A SCENARIO DEVELOPMENT METHODOLOGY FOR ROBUST GRID PLANNING IN THE GCC CONTEXT

M. AL-SHEHRI[1], S. T. ALTURKI[1], T. R. A. AL-OTAIB[1], K. SCHMIED[2]*, G. PAPAEFTHYMIOU[2], S. STEPANESCU[2], T. KÖBINGER[3]

Abstract — **This paper presents a tailored scenario development methodology in the context of the GCC region that can identify and cover all uncertainties required in a robust grid planning process. Using a state of the art approach applied by European TSOs, possible development paths for the KSA energy sector have been analyzed based on a bottom-up approach. The methodology includes four main steps, namely a) scenario framework setting, b) identification of main drivers, c) impact and predictability assessment, d) scenario definition. The approach has been applied to the challenges faced by the planning departments of National Grid in Saudi Arabia. The paper presents in detail how this methodology can be deployed for the GCC energy landscape, using the Saudi Arabia study case as key example.**

Index Terms—**Energy Scenarios, Renewable Energy Sources, Load Forecasting, Robust Grid Planning**

I. Introduction

THE energy landscape in the GCC region is changing rapidly. In the Kingdom of Saudi Arabia (KSA), the rollout of the Vision 2030 [2] sets ambitious plans for diversifying the economy. This plan poses key challenges for the power sector in the coming years, in the form of a combination of high load growth with a radical transformation of the generation mix from oil and gas to variable renewable energy sources (such as solar and wind) [3] and nuclear energy [4]. In this context, National Grid SA faces significant uncertainties regarding the possible development paths of the electricity system.

The current grid planning process is based on load forecasting approaches that use a combination of bottom-up and top-down methodologies for the determination of the future system load. The resulting load forecast scenarios rely on sensitivity analyses with respect to the major impacting factors (GDP, population, new bulk customer connections, major events and temperature). These load scenarios are used as critical basis for both generation and grid planning processes. This is an efficient and well-functioning approach in a system with stable growth rates and a generation portfolio dominated by conventional power plants. However, due to the changing power mix, it is necessary to account for different development paths that cannot be covered with those sensitivities exclusively.

*Corresponding author: Kai Schmied, Elia Grid International, Heidestrasse 2, 10557 Berlin, Germany

The goal of this paper is to present a tailored scenario development methodology that can identify and cover all uncertainties required in a robust grid planning process in the context of the GCC region. The methodology is based on a state of the art approach applied by European TSOs (i.e. [5], [6], [7]). Through a bottom-up scenario development approach, possible development paths of the KSA energy sector have been developed. The approach includes four main steps and it has been tailored to suit the challenges faced by the planning departments of National Grid in Saudi Arabia.

The approached is based on 4 steps, as follows:

1. **Scenario framework setting:** The initial step is the set-up of the scenario framework defining the purpose of the scenarios, establishing the considered time horizon as well as the regional focus. The focus has been on likely local and international trends and developments between now and the target year of 2030.

2. **Identification of main drivers:** The main drivers for the development of the future electricity system can be categorized into five broad categories:
   a. Political framework
   b. Demand
   c. Supply
   d. Grid design
   e. New technologies

3. **Impact and predictability assessment for all drivers**: This step enables the identification of the severity of each of the drivers outlined above. To capture the impact of the most dominant uncertainties, an evaluation method focusing on the impact of those uncertainties on power system and the likelihood/predictability of the different drivers has been developed and performed on the KSA case, through assembling an impact-predictability-matrix.

4. **Scenario definition and qualitative scenarios description:** After the prioritization of drivers and their specifications, three scenario story lines have been developed in order to capture those most dominant uncertainties.

The paper presents in detail how this methodology can be deployed for the GCC energy landscape, using the KSA study case as key example. Although there are many specificities that are related to the developments in KSA, the general structure of key uncertainties is shared by many systems in the region and will form a useful basis for performing similar exercises in other contexts. The paper is structured as follows: In section II we present the general concept of using scenarios for grid planning purposes and the key reasons for the need of scenario approach. Section III presents how scenario development is applied in Europe. Section IV discusses the scenario building approach, while Section V presents the drivers and specifications tailored to the GCC region.

