospect looking into the major factors influencing him: cost of electricity, consumption and ability to conserve or generate power to sell the excess. The consumer in the new proposed market that is depicted in figure 1 will be able to have some leverage and different behavior. Furthermore, the consumer can react to the increase of tariff prices with different strategies like:

- Choose to Self-Generate through installing PV systems
- Implement Energy Efficiency Measures to curtail consumptions
- Choose power storage capabilities
- Enhance energy automation and control in the building
- Change energy consumption behavior
- Choose different plans for his electricity provide with new retailer or renegotiate existing deals
- Complain to regulator and earn compensation for damaged goods or appliances.

Since the ISO will ensure fair competition, the production cost for the generators participating in the day ahead market which is in every day there will be a merit order for a short term forecast and a PPA (Power Purchase Agreement) with Principle Buyer, it is expected to have varying production costs for each kWh produced taking into account the thermal efficiency for power plants and possibility of large scale renewables participating. The key idea is at market equilibrium, there must be a minimum average production cost that is expected. In order to do that, an optimization must be performed to reach the production cost at which the market is in fair competition.

The drastic change that will occur in Saudi Arabia is the fuel prices will not be subsidized which will lead to more efficient electricity market. Therefore, the production cost based from all bidding generators must be optimized to reach a cost that reflects the fair competition in the market. The optimization equation can be described as follows:

$$min_{xi(t),ui(t)} \sum_{i=1}^{N} \sum_{t=1}^{T} [Ci\big(Pi(t)\big) + SCi\big(u_i\,(t), u_i\,(t-1)\big)] \quad (1)$$

Where:

$Pi(t)$: is the power produced by unit i during period t

$u_i\,(t)$: is the status of unit I during period t; $u_i\,(t)$= 1 if unit i, is on and 0 otherwise

N is the number of generating units that have submitted bids

T is the number of trading periods into which the day is divided

$Ci\big(Pi(t)\big)$: is the cost of producing constant $Pi(t)$ with unit i, during period t.

$SCi\big(u_i\,(t), u_i\,(t-1)\big)$: is the cost of staring up unit I at period t. this cost is nonzero only if the unit was off at period t-1 and is on at period t.

The other constraint to find the optimization is that the load generation must be equal to the load (demand) [39].

Based on the previous optimization equation the cost of production is obtained. For Saudi market and based on the structure laid out in this thesis , a study by KAPSARC (King Abdullah Petroleum Studies and Research Center) carried a study [40] to determine the production cost as per the new electricity market laid out in Figure 1 taking into considerations the whole inputs and performance of power system in Saudi Arabia. With all subsidies left up and assuming averaging of $ 58 for barrel of oil equivalent the production cost for generation will be 33 halahah/kwh. Such number must also add to the cost of transmission, distribution, retail and must compensate for energy losses in Transmission and distribution.

The cost of transmission equals to 2.23 halalah/kwh and for distribution is 2.75 while the losses in account for 10.1% in the grid. Based on that the estimated minimum production cost till the meter of consumer is 39 halalah/kwh taking into consideration the wheeling charges for the gird. At the same time since SEC contributes for 62% of generation production such percentage is expected to decrease due to market penetration of new producers and the impact of PV at consumers end. The impact will be laid out in subsequent chapters.

5.2 Model Design to Link Electricity Market Restructuring & Energy Performance of Buildings

The energy performance of buildings has been studied in many cases independent of the performance of power system and electricity market nature although the two are strongly correlated. Furthermore, the advent of new technologies will make it imperative to study the impact since the buildings can be controlled for their energy performance and can now produce energy using PV systems adding more energy to the system and possibly compete with large producers in cost competition. The aim of this section is to design the model that link such performance and make it easier to predict the energy performance of a building depending on the electricity market forecast and it is nature.

As laid out in Figure 12, the block diagram of the model consists of certain inputs which are: Building floor area in meter square, Maximum Demand in (KWp) which indicates the maximum power the peak of consumption would not reach otherwise the energy requirements cannot be met, load factor which compares the maximum demand to average demand, market type and net metering option. Such inputs will determine the energy yield and performance without taking into consideration the detailed architectural aspects of the building which is out of scope for this study. This model will work for existing buildings with known energy profile. It can also work for design stage for future buildings but provided a separate simulation model like Design Builder or any energy modeling software for buildings. Then the output can be used in the model.

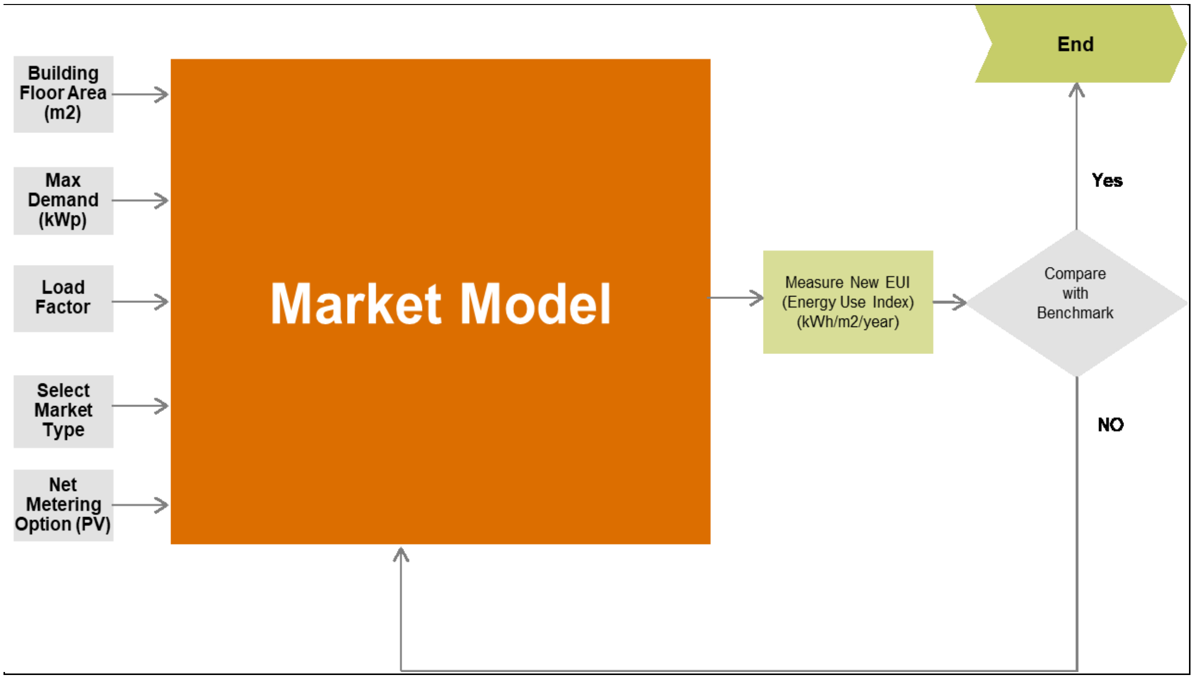


Figure 12: Block Diagram of Designed Model to Link Electricity Market Type to Energy Performance of Buildings

The output of the model will yield the measurement of EUI which is going to be compared to predefined set of EUIs for average readings for particular zone. If the output is satisfying then the energy performance is accepted if not another measures can be taken to reduce the EUI to acceptable levels. A detailed view of the model is depicted in Figure 13. The area will determine the total available area for PV depending on the Saudi houses lay out which has been studied before [40]. By using Homer software modeling energy yield can be obtained depending on the designed system chosen for the house which will be laid out in subsequent sections.

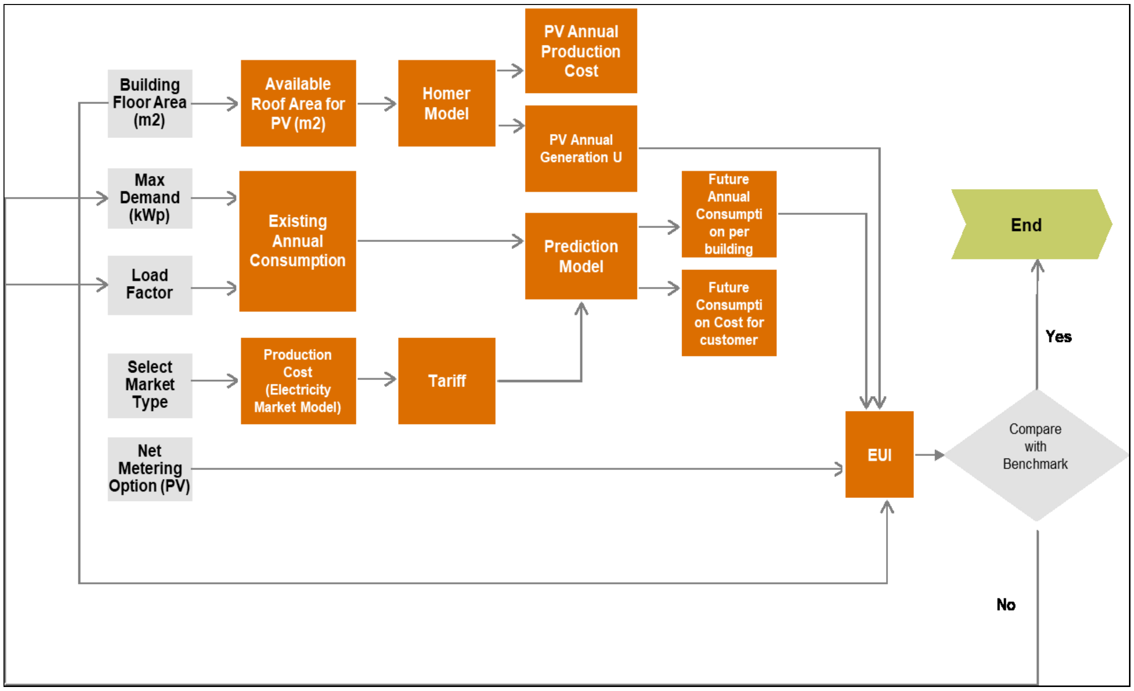


Figure 13: Detailed Block Diagram of Designed Model to Link Electricity Market Type to Energy Performance of Buildings

In addition, the Maximum demand and load factor will determine the consumption at every hour through equation:

$$Energy\ Consumption = Maximum\ Demand\ \times Load\ Factor\ \times 8760 \qquad (2)$$

Where:

Maximum Demand (kW): is the maximum demand for the building power demand at the peak

Load Factor: is the utilization factor or comparison between maximum and average demand

8760: number of hours in a year

For the model to work, the existing energy demand must be provided. The other input, is the market type. In this selection the market can be a natural monopoly and it will yield a production cost that will give a certain tariff or competitive market that will have varying production costs based on market supply and demand and hence a tariff structure that can be also dynamic like Time of Use (TOU). Based on the relationships derived in chapter 4 for increase in tariff costs and consumption of electricity, the prediction can be made to predict future annual consumption in the building and future consumption costs. The option for net metering by using PV systems will make a substation difference based on the feasibility. For Saudi future electricity market, the PV net metering will be feasible the production cost of electricity is less than that of production cost by grid.