II. Energy Scenarios for Robust Grid Planning

A. Scenarios: framework for uncertainty analysis

Scenarios are a description of plausible energy futures. Usually a set of energy scenarios is used and each scenario follows a certain development, describing a possible pathway to a future based on specific assumptions on major developments. The goal is to describe these different developments realistically and consistently in storylines including all underlying causes and consequences. These storylines (scenarios) should form a framework that captures the full extent of possible developments that can be used in the proceeding grid planning process. For this, together with some base development scenario, some “marginal” storylines are chosen as the boundaries of the combined uncertainty. In this respect, most likely none of the scenarios becomes true as described, but rather an intermediate form can be expected that combines certain developments of all scenarios.

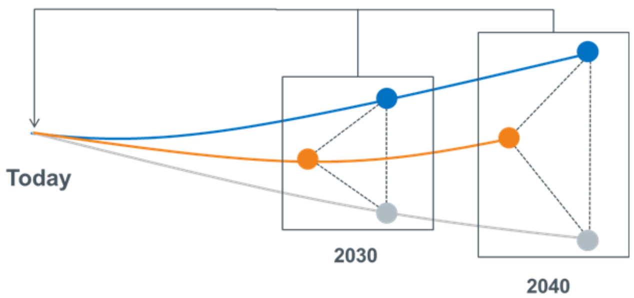

Figure 1: Scenarios support in taking the right decisions making today

As shown in Figure 1, scenarios are needed to map the increasing uncertainty for the future (mid to long term horizons) in order to support optimal decision making today. This scenario framework is used as basis for the assessment of the different grid expansion options. The robustness of grid expansion options relates to how far they qualify in different scenarios; grid development projects needed in all possible scenarios are robust and should be prioritized. In this respect, the scenario analysis forms the vital basis for the decisions taken today. The scenario development process should be repeated regularly in order to allow the incorporation of new developments, support new decisions and adjust previous ones.

B. Key reasons for scenario analysis

A major need for establishing scenarios in grid planning is the increased uncertainty related to the changing energy landscape due to the changing power mix through the introduction of renewable energy sources (RES). Reasons for this increased uncertainty are:

1. ***Planning uncertainty:*** The process of introducing RES differs from traditional generation capacity planning. In particular, the process is mostly politically driven and steered by policy targets. These targets are set on the basis of planned capacities or energy quotas, and are supported through universal support mechanisms, which are generally agnostic to locational aspects. Therefore, RES plants are developed first in locations with most favorable conditions (higher LCOE). As a result, the location of RES plants and commissioning dates are not solely in the hand of the Transmission System Operator (TSO) which poses a significant spatial and temporal planning uncertainty.

2. ***Intermittency***: The intermittency of variable RES such as wind and solar energy typically translates into low capacity factors (amount of energy produced per installed MW) and high volatility (periods of no production and periods of max production). This means that higher RES capacities should be installed to reach specific energy targets, with respect to conventional units, and the transmission grid should be dimensioned accordingly , creating a high impact on the grid infrastructure.

3. ***Location far from load for large-scale centralized RES development:*** As RES power plants have higher spatial footprint, large-scale plants are developed in areas that have less spatial constraints and where the resource potential is higher, which in most cases are far from consumption. This leads to the changes in transmission paths in the system due to the transportation of renewable energy from the production areas (e.g. desert, offshore locations) to the load centers.

4. ***Distributed nature:*** Additionally RES can be deployed in as distributed generation, in small scale plants connected to distribution grids. Although a trend toward large scale sites is observed in the GCC region, a decentralized RES development cannot be neglected and in many cases is favored by policy makers, as it reduces the electrical distance between RES production and consumption. Especially keeping in mind the constantly sinking PV costs, autoproduction (behind the meter) is becoming a viable option without the need of economic support.