After the model calculates in either scenario the new EUI will emerge and can be compared to existing EUI numbers which are reasonable for good performing building or not. In addition, the model will lay out the excess of energy that can be sold to the network in case the demand is low. Such will change the behavior of the consumer to ensure that his PV system can produce more and fend off the costs he has to bear with the importing energy from the gird. It can be noticed that the model has within two models which are: Homer for modeling PV systems and Electricity Market Production cost model.

5.3 Scenarios to Model and Show Results

The two scenarios that will be studied are the consumption, costs and EUI for buildings using PV net metering and without net metering. Those two scenarios are the basic and most important scenarios for the aspects of the building energy performance in the electricity market. In each scenario the energy consumption based on the new electricity market will be laid out along with the cost of consumption and consumption EUI for both scenarios. The reduction in energy that is expected will be again calculated as benefits toward aggregated level.

5.3.1 Future Consumption, Costs & EUI without Using Net Metering Scenario

In this scenario the buildings chosen for the study will not use PV systems for net metering. Rather, the buildings with the same existing architectural aspects will experience increase in the tariff costs that will be competitive for the electricity market. Such tariff will be based on the minimum of the production cost for the new electricity market in Saudi Arabia. The cost is estimated to be 39 halalah/kWh. Since the relationship between tariff increases, consumption cost and electricity consumption is estimated linearly for every 3% increase in tariff cost, the consumption cost will increase 5% and the electricity consumption will decrease by 1%.

Table 4: Future Annual Consumption and Cost

Dhahran	Area (m*2)	Amper (A)	Installed Capacity (KW)	Annual Consumption in Free Market Scenario (kWh) (Without Net Metering)	Annual Consumption Cost at Free Market (SR) (Without Net Metering)
Building 1	120	60	22.8	35,035.91	20,965.43
Building 2	120	60	22.8	30,343.86	16,330.51
Building 3	120	60	22.8	19,520.12	7,880.81
Building 4	120	60	22.8	38,855.27	24,621.38
Building 5	120	60	22.8	9,891.95	2,419.98
Building 6	120	60	22.8	15,735.08	11,915.06
Building 7	120	60	22.8	19,167.36	6,419.58
Building 8	120	60	22.8	9,114.60	3,035.08
Building 9	120	60	22.8	11,013.16	3,667.51
Building 10	120	60	22.8	13,303.88	4,331.70
Building 11	120	60	22.8	15,075.32	4,782.20
Building 12	120	60	22.8	6,850.57	2,035.90
Building 13	220	100	38	25,871.10	10,289.23
Building 14	220	100	38	21,095.15	7,017.35
Building 15	220	100	38	23,483.12	8,374.62
Building 16	220	100	38	23,863.22	9,272.73
Building 17	220	100	38	21,271.21	7,086.66
Building 18	220	100	38	25,586.35	10,396.08
Building 19	320	150	57	21,078.62	11,623.40
Building 20	320	150	57	29,398.08	13,618.86
Building 21	320	150	57	24,257.29	9,529.74
Building 22	320	150	57	26,822.60	10,814.81
Building 23	320	150	57	25,399.48	10,309.45
Building 24	320	150	57	26,553.74	10,684.86
Building 25	550	200	76	27,458.21	11,990.15
Building 26	550	200	76	31,914.45	14,499.64
Building 27	550	200	76	32,630.78	14,823.08
Building 28	550	200	76	35,204.98	17,592.48
Building 29	711	250	95	43,475.50	30,870.58
Building 30	740	250	95	45,332.10	32,187.42

The base year is 2017 tariff and from the strong correlation between tariff increases, consumption cost and electricity consumption, the relationship is linear and can deduce the future amounts. Therefore, the correlation indicators can be summarized in the following table:

Table 5: Correlation Values based on Tariff Increase and Change in Consumption

Old Tariff (h/kWh)	New Tariff (h/kWh	Increase in Tariff %	Change in Cost of Consumption %	Change in Electricity Consumption %
14.5	18	24.14%	41.25%	-8.19%
14.5	39	168.97%	288.78%	-57.88%

Table 5 and from the behavior of consumption for the costs and consumptions in years 2017 and 2018 will give us a base to predict future values in this scenario. Table 4 shows the values for the new consumption of electricity and consumption costs. It can be noticed that the change in consumption is almost tripled and the consumption in electricity will be amply reduced 57.88 %. Although the numbers are hypothetical but they are very important in predicting the consumer behavior which will lead him to adopt other measures to reduce the cost of consumption which will impact the consumption.

For the EUI numbers, it can be noticed that that by dividing the total new consumption in kWh over the total floor area; the average reduction will be 36.44% which is significant improvement in the energy performance without performing any extra investments. The numbers seem to be a bit higher than expected since it would be difficult for a consumer to cut his consumption by 58% since that will mean air conditioning must be compromised as it accounts for almost 70% of the house loads. However, it is expected to have extreme behavioral change in consumption by cooling some rooms and buying more efficient A/C units.

5.3.2 Future Consumption, Costs & EUI Using PV Net Metering Scenario

In order to design a PV system for such selected homes, certain aspects must be taken into consideration such as the location, PV panel's type, available area, orientation of the building, the costs associated to calculate the Levelized Cost of Energy (LCOE). Such challenges can be overcome when using sophisticated system known as Homer. The software major components are described in figure 14 where the software will model the solar insolation in the house area (Dhahran). The Homer biggest advantage it can model for grid tied PV system or grid connected and it will give the priority based on the cost of consumption. Net Metering will work as the priority for power will come from PV system and the remining will be imported from grid but when the demand in the house is lower than the generation or production of PV system, the excess will be feed in to the grid.

The utility in monthly basis will calculate the net of what has been sold to the customer and what has been imported and will compensate the consumer for the excess.

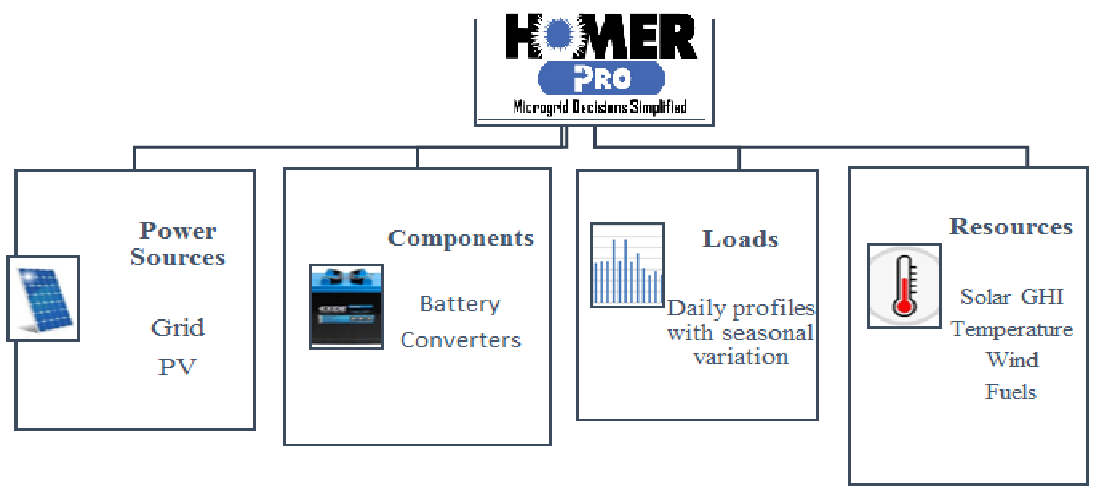


Figure 14: Homer PV Modeling Software Components

System architecture:

When running the analysis, we use the weather data for Dhahran city and making assumptions for the input data such as the tilt angle, load profile, the net metering scheme, operational cost and life time of the PV system. The General characteristic features of modeled grid-connected PV system are shown in table 6. Such general characteristics features focus on calculating the benefits generated from the PV system. The discount rate and inflation rates are considered based on Saudi Arabia market.

Table 6: General characteristic features of modeled grid-connected PV system

Name	Description
Diesel cost	0.067 $/L
Project Lifetime	20 years
Discount rate	2.75%
Inflation rate	2%

The major component in PV system is the PV panels where most of the cost is accounted. The photovoltaic modules used for the system design are type 'Mono-crystalline. The technical specifications of the PV panels are described in table 7. The specifications highlight the PV types which differ in efficiency, shapes and other features. Also the table describes the type of axis, temperature coefficient and loads types.

The cost per kilowatt peak of the PV panels is 1200$ [41] with very strong potential for reduction in the future due to economy of scale phenomena. The cost includes installation, engineering, and wiring costs. HOMER requires the capital and replacement price of one kilowatt. Also, the maintenance fee was estimated be 10$/kWp.