5. ***New technologies:*** Small scale distributed generation and energy storage enables consumers in becoming active participants in the electricity systems with own production, flexible demand and the possibility to provide ancillary services. A decentralized approach is driven by the digitalization of the power system. Smart grids, the internet of things (IOT) and new technologies such as block chain, small and large scale storage possibilities

offer new methods to integrate large numbers of participants and to efficiently connect production and demand.

C. Scenarios for systems with RES: multi-snapshot forecasts

Traditionally, load forecasting methodologies are focusing on the analysis of specific critical system operational snapshots, e.g. system peak demand. Due to the intermittent stochastic nature of RES production and the changing load flow patterns, it is very difficult to predict the evolution of critical system snap shots. Instead, it is needed to assess the system variability by the analysis of multiple snapshots in order to capture the impact of all changing flow patterns. Typically this means the analysis of a full operational year, i.e. 8760 hourly system snapshots. To depict this, in Figure 2 the impact of increasing RES levels to the KSA residual system load for 2030 is shown, indicating with a bold line the current RES capacity target of 60GW. As can be seen in the left side of the graph, the system peak load situation remains unaffected, indicating the low effect of PV production to evening peak. However, looking on the right side of the graph, one can see the emergence of a variety of additional critical snapshots, in cases where the RES production is peaking and where the system net load is minimized (and in some cases it becomes negative). These cases indicate situations of high RES transportation through the system, or need for exporting of excess production to neighboring countries. Depending on the local allocation of RES capacity, different snapshots may be critical for different transmission corridors.

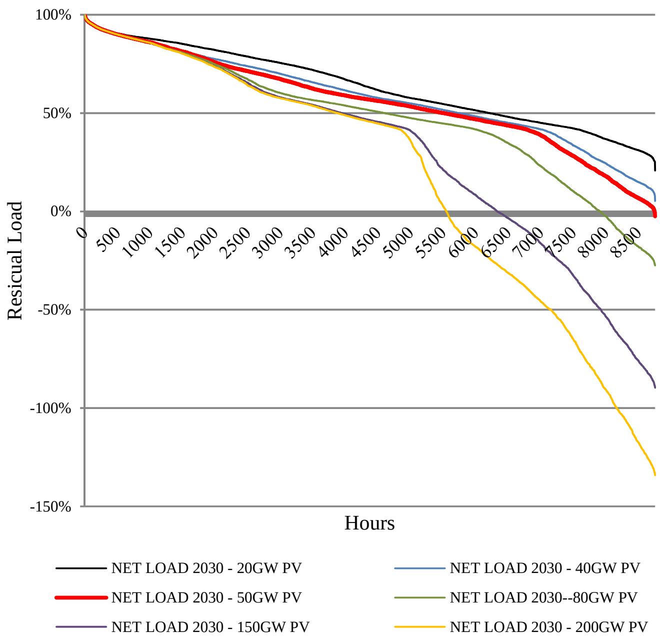

Figure 2: Residual load with different amount of PV generation capacities.

III. ENERGY SCENARIO DEVELOPMENT IN EUROPE

Energy scenarios are widely used in Europe and other parts of the world. In order to give a background on the different processes, an overview of the scenarios developed for Germany (German Scenario Framework [7]), Belgium (Electricity Scenarios developed by Elia [6]) and Europe (scenarios developed by ENTSO-e [5] for the Ten Year Network Development Plan (TYNDP)) are presented.

A. Germany: Netzentwicklungsplan (NEP)

Energy scenarios are developed by the four German TSOs and used as the basis in the German Network Development Plan (NEP). In total four different scenarios are developed to describe the assumed development of the energy sector; three scenarios cover the time period of the 10 to 15 years and one scenario focuses on a period of 15 to 20 years.

The main differences between the scenarios are the share of RES and assumptions regarding innovations influencing the efficiency, flexibility and CO_2 emissions of the energy system. Relevant considerations in the scenarios are the differentiation between decentralized and centralized electricity generation, sector coupling (especially to the transportation sector by electric vehicles and to the heat sector by heat pumps, Power-to-Gas and Power-to-Heat) and other flexibility options such as Demand Side Management and different types of storage solutions.