One PV panel size is 994 mm width by 1640 mm length with a total area of 1.63 m2. Thus, a 33.6 m2 is enough to fit 85 PV panels with a total system output of 25 kW. Hence, the sizes of the system that entered in HOMER software were 20 kW. Also, solar panel efficiency, temperature, and tilt angle were selected.

Table 7: General characteristic features of PV panels

PV	Description
PV technology type	Mono-crystalline
Name of PV	Canadian Solar All-Black CS6K-290MS
Manufacturer of PV	Canadian Solar
Efficiency (PV)	17.72%
Nominal operating temperature	45^0C
Temperature Coefficient	-0.39%/ ^{0}C
Lifetime	25 years
Frame area/PV module	1.63 m2
Collector slope	Latitude of location
Solar tracking mode	Fixed
Installed PV panel cost	700 $/kW
Nominal Max Power	25 kW
Dimensions	1640mm x 994mm x 40mm

The other major component of PV system architecture is the Converter which basically responsible to change from AC to DC and vice versa. In the design and installation of grid-connected PV systems, the inverter ratings are recommended to be smaller than those of PV arrays (< 10%). The optimum inverter size can either be lower than or the same as the PV array rated size, basically due to meteorological factors, economic factors and inverter intrinsic parameters [42]. The second part of the solar home system is the inverter sizes which were chosen to be 24 kW, same as the sizes selected for the PV array. The capital prices for inverters are between 50 to 80 $/kW, with an average of 65 $/kW [43]. A grid connected central inverter (Frounius Symo 20.0-3-M) was used in the PV system Design. The converter has an efficiency of 98% and a rated power of 24 kW.

Table 8: General characteristic of Converts Used in the PV System

Converter	**Description**
Name	Frounius Symo 20.0-3-M
Efficiency	98%
Lifetime	10 years
Converter cost	65 $/kW
Replacement	60 $/kW

Figure 15 shows how the daily and seasonal load profiles are calculated. The model will provide in the simulation expected daily and seasonal load profile based in the input data provided explained earlier: location, area provided, angles, consumption, and costs. Such data are essential for the model to run. The model will give priority to the generation yield of the PV panels provided the cost is competitive to the cost of importing from grid.

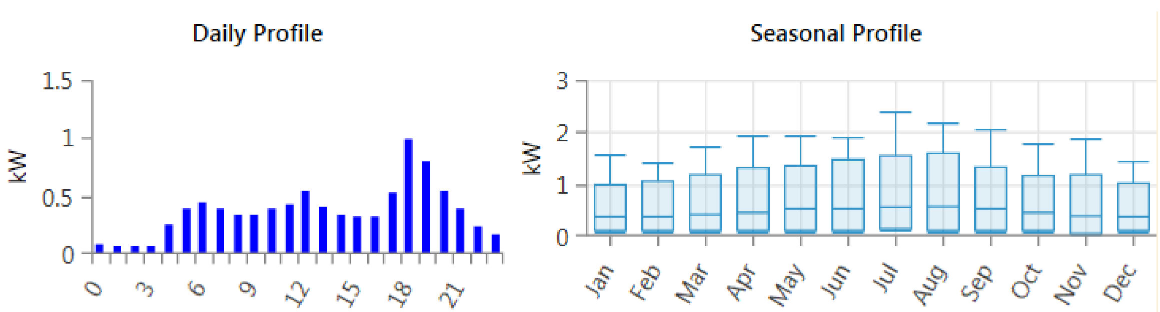
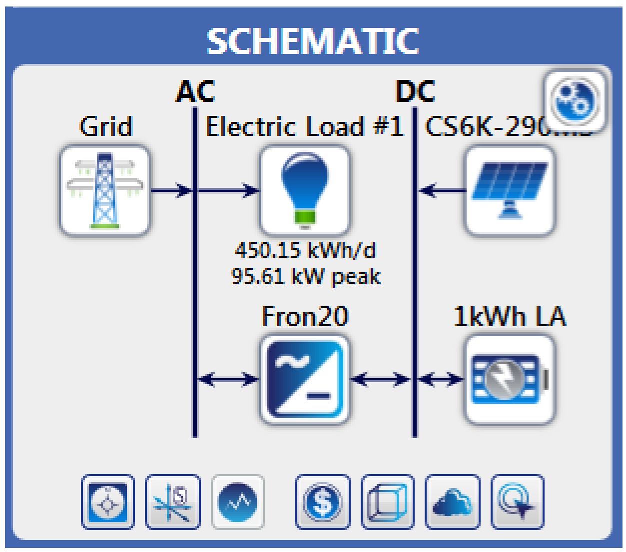


Figure 15: The home load profile

As shown in figure 16, the circuit diagram of the system is shown where the imported energy from grid AC system and the load of the house (Peak Load = 95.61 kW). Also the average daily consumption is presented to be 450.15 kWh/day. The DC system consists of the PV panels with battery with minimum days of autonomy in increase the reliability of the system at the building. Also, the convert is shown to convert DC to AC.



Metric	Baseline	Scaled
Average (kWh/day)	11.27	450.15
Average(kW)	.47	18.76
Peak (kW)	2.39	95.61
Load factor	.2	.2

Figure 16 : PV System Circuit Connections Showing Major Electrical Components with Loads

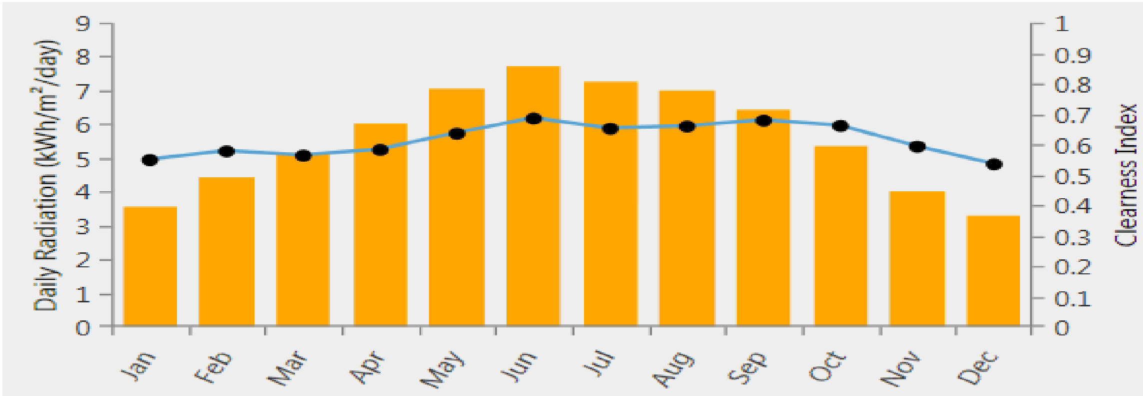


Figure 17: Daily Radiation of Dhahran (kWh/m2/day)

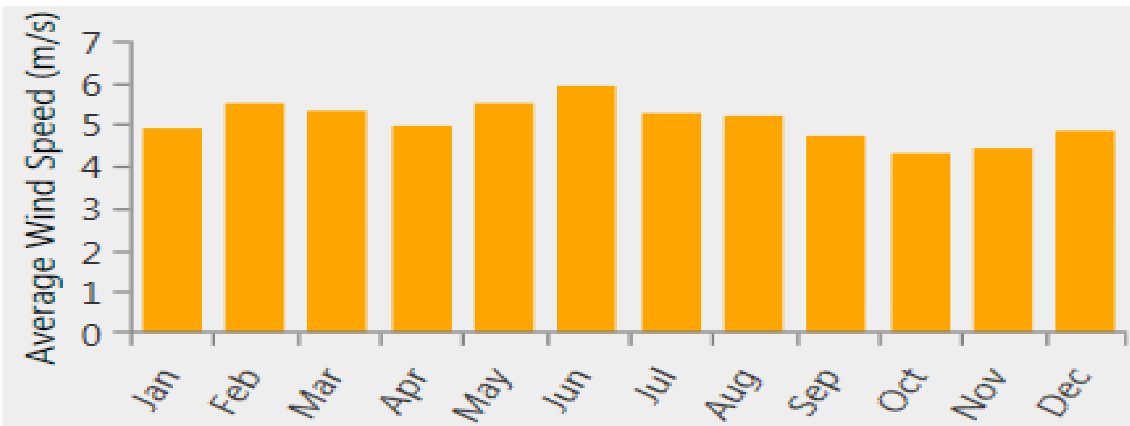


Figure 18: Average Wind Speed in Dhahran (m/s)

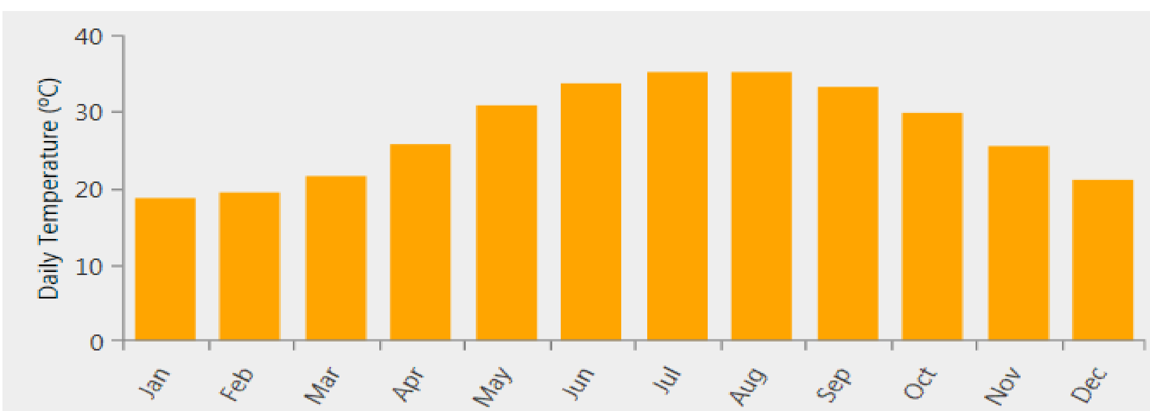


Figure 19: Daily Temperature Forecast

The factors affecting the PV generation capacity is laid in figures 17, 18, 19 with the solar radiation are the most important. The other factors like wind and temperature affects the efficiency of solar panels.

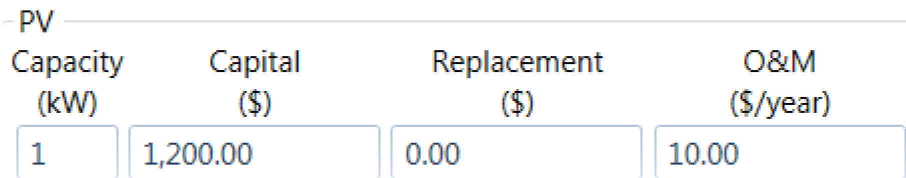


Figure 20: Cost Data Input For PV and Battery

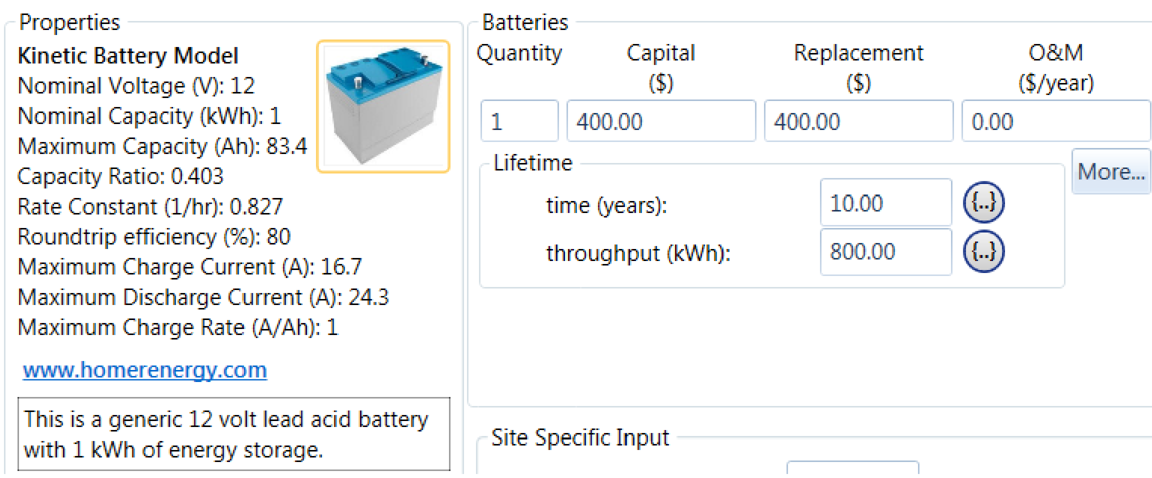


Figure 21: Battery Technical Specification

Also, important data for costs must be provided as shown in figure 20 and the number of days of autonomy where the whole system can be fed from battery is provided as per figure 21. Such PV grid-Tied system specifications and input data for the 30 selected buildings have been inputted. The major set of data needed are the generation yield and cost of production. Such data will enable us to know how much of energy is to be imported from grid and possibly excess can be sold out and at what costs are the energy is generated in the PV system to compare the costs with the grid coming from the grid.

Table 9: PV System Generation Yield and Cost of Production for Dhahran 30 Buildings

Dhahran	Area (m*2)	Amper (A)	Installed Capacity (KW)	Avilable Area in the Roof for PV (m2)	Annual PV Generation Per House (kWh)	Annual PV Generation Cost (SR)
Building 1	120	60	22.8	33.6	10600	1431
Building 2	120	60	22.8	33.6	10600	1431
Building 3	120	60	22.8	33.6	10600	1431
Building 4	120	60	22.8	33.6	10600	1431
Building 5	120	60	22.8	33.6	10600	1431
Building 6	120	60	22.8	33.6	10600	1431
Building 7	120	60	22.8	33.6	10600	1431
Building 8	120	60	22.8	33.6	10600	1431
Building 9	120	60	22.8	33.6	10600	1431
Building 10	120	60	22.8	33.6	10600	1431
Building 11	120	60	22.8	33.6	10600	1431
Building 12	120	60	22.8	33.6	10600	1431
Building 13	220	100	38	61.6	19500	2632.5
Building 14	220	100	38	61.6	19500	2632.5
Building 15	220	100	38	61.6	19500	2632.5
Building 16	220	100	38	61.6	19500	2632.5
Building 17	220	100	38	61.6	19500	2632.5
Building 18	220	100	38	61.6	19500	2632.5
Building 19	320	150	57	89.6	28300	3820.5
Building 20	320	150	57	89.6	28300	3820.5
Building 21	320	150	57	89.6	28300	3820.5
Building 22	320	150	57	89.6	28300	3820.5
Building 23	320	150	57	89.6	28300	3820.5
Building 24	320	150	57	89.6	28300	3820.5
Building 25	550	200	76	77	24300	3280.5
Building 26	550	200	76	77	48700	6574.5
Building 27	550	200	76	77	48700	6574.5
Building 28	550	200	76	77	48700	6574.5
Building 29	711	250	95	99.54	31500	4252.5
Building 30	740	250	95	103.6	32800	4428

Table 9 details the generation yield of each building. For each building the system was designed and run and the generation capacity can be noticed it increases with the available area on the roof for each building. Note that some buildings consist of floors so only the total floor area is calculated although the installed capacity needed is high. On average the PV system can take up to 41% of the required energy on a year. Although that technically should be verified in the sense that the nature of loads in houses may vary. However, such percentage is the maximum can be imported from PV based on the energy performance of group of the buildings.

The generation capacity however here is more desirable as consumer can control his generation and storage of power. Also, sudden blackout from electricity can be less since two feeding systems for energy are working which will enhance the reliability the customer is looking for. Also, for the customer and based on 2017 tariff , the PV system can reduce the cost on average by 11% and the reason for the low share is because of the lower tariff and high consumption but that share will increase significantly with the tariff price increase due to the electricity market restructuring.

Going back to the model figure 13, a generated data has been estimated for future consumption cost and electricity consumption based on the future electricity market restructuring as shown in table 10.

Table 10: Consumption cost, Electricity Consumption and Future EUI for Net Metering Scenario

Dhahran	Avilable Area in the Roof for PV (m2)	Annual PV Generation Per House (kWh)	Annual PV Generation Cost (SR)	Annual Consumption from the grid (With Net Metering) (kWh) Free	Annual Consumption From PV with (Net Metering) Free Market	Annual Consumption from the grid and PV (Net Metering) Free Market Scenario	Annual Cost of Consumption from Grid (SR) (With Net Metering)	Annual Cost of Consumption from Grid & PV for (Net Metering)	Future EUI (kWh/m2) with PV (Net Metering)
Building 1	33.6	10600	1431	769.21	10,600.00	11,369.21	460.30	1,891.30	94.74
Building 2	33.6	10600	1431	641.67	10,600.00	11,241.67	345.34	1,776.34	93.68
Building 3	33.6	10600	1431	347.46	10,600.00	10,947.46	140.28	1,571.28	91.23
Building 4	33.6	10600	1431	873.03	10,600.00	11,473.03	553.21	1,984.21	95.61
Building 5	33.6	10600	1431	85.75	10,600.00	10,685.75	20.98	1,451.98	89.05
Building 6	33.6	10600	1431	244.57	10,600.00	10,844.57	185.20	1,616.20	90.37
Building 7	33.6	10600	1431	337.87	10,600.00	10,937.87	113.16	1,544.16	91.15
Building 8	33.6	10600	1431	64.62	10,600.00	10,664.62	21.52	1,452.52	88.87
Building 9	33.6	10600	1431	116.22	10,600.00	10,716.22	38.70	1,469.70	89.30
Building 10	33.6	10600	1431	178.49	10,600.00	10,778.49	58.12	1,489.12	89.82
Building 11	33.6	10600	1431	226.64	10,600.00	10,826.64	71.90	1,502.90	90.22
Building 12	33.6	10600	1431	3.08	10,600.00	10,603.08	0.91	1,431.91	88.36
Building 13	61.6	19500	2632.5	366.33	19,500.00	19,866.33	145.69	2,778.19	90.30
Building 14	61.6	19500	2632.5	236.51	19,500.00	19,736.51	78.67	2,711.17	89.71
Building 15	61.6	19500	2632.5	301.42	19,500.00	19,801.42	107.49	2,739.99	90.01
Building 16	61.6	19500	2632.5	311.75	19,500.00	19,811.75	121.14	2,753.64	90.05
Building 17	61.6	19500	2632.5	241.29	19,500.00	19,741.29	80.39	2,712.89	89.73
Building 18	61.6	19500	2632.5	358.59	19,500.00	19,858.59	145.70	2,778.20	90.27
Building 19	89.6	28300	3820.5	84.02	28,300.00	28,384.02	46.33	3,866.83	88.70
Building 20	89.6	28300	3820.5	310.16	28,300.00	28,610.16	143.68	3,964.18	89.41
Building 21	89.6	28300	3820.5	170.42	28,300.00	28,470.42	66.95	3,887.45	88.97
Building 22	89.6	28300	3820.5	240.15	28,300.00	28,540.15	96.83	3,917.33	89.19
Building 23	89.6	28300	3820.5	201.47	28,300.00	28,501.47	81.77	3,902.27	89.07
Building 24	89.6	28300	3820.5	232.84	28,300.00	28,532.84	93.69	3,914.19	89.17
Building 25	77	24300	3280.5	326.54	24,300.00	24,626.54	142.59	3,423.09	44.78
Building 26	77	48700	6574.5	26.11	48,700.00	48,726.11	11.86	6,586.36	88.59
Building 27	77	48700	6574.5	45.58	48,700.00	48,745.58	20.70	6,595.20	88.63
Building 28	77	48700	6574.5	115.55	48,700.00	48,815.55	57.74	6,632.24	88.76
Building 29	99.54	31500	4252.5	637.53	31,500.00	32,137.53	452.69	4,705.19	45.20
Building 30	103.6	32800	4428	665.53	32,800.00	33,465.53	472.55	4,900.55	45.22

From table 10 the values are estimated for future consumption of electricity, the cost of consumption and future EUI. The calculation logic was performed taking into consideration that the energy yield from PV will be consumed first. Therefore, all of the energy generated will be consumed due to it is cheaper price compared to the energy imported from the grid (39 halahlah/ kWh). The remaining will be imported from the grid. To calculate that based on that fact, the total PV generation yield will not change in the future and will be consumed due to it is priority and same cost while the energy imported from grid will be consumed less and it is cost will be higher as the same scenario and relationships used for without net metering .

The results of such scenario will make the consumption decreases by 43% and the cost also will decrease by 24% and the EUI will be improved by 51%. Such numbers explain the superiority of the PV systems for net metering in the future electricity market and how such technology will gain a lot of momentum.

5.4 Results Analysis and Discussions

In order to link the performance of building energy and the new electricity market in Saudi Arabia, a proposed model is designed where it links the electricity market and it is production cost of electricity as optimized price due to competition and no subsidies to the performance of energy in buildings where the consumption and generation through PV systems are captured. The model asks through total floor area, maximum demand, load factor and option to have net metering. Such inputs will yield the generation capacity and consumption in the buildings and such demand will have response from a competitive market. The production cost is estimated to be 39 halalah/ kWh taking into consideration the cost of transmission and distribution networks all the way to consumer meter. Homer as a modeling is used to generate the PV generation output for the buildings selected. The output then will be deducted from the demand for each building. It is noticed that the PV generation can be utilized to generate 42% of typical residential building on average for a tariff more than 18 halalah/kwh.

When the model calculates the consumption number and cost of consumption there are two scenarios can be selected. The first scenario is without PV net metering option. In this scenario, we take 2017 as the base year and through correlation between increase in tariff and consumption, the calculated numbers are high. The consumption cost will ramp up to 288.78% and the consumption will be reduced by 57.33%. Such numbers although high, but they make sense in the way that the consumption will cost very high amount of money that will enforce the consumer to respond. But such numbers are assuming that the consumer will not choose to respond except by reducing the consumption.

In addition, the EUI in this scenario will be in average 111.4 kwh/m2/year which is lower than 2017 by -36.4% which indicates that the energy performance of the building will amply improved in such condition. The number is reasonable given some international indicators. However, the consumer in this scenario cannot respond except by changing the retailer or choose different billing plans or introduce Energy Efficiency Measures which can be costly.

For the scenario with PV net metering the results are quite different. For each building, PV system has been designed taking into considerations all required input data. The modeling was carried out by Homer which is PV optimization software that can work on grid tied PV systems. By using the system and modeling for each building. The energy yield was ample. The production cost was 13.5 halalah / kWh and depending on power storage such cost can reach up to 19 halalah/kwh. It has been calculated for assuming the cost of production for PV will remain at 13.5 halalah/kwh and the remaining energy demand will be imported from grid. The remaining amount will come at high cost and will be consumed less.

The future consumption cost will be reduced by 43.11% and the cost will also be reduced by 24% while the EUI will be reduced by 51.14%. As expected PV net metering will be the best option and will be win-win for the consumer and the electricity market competition and for ISO balancing and shaving the peak demand which is typical high in Saudi Arabia. The average contribution of PV system at the market price of 39 halalah/kwh can reach up to 94% when taking the average contribution of the sampled buildings.

Each consumer can save 26 halalah/kwh when installing PV system for net metering. Also, for PV option the power system and electricity market will be affected providing more energy to the market and allow peak shaving as follows:

Energy Demand (MWH) = Maximum Demand (MW) X Load Factor X 8760 hrs. (3)

And since the PV system according to the data gathered and analyzed can generate 41.98% and the residential sector typical constitutes 50% of energy demand and according the SEC data the energy sold to residential in 2017 was 144,259,520 MWH and the Load Factor can be estimated at 65% as an average for the power system in Saudi Arabia. Then the power can be saved = 25,336 MW. This is assuming all residential houses in Saudi Arabia install PV systems. Such number can significantly improve the load factor and shave the peak demand which is estimated at 63 GW. Also, such contribution will decrease the prices of electricity and will save a lot of investments in Generation and in the gird.

CHAPTER 6

ECONOMIC, ENVIRONMENTAL AND SOCIAL IMPACTS OF SAUDI ELECTRICITY MARKET RESTRUCTRUING

In this chapter, the focus is to evaluate the impact of the electricity market restructuring from economic, environmental and social angles. The approach is to evaluate the impact and come up with assessment of such restructuring. The economic impact will focus on consumer benefits and kingdom benefits. Furthermore, consumer although will bear the higher energy costs expected but in return the country as a whole should benefit from such restructuring as it is evident from other international experiences. On the other hand, there are other important benefits from environmental perspective for CO2 emissions reduction. However, social impact will be evaluated based on the concept of energy poverty.

6.1 Establishing a Baseline for the Economic Evaluation

6.1.1 Background

Economic, environmental and social impacts of electricity market restructuring are important to evaluate. The economic evaluation investigates the impact from two different perspectives: consumer and the country (kingdom) perspective. The reason for that is to understand the full spectrum of the impact. Also, such method will give more balanced view in order to capture the benefits of such transformation or restructuring. The economic evaluation focuses on the benefits and costs. Benefits can be represented by actual revenues, costs avoided and other types of benefits with respect to reliability and economic value added.

The environmental impacts are studied through measuring the savings of equivalent of CO2 emissions based on the energy saved through electricity market restructuring. Also, such impact can be evaluated toward Carbon trade if possible. On the other hand, the social impact can be evaluated through energy poverty definition and how energy prices will impact people daily lives. The measure will focus on energy poverty which is defined as if a person pays more than 10% of his annual income to meet energy requirements then such person has energy poverty [46].

6.1.2 Base Case Analysis

The base case focuses on the Business As Usual (BAU) option. In this respect, the consumer will continue the current situation without installing PV either in at the current tariff (18 halalah /kWh) or at the future tariff (39 halalah /kWh). The cashflow will be negative with respect to the payments the consumers have to bear and the results generated are based on the following cash flow diagram:

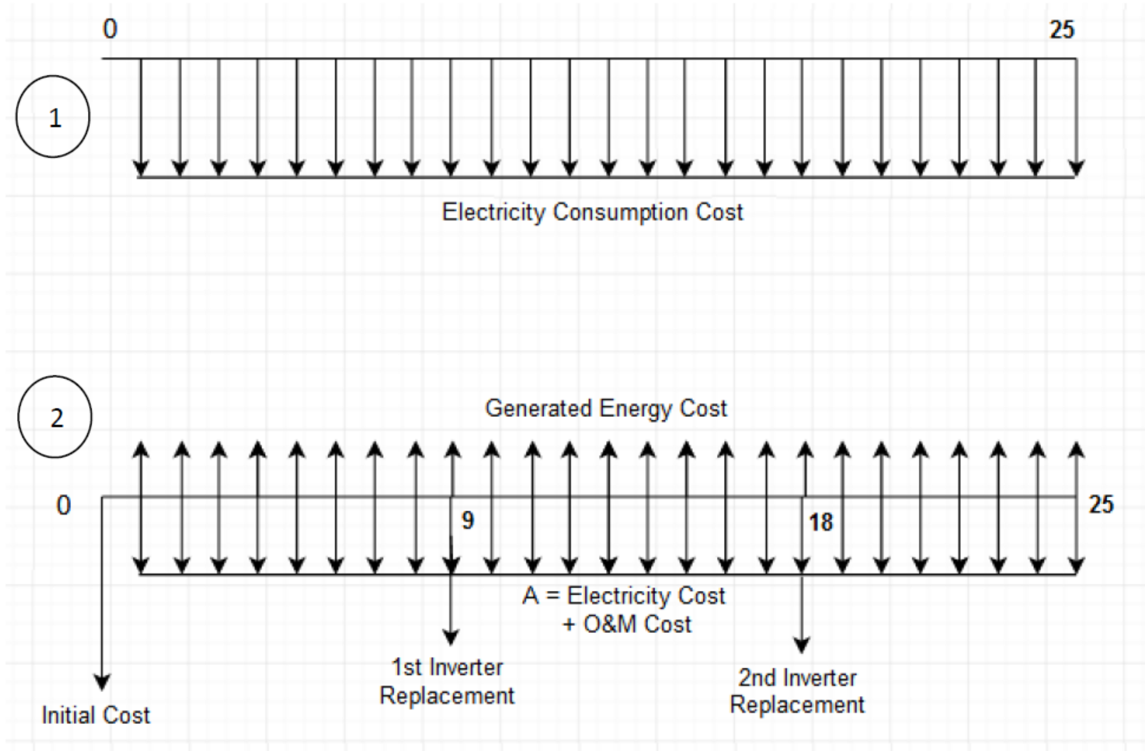


Figure 22: Cash Flow Analysis Comparison between the Base Case & PV Options

When running the Discounted Cash Flow (DCF) for the base case for the existing tariff and future tariff the consumers in the zone of the study have to pay annually as per Table 10 (170,891 SR) for 18 halalah/kWh and (349,386 SR) for 39 halalah /kWh tariff and the results are as follows:

	Current Tariff (18 halalah /kWh)	Future Tariff (39 halalah /kWh)
NPV	-3,743,102 SR	- 7,652,758

The results are obtained for P (F/P, i, n) = 170,891 (F/P, 2.75%, 20) for 18 halalah scenario. For 39 halalah scenario the formula = 349,386 (F/P, 2.75%, 20). It is evident that the consumers are losing more value when the tariff is higher in the future compared to the existing tariff. Therefore, the PV would justify investing if it can reduce the financial losses by consumers.

6.2 Consumer Perspective

The impact of Saudi Electricity market restructuring will result in increase in tariff prices to the consumer which will not be adding value to his purchasing power. However, some savings are expected by using PV systems in order to respond to the increase in tariff. The production cost based on Homer Software is in all cases less than the tariff cost (18 halalah/kWh). Such reality entails that the savings should be calculated as with and without PV scenarios. Also, the calculation should include the follow two scenarios looking into the response of the consumer:

6.2.1 Consumer Net Metering Cost (Energy Independence Standpoint) where customer can aspire to use all of his electricity from PV and not to import any from the grid.

6.2.2 Savings Based on Using PV Systems

For each scenario, we shall run Discounted Cash Flow (DCF) analysis and determine the Net Present Value (NPV) and Internal Rate of Return (IRR) and Benefit Cost ration

(B/C). If the NPV is positive and IRR is greater than the discount factor then the consumer is adding value to his investments in the electricity market.

6.2.1 Consumer Net Metering Cost (Energy Independence Standpoint)

For this scenario we will calculate the benefits and costs as per the following steps:

1- Calculate the installed capacity for the sample houses in (kW)

2- Estimate the capital cost required (market price of kW as of 2018)

3- Calculate the benefits as follows :

   Energy Yield = (PV Generation annually – Imported energy from the grid) X Tariff Cost

4- Run the Discounted Cash Flow (DCF) assuming the discount factor , salvage value, inflation and O&M costs for PV

5- Calculate NPV , IRR & B/C for current Tariff and Future Tariff (18 halalah/kwh and 39 halalah/kWh)

6- The analysis includes the whole sample of 30 selected houses and will be treated as one point of investment

6.2.1.1 Consumer Net Metering Cost (Energy Independence Standpoint) for current Electricity Market Condition

In this scenario, the consumer will aim to use his PV systems to meet his energy requirements. However, assuming there is no battery backup (very costly beyond justification); the consumer according to the previous consumption tables in chapter 5 and chapter 6 has to import electricity from the grid. The difference here is that consumer will import less electricity in the future electricity market as per prediction since the tariff prices will increase from 18 halalah /kWh to 39 halalah /kWh.

Next table summarizes the input data used to run the Discounted Cash Flow (DCF) analysis in order to obtain the NPV and B/C

Table 11: Values for Energy Independence Scenario Based on the Existing Electricity Market

Factor	Value
Tariff	0.18 halalah/kWh
Capital Cost	683,078 SR
Revenue	742 SR (annually)
O&M	1% of Capital Cost
Discount Factor	2.75%
Inflation	2%
Salvage Value	40985
Project Life	20 years

Note: in order to calculate the installed kW for PV for each house, the net area (28% of the total area of the house roof) is divided by 8 in order to obtain the installed capacity (8 m2= 1 kW) as per practice. The capital cost then is calculated by multiplying the resulting (kW) by the available market cost per (kW) in Saudi Arabia. The revenue is calculated as the net between the production cost of PV system and imported electricity from the grid. The salvage value is assumed to be 6% of capital cost as per Saudi Electricity Company financial practice. The lifetime of the project is assumed to be 20 years due to the harsh climate conditions in Saudi Arabia.

The results by using Discounted Cash Flow are as follows:

NPV = -650,219 SAR

B/C =0.05

At this tariff the , there cannot be energy independence for consumer and the NPV and IRR values are not worth investing based on this strategy. Also, from benefit cost ratio the project is not worth considering. Either the consumer has to bear the cost of imported energy from the gird or he has to use battery or stand by generator. Both options are not going to yield positive business case.

6.2.1.2 Consumer Net Metering Cost (Energy Independence Standpoint) for future Electricity Market Condition

In this scenario, the tariff cost will change to 39 halalah /kWh. Based on the consumption table (Table 10), the consumer will meet most of his energy needs from PV systems and will reduce dependence on the imported electricity from the grid. The following table summarizes the input data in order to run the Discounted Cash Flow (DCF).

Table 12: Values for Energy Independence Scenario for the Future Electricity Market

Factor	Value
Tariff	0.39 halalah/kWh
Capital Cost	683,078 SR
Revenue	3417 SR (annually)
O&M	1% of Capital Cost
Discount Factor	2.75%
Inflation	2%
Salvage Value	40985
Project Life	20 years

In this scenario, the future tariff is 39 halalah /kWh. The capital cost is assumed to be the same as per previous scenario although PV panels experience reduction in costs based on the experience of past years but the assumption is that the future electricity market is going to exist soon as per Kingdom of Saudi Arabia 2020 National Transformation Program (NTP). The revenues are calculated as follows:

Revenues = PV Production Cost – Future Cost of Imported Electricity from Grid. Note that the imported electricity from grid will decrease based on the established correlation and hence greater benefit from the consumer. The results by using Discounted Cash Flow are as follows:

NPV = -613,110 SAR

B/C = 0.11

At this tariff the , there cannot be energy independence for consumer and the NPV and IRR values are not worth investing based on this strategy. Also, the benefit cost ratio shows that no value is created and the costs outweigh the benefits. The consumer still has to pay for the utility amount of money that exceeds his justification to install the PV systems. This perspective may turn to positive business case if the costs of batteries or stand by generators are less than that of utility. In addition, the net metering strategy is not adapted but use instead spot market where consumer can sell his excess of energy at the highest price possible but both scenarios are not practical for the current situation in Saudi Arabia.

6.2.2 Savings Based on Using PV Systems

This perspective focuses on the cost avoided by installing PV system so that consumer does not have to pay full amount of his energy needs to the utility. Instead, the saved amount or benefits will outweigh the investments required for the PV systems. In other words, the consumer if not installing PV net metering he would be paying certain amount but if he installs PV system ,the cost he has to pay to utility will be different. The cost avoided is the benefit the consumer obtains and will be calculated to find whether net metering is worth investing or not. There are 2 scenarios: one is based on 18 halalah/kwh and the other for the future market where the tariff will be at 39 halalah/kwh. The production cost of the PV energy generation is calculated by using Homer software.

6.2.2.1 Savings Based on Using PV Systems at 18 Halalah/kwh

In order to calculate the cost avoided it will be as follows:

Cost Avoided = (Cost of Total Consumption at 18 halalah/kwh) – (Imported energy from grid at 18 halah+ PV energy generated at PV production cost)

By solving the previous equation, the cost avoided can be calculated as:

Cost Avoided = PV Energy Generation at 18 halalah/kwh – PV Energy Generation at PV production Cost). The cost avoided for the sampled homes is calculated as a benefit. The following table summarizes the inputs needed for the economic assessment:

Table 13: Values for Existing Market for Cost Savings Scenario

Factor	**Value**
Tariff (net)	0.045 halalah/kWh
Capital Cost	683,078 SR
Benefits (Costs Avoided)	98024 SR
O&M	1% of Capital Cost
Discount Factor	2.75%
Inflation	2%
Salvage Value	40984.68
Project Life	20 years

From the previous table, when we run the Discounted Cash Flow (DCF) the results are as follows:

NPV = 869,535 SAR

IRR = 11.22%

B/C = 2.3

It is clearly the investment in PV systems for net metering when measured to the cost avoided is worth investing. The benefits outweigh the costs and value is created. The consumer can justify his investment in order to save money that will not force him to pay the full amount to the utility.

6.2.2.2 Savings Based on Using PV Systems at 39 Halalah/kwh for Future Electricity Market

In order to calculate the cost avoided it will be as follows:

Cost Avoided = Net Tariff X PV Generation in kWh

The other input values are the same as in previous scenario. The following table summarizes the input values.

Table 14: Values for Future Market for Cost Savings Scenario

Factor	Value
Tariff (net)	0.255 halalah/kWh
Capital Cost	683,078 SR
Benefits (Cost Avoided)	555669 SR
O&M	1% of Capital Cost
Discount Factor	2.75%
Inflation	2%
Salvage Value	40984.68
Project Life	20 years

From the previous table the Discounted Cash Flow results are as follows:

NPV = 8,009,980 SAR

IRR = 42.2%

B/C = 12.7

Clearly in the future market, having PV system will be very worth it of investing. The reason to having high IRR is that the benefits are high relative to the costs incurred by purchasing the PV panels. The future tariff will be 39 halalah /kWh while the production cost is only 13.5 halalah/kWh. The savings here is 25.5 halalah/kWh. This amount is almost double the production cost of the existing PV panels. Therefore, the consumer will have very justifiable reasons to buy the panels. The savings here are not financial gain but rather costs avoided buy customer not to pay the full amount to the utility at the tariff price of 39 halalah/ kWh.

6.2.3 Summary of Results

The following table summarizes the results of all scenarios:

	Base Case (Without PV Option)		PV Option			
			Energy Indepdence		Energy Savings	
	18 Halalah Tariff	39 Halalah Tariff	18 Halalah Tariff	39 Halalah Tariff	18 Halalah Tariff	39 Halalah Tariff
NPV	-3,743,102	-7,652,758	-650,219	-613,110	869,535	8,009,980
IRR	N/A	N/A	N/A	N/A	11.22%	42.20%
B/C	N/A	N/A	0.05	0.11	2.3	12.7

From the previous table it is evident that PV option would be far more economic to have for the future market. Consumers will lose less in the energy independence scenario and their investment can be justified.

6.3 Kingdom Perspective

The major benefits of the new market are to curb consumption of electricity , utilize assets better and make significant savings in oil and gas which can be exported instead of used locally for subsidized prices. Also, by using PV systems for net metering , that would help further reducing the consumption from hydrocarbon based and savings from transmission and distribution networks where investments can be avoided. The scenarios here are as follows:

1- Savings at Tariff of 18 halalah/kwh for Existing Electricity Market
2- Savings at Tariff 39 halalah/kWh for Electricity Future Market with Net Metering (PV Systems)

The benefits and costs are going to be estimated for the sampled houses. Then, the figure can be aggregated to national level taking into account certain assumptions. This way, the assessment can be more generic. In addition, the environmental assessment can be added along with social impact.

6.3.1 Savings at Tariff of 18 halalah/kwh for Existing Electricity Market

When the tariff increased by 24.14% from 2017 to year 2018, the consumption for the sampled homes reduced by 8.19%. Such decrease has an impact. The benefits can be attributed to increase in tariff are as the following:

1- Savings of oil and gas equivalent
2- Cost avoided in building new capacity in Generation, Transmission and Distribution
3- Shaving the peak demand where the peak has higher production cost

The analysis will deal with the whole sampled homes and then aggregate figures to national level. Aggregation will be done assuming that all zones experience the same behavior as Dhahran.

The total energy consumption reduction in the sample homes will yield the following values as per the table:

Table 15: Values for Existing Electricity Market from Kingdom Perspective

Factor	**Value**	**Data Source**
Energy Consumption Reduction (kWh)	427,205	From Data Sampled
Barrel of Oil Equivalent (SR)	9,413	Done Through online Calculator (Shadow Price of Oil is 10 USD as per SEC data converted to SR)
Power (kW)	75	Convert Energy to Power by using (Energy/Load Factor X8760 hrs.)
Cost Avoided for Generation (SR)	17,706	Study by ECRA (avoided cost 263 SR/kW) [43]
Cost Avoided for Transmission & Distribution (SR)	6,377	Study by ECRA (avoided cost 85 SR/kW) [43]
Capital Cost to Connect to Customers incurred by SEC (SR)	121,919	SEC Data (1,625 SR/kW)
O&M Cost (SR)	6,096	SEC Data (5% of Capex)
Salvage Value (SR)	7,315	SEC Data (6% of Capex)

The energy consumption reduction is calculated based on the difference in energy consumption in 2017 and 2018. The tariff increase between the two years has resulted in consumption increase although the consumer has beard the cost but the Kingdom has benefited from such consumption reduction. Hence, such reduction is calculated as a benefit that can be translated into cost savings when converted to Power in (kW) using the formula specified in the table assuming the load factor is 0.65 as it is the average load factor in Saudi Arabia. Other values are calculated based on previous studies for the impact of energy savings in the kingdom [43]. The costs avoided in generation, transmission and distribution are the result of multiplying the power in (kW) by the cost of avoided costs based on ECRA study [43].

The WACC (Weighted Average Cost of Capital), Salvage value, O&M costs, Capital Costs to connect to customers are based on Saudi Electricity Company (SEC) obtained data. Such data will enable us to run DCF analysis in order to find the NPV and IRR respectively.

From the previous table we can run Discounted Cash Flow (DCF) analysis to determine NPV and IRR by assuming WACC (Weighted Average Cost of Capital) is 7% and inflation is 2%. The results are as follows:

NPV = 154,093 SAR

IRR= 15%

B/C =1.8

In this scenario the mere increase of Tariff cost by 24 % will yield benefits for the kingdom such benefits will be of various types such as oil savings, cost savings in generation, transmission and distribution networks. The business case in this scenario is positive.

6.3.2 Savings at Tariff 39 halalah/kWh for Electricity Future Market with Net Metering (PV Systems)

In the future electricity market, this scenario captures the whole benefit for the system using PV net metering to calculate the whole benefits. The energy saved in this scenario is as follows:

Energy Consumption Savings = Energy Savings Due to New Tariff Hike + PV System Energy Generated. The next table summarizes the results:

Table 16: Values for Future Electricity Market from Kingdom Perspective

Factor	Value	Data Source
Energy Consumption Reduction (kWh)	1,069,848	From Data Sampled
Barrel of Oil Equivalent (SR)	23,625	Done Through online Calculator (Shadow Price of Oil is 10 USD as per SEC data converted to SR)
Power (kW)	188	Convert Energy to Power by using (Energy/Load Factor X8760 hrs.)
Cost Avoided for Generation (SR)	44,342	Study by ECRA (avoided cost 263 SR/kW)
Cost Avoided for Transmission & Distribution(SR)	15,971	Study by ECRA (avoided cost 85 SR/kW)
Capital Cost to connect to customers incurred by SEC (SR)	121,919	SEC Data (1,625 SR/kW)
O&M Cost (SR)	6,096	SEC Data (5% of Capex)
Salvage Value (SR)	7,315	SEC Data (6% of Capex)

From the previous table, we run Discounted Cash Flow (DCF) analysis and it has yielded the followings:

NPV = 662,941

IRR = 35%

B/C = 4.6

In future electricity market, the business case is positive and the restructuring is worth embarking on. The economic evaluation KPI's are better compared to existing electricity market results due to the huge savings in energy. The resultant savings can be with careful reservations generalized to the kingdom wide based on the fact that the load growth as per Saudi Electricity Data for the whole Dammam Area has dropped by 6.4% as explained in chapter 6. As known, electricity demand is dependent on GDP growth and electricity market competition based on supply and demand theory. The GDP growth in Saudi Arabia for the 2017 and 2018 are: -0.86 % and 2.2% respectively. According to the conventional wisdom, the demand or load growth rate should increase in 2018 because of positive GDP growth but the load growth has dropped; therefore, the tariff increase which is the only factor took place in the market is the primary cause for the energy consumption decrease experienced in 2018.

6.4 Environmental and Social Impacts

The emissions calculation is based on EPA (Environmental Protection Agency) in the USA. For the reduction in energy for the existing and future electricity market are as follows:

Table 17: CO2 Emissions Reductions

Market Scenario	Energy Savings (kWh)	CO2 Emissions (ton)	Equivalent (Number of Houses for Energy Consumption for a Year)
Existing Electricity Market Savings	427,205	318	34.3
Future Electricity Market Savings	1,069,848	796	86

From the previous table and based on existing and future electricity market, the savings in energy in kWh for the sampled houses will result in savings in CO2 emissions in ton and it is equivalent in number of houses that can be powered (according the US standards). Such numbers are important to Saudi Arabia as it is considered among top countries for CO2 emissions per capita worldwide and has international obligations to curb CO2 emissions.

For social, the energy poverty and as per the definition of energy poverty, it would be cumbersome to calculate the percentage of people who are going to be energy poor for the existing and future electricity market. However, based on a study conducted by Saudi General Statistics Authority for 2017 electricity consumption at households 15.76% of households spend 11-15% of their income on electricity costs. Therefore, the energy poverty percentage in Saudi Arabia based on the study is 15.76% [44]. It is expected based on the tariff of 39 halalah /kWh to have more sections of society who are energy poor since the mean incomes will not grow with the same percentage as energy prices expected for the future market. This number will have more impact socially and government has already enacted initiatives such as Citizen Account to compensate for increases in energy prices. However, it would be very difficult to estimate the energy poverty percentage.

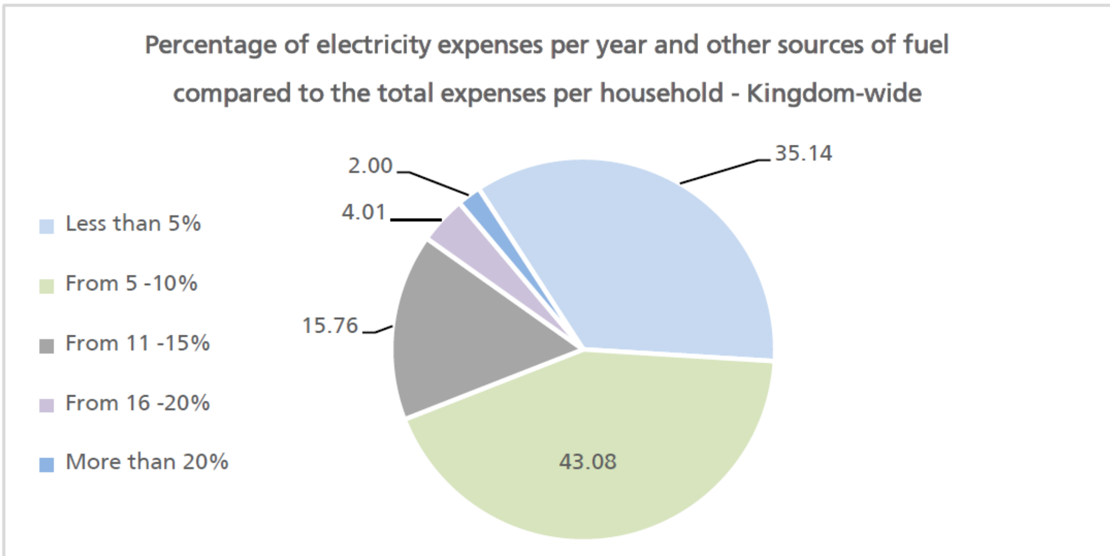


Figure 23: Energy Poverty Chart in Saudi Arabia for 2017 [46]

CHAPTER 7

CONCLUSIONS AND FUTURE RESEARCH

The future electricity market in Saudi Arabia will entail many prospects that will affect buildings energy performance. The objectives of this research have been examined and discussed. The key features of the energy market restructuring have been laid out with details explaining the key market actors like the generation companies, independent system operator (ISO), principle buyer , Transmission company, distribution companies, retailers and balancing fund which is used to pay off for imbalances in the market. Also, the new market has been studied while shedding light on the existing market that is vertically integrated where one company has monopoly over the market.

The buildings energy performance has been studied and values have been discussed where in the existing market the consumption cost and electricity cost has linear relationship can be predicted. Also, the impact of having PV system option was studied and as a takeaway it turns to be the most feasible and attractive option in order to maximize the value of the building energy performance in such new electricity market.

A model has been designed to have inputs determined by building energy characteristics and electricity market. Such model will predict future demand based on the existence consumption in the building and will provide EUI numbers that can be used to measure the energy performance of the building. Such number can be later used as a key feature of buildings when they are offered for sales for example since such number will indicate the costs of energy associated with a building. This will also encourage asset owners in real state to tag their buildings and ensure the energy performance is optimum.

The model can be further improved in two ways although will make it more complex. The first is for the newly designed buildings the output of energy simulation software such as design builder or eQuest can be used for buildings with not energy profile. Also, the building owner for many buildings can auction their energy in energy market and sell it with better price. Such will make the buildings themselves generation units and can be used as vehicles to generate more for the asset.

From the calculation it is evident that for a 3% increase in tariff cost, the consumption cost will increase by 5% and consumption of electricity will decrease by 1%. However, in the case of installing PV systems for net metering, both the consumption cost and electricity consumption will decrease 43% and 24% while the EUI will be reduced by 52.14% as the maximum value can be obtained in all scenarios.

The peak demand in Saudi Arabia can be reduced maximum by 25,336 MW but half of that number will be very good news for the system efficiency and asset utilization as it will improve the load factor. At the same time, when the peak is shaven, the electricity prices will go down due to increase in competition.

The new restructuring will have economic, environmental and social impacts. The economic evaluation for the consumer is evaluated from two angles: energy independence and cost avoided by using PV for net metering. In the first scenario, consumer will not have energy independence and has to pay for the imported energy from the grid. In that perspective, the business case is not positive. On the other hand, to use

PV to save costs the difference between the production cost of PV systems evaluated at 13.5 halalah /kWh while the imported energy from the grid costs 39 halalah /kWh will entail positive business case.

In addition, the Kingdom will save in fuel consumption, generation build up capacity, transmission and distribution for the new electricity. Such scenarios have been studied and it has yield positive business case at the level of the sampled houses. Furthermore, the CO_2 emissions reduction has been studied and significant savings have been laid out which will help the country to adapt more environmentally friendly policies. Socially, the electricity market restructuring will increase energy poverty levels among households and such can be averted by improving the safety net for low income people.

Future studies can help improve the model developed to model for the whole power system with respect to consumption and energy performance of buildings of all types. Software can be developed to encompass the results of other software that play to generate results for the model. For example, Plexos software (used to model electricity market) , Homer (used to model PV systems) and Design Builder (used to model building energy performance) can be linked through the model and make common inputs to find the most optimized situation and find most optimized production cost. At the same time, such model will help utilities to forecast and study impact of increase or decrease cost of electricity production and can predict consumer response to changes in prices and policies.

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APENDEX A : LOAD GROWTH IN MWH IN SAUDI ARABIA FROM 2015-2018

1. Load Growth in KSA : Eastern Operating Area & Central Operating Area

		2015	2016	2017	2018
KSA	KSA Interconnected	59,900	58,597	61,402	61,273
	Total SEC	62,260	60,828	62,121	61,743
EOA	EOA Demand	18,667	18,577	19,016	18,638
	DOA	6,040	5,701	5,665	5,301
	HOA	1,910	1,861	1,848	1,851
	NOA	1,863	1,818	1,862	1,811
	Saudi Aramco	3,227	3,659	3,648	3,574
	Jubail Industry	5,454	5,953	5,911	5,906
COA	COA with NEA	19,999	19,723	20,232	19,869
	COA w/out NEA	19,310	19,045	19,119	18,718
	Riyadh System	15,452	15,026	15,332	15,039
	Riyadh City				
	Qassim	2,854	2,891	2,852	2,771
	Ha'il	1,061	1,172	1,248	1,185

2. Load Growth in Western Operating Area

		2015	2016	2017	2018
WOA	WOA Demand	16,972	16,294	17,203	16,670
	Makkah System				
	Makkah City	4,337	4,286	4,626	4,301
	Taif	970	958	1,072	1,062
	Turabah	63.1	65		
	Ranyah	89.5	85		
	Khurmah	71.3	74	77	
	Jeddah System				
	Jeddah City	7,625	7,139	7,219	7,025
	Rabigh	233	240	229	223
	Madinah City	2,508	2,488	2,588	2,482
	Yanbu System	473	541	501	473
	Yanbu City				
	Omloj	86	89	90	

3. Load Growth in Southern Operating Area

		2015	2016	2017	2018
SOA	SOA_Demand	5,133	5,851	5,824	5,640
	Asir	971	1,059	1,084	1,110
	Tihama	1,077	1,098	1,205	1,166
	Baha	290	319	278	272
	Jazan System				
	Jazan City	2,004	2,052	2,074	2,070
	Bisha	492	564	494	490
	Najran	520	617	614	606
	Wadi Al-Dawasir	316	334	354	322

4. Load Growth in North Eastern Operating Area & North Western Operating Area & Isolated Systems Areas

		2015	2016	2017	2018
NeOA	NeOA Intercon. Sys.	737	740	1,070	1,336
	Jouf	467	478	507	462
	Ar'ar	271	270	268	263
	Qurayyat	197	204	216	189
	Tabarjal	111	119	122	113
	Turaif	66	72	67	64
	Waad Al-Shamal	--	--	115	171
NwOA	NwOA Intercon. Sys.	1,279	1,218	1,093	1,208
	Tabuk	895	827	846	868
	Dhuba	155	150	162	165
	Al-Wajh	65	64	73	66
	Al-Ullah	118	129	140	128
Isolated	Rafha	131	144	146	141
	Sharourah	126	116	121	123

APPENDEX B: ACTUAL LOADS FOR 2017 AND 2018 FOR ALL SECTORS

Acutal Consumption of SEC Customers for 2017			
Sector	**Type**	**Consumption (kWh)**	**Consumption Cost (SR)**
Central Operating Area	Reidential	48,364,699,520	4,487,516,956
	Commercial	16,752,842,112	3,788,575,540
	Industrial	6,458,277,985	1,202,871,360
	Health & Education	901,479,978	162,379,591
	Agricultural	3,519,111,453	488,432,509
	Governmental	15,070,123,456	4,817,518,521
Total		71,575,819,617	9,478,963,856
Western Operating Area	Reidential	50,199,828,117	4,089,632,035
	Commercial	17,762,556,412	4,217,024,841
	Industrial	5,800,702,628	1,020,186,724
	Health & Education	610,478,506	109,567,679
	Agricultural	974,609,642	125,879,590
	Governmental	12,004,143,112	3,828,500,739
Total		73,763,087,156	9,326,843,599
Eastern Operating Area	Reidential	27,743,337,329	2,526,308,635
	Commercial	9,342,325,664	2,167,564,041
	Industrial	35,261,691,776	6,274,278,823
	Health & Education	496,580,510	88,431,660
	Agricultural	1,040,276,473	130,615,106
	Governmental	6,649,161,282	2,178,660,690
Total		72,347,354,769	10,968,151,500
Southern Operating Area	Reidential	17,387,708,477	1,306,532,381
	Commercial	4,441,441,213	903,123,432
	Industrial	525,258,119	94,453,776
	Health & Education	97,157,326	17,499,385
	Agricultural	147,301,136	19,462,702
	Governmental	4,876,510,034	1,556,026,825
Total		22,354,407,808	2,304,109,588
Business Sector	Reidential	143,695,573,443	12,409,990,008
	Commercial	48,299,165,400	11,076,287,854
	Industrial	48,045,930,507	8,591,790,682
	Health & Education	2,105,696,320	377,878,315
	Agricultural	5,681,298,704	764,389,907
	Governmental	38,599,937,884	12,380,706,775
Total		286,427,602,258	45,601,043,540

Acutal Consumption of SEC Customers for 2018			
Sector	**Type**	**Consumption (kWh)**	**Consumption Cost (SR)**
Central Operating Area	Reidential	41,263,931,934	7,597,536,902
	Commercial	15,021,375,526	3,689,795,340
	Industrial	5,930,194,292	1,072,722,984
	Health & Education	892,487,073	162,461,657
	Agricultural	2,999,649,008	548,773,138
	Governmental	14,497,577,148	4,422,167,113
Total		62,215,501,752	12,360,055,226
Western Operating Area	Reidential	43,178,865,276	7,798,052,796
	Commercial	15,664,462,093	3,930,939,943
	Industrial	6,607,142,140	1,071,015,795
	Health & Education	585,318,802	105,293,093
	Agricultural	903,686,599	159,687,798
	Governmental	11,976,541,043	3,337,278,118
Total		65,450,469,508	12,800,008,534
Eastern Operating Area	Reidential	23,855,963,436	4,379,504,006
	Commercial	8,463,127,653	2,112,895,884
	Industrial	32,863,838,731	5,883,932,432
	Health & Education	435,584,137	78,433,290
	Agricultural	940,112,706	162,058,722
	Governmental	8,077,703,379	2,581,227,950
Total		65,182,929,820	12,376,332,321
Southern Operating Area	Reidential	14,954,995,098	2,618,244,100
	Commercial	4,533,398,524	1,073,558,567
	Industrial	658,982,958	116,663,820
	Health & Education	95,543,868	17,204,803
	Agricultural	130,923,868	23,195,579
	Governmental	5,483,514,275	1,749,781,780
Total		20,147,376,581	3,808,466,486
Business Sector	Reidential	123,253,755,744	22,393,337,804
	Commercial	43,682,363,796	10,807,189,733
	Industrial	46,060,158,121	8,144,335,031
	Health & Education	2,008,933,880	363,392,842
	Agricultural	4,974,372,181	893,715,238
	Governmental	40,035,335,844	12,090,454,962
Total		260,014,919,566	54,692,425,610

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