After the TSOs agree on the scenarios they are reviewed and approved by the regulator who is entitled to adapt assumptions or to request the consideration of additional sensitivities. The NEP is repeated every 4 years and serves as the basis for realizing grid development projects.

B. Belgium: Long-term energy scenarios

Elia conducted a study to develop three different long term energy scenarios for 2030, 2030 and 2040. Simulation perimeter contains 22 countries that have relevant influence on Belgium. For each scenario a full adequacy assessment is conducted and sensitivities are included for the most relevant drivers. These are the amount of interconnections in Europe, the assumption that 50% of the electric vehicles (EV) can be used as energy storages and that 50% of the EV and heat pumps are optimized during the day to provide flexibility.

Based on TYPND scenarios three different storylines are describing a base case, decentral RES and large scale RES scenario: The **"base case"** scenario represents the minimum that has to achieved to reach the EU 2030 targets in terms of RES. Electrification of the transportation and heating sector is assumed to be low as no major incentives are given to speed up this development. In a **"decentral"** scenario is assumed that a fall in prices for PV and story technology lead to a massive investment by the private sector. Traditional consumers convert into prosumers. These prosumers are actively participating in the energy system by providing flexibility from an interactive system of electric vehicles, rooftop PV installations and heat pumps. Digitalization is the main driver in this scenario allowing a higher amount of voluntary load shedding during peak periods and a reduction in demand from industrial and commercial consumers. In the **"large scale RES"** scenario interaction among the European countries is assumed to be increased. A highly interconnected European electricity system uses RES in the most efficient way by allocating RES in regions with the highest potentials: Large amounts of onshore and offshore wind developments in the North Sea as well as PV sites in Southern Europe are realized and energy is transported in a strongly reinforces transmission system. It is assumed that coal and lignite production is phasing out and that large scale flexibility options are available to cover residual load.

C. *Europe: Ten Year Network Development Plan (TYNDP)*

The 10-year network development plan published by ENTSO-E provides energy scenarios for 2030 and 2040 including a cost-benefit analysis of transmission and storage projects with socio-economic and environmental criteria. The TYNDP aggregates input from different stakeholders (environmental organizations, consumer and producer associations, regulators, etc.) and is publicly consulted before it is finally adopted by the European Commission. The TYNDP analyses 18 scenarios for 2030 and 2040, based on three main different story lines:

1. Sustainable Transition
2. Global Climate Action
3. Distributed Generation

IV. A Scenario Building Approach

The process of deriving energy scenarios can be subdivided into 6 steps which are examined below:

1. Framework setting: The initial step is setting-up the scenario framework. The framework needs to describe the purpose of the scenarios, the considered time horizon, the simulation perimeter (regional focus) and if a top-down or bottom approach is followed. Furthermore the recipients of the scenarios need to be defined as well as the required stakeholder participation. Setting the framework is a crucial first step as it establishes a common understanding among the involved stakeholders. It narrows down the scope and defines the requirements for the proceeding usage of the scenarios.

2. Drivers and specifications: After a common basis for discussion has been established the main drivers and specifications influencing the energy system need to be defined and interdependencies described. This step requires comprehensive research, workshops and expert interviews within and outside of the organization. Our approach identifies 5 main drivers, as shown in the figure below**Error! Reference source not found.**:

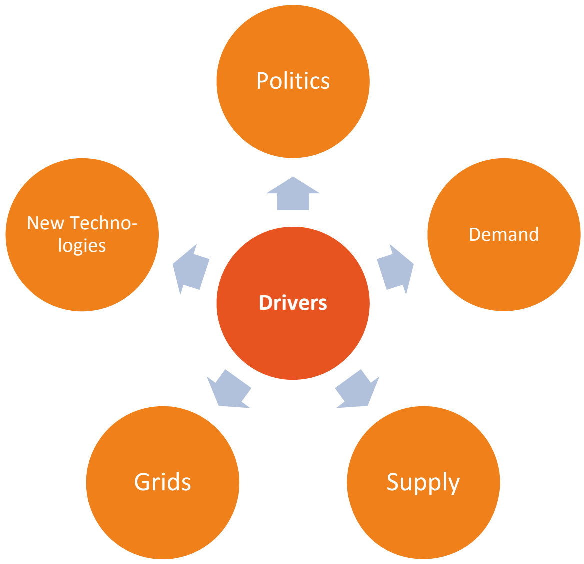

Figure 3: Mapping main drivers for scenario development.

1. **Political decisions** include targets for RES, efficiency and CO2 emissions but also define information on macro-economic developments (i.e. market liberalization or integration trends).
2. The future **demand** development in all sectors should be defined. The impact of efficiency measures to the different sectors e.g. industrial, domestic, residential should be considered. New demand should be added in the form of sector coupling (cooling, electric mobility, etc.), with a strong interdependency to new technologies.
3. On the **supply** side, main driver and uncertainty is the implementation of RES and its impact on conventional generation. As discussed, many scenarios consider centralized and decentralized RES development as key scenario basis.
4. The **grid development** strategy should be considered, especially regarding interconnections to neighboring areas.
5. Last but not least the impact of **new technologies** should be evaluated. Recent developments such as energy storage, sector coupling (Power-2-X) and the impact of digitalization fall in this category.

3. Impact – probability assessment: After all drivers and specifications have been assessed the probability and the impact of different specifications on the power system needs to be assessed. A categorization in an impact-predictability-matrix (see figure below) is used based on four different categories. The most important specifications are those with low predictability but high impact. They have to be addressed in scenarios and usually form the basis of the story line. Specifications with high predictability and high impact are the foundations of scenarios and are due to predictable character easier to handle. Specifications with low impact are less important. In case of a low predictability the specifications should be monitored.

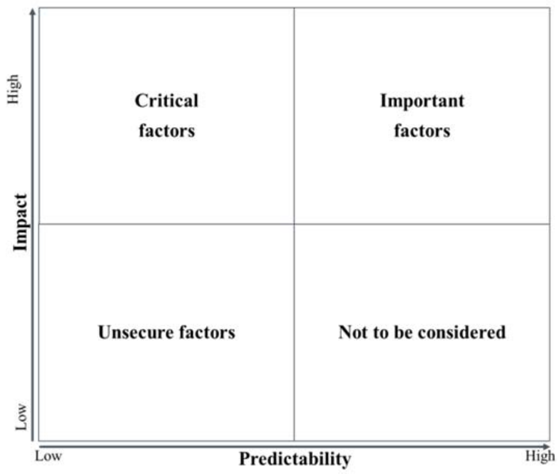

Figure 4: Impact-predictability-matrix

4. Qualitative story lining: After categorizing the specifications the story lines are developed. The specifications with the highest uncertainty and low predictability form the beginning of a storyline. It is crucial to fully understand the interdependencies between the specifications in order to describe a logical and consistent story line.

5. Consultation: The last step before quantifying the scenarios should be a consultation within in the organization. As scenarios are a highly strategical and the foundation of the proceeding grid planning, top management should be involved in this step and approve the qualitative set up of the scenarios.

6. Quantification: in this step the qualitative scenarios are transformed to comprehensive datasets that can be used as input to the analytical assessment.

V. Drivers and Specification in the GCC context

In cooperation with the Network Planning Department of National Grid SA the first four steps of the scenario building approach were executed. The results of the second step (analysis of drivers and specifications) are outlined hereafter, highlighting peculiarities that are relevant for Saudi-Arabia as well as for countries with similar conditions in GCC region.

A. Politics

The kingdom of Saudi-Arabia is currently undergoing major reforms. With the Vision2030 [2] Saudi Arabia presented its view of a diversified and strong economy where the energy sector plays a key role: The integration of renewable energies as well as electricity market reforms and ownership unbundling processes are about to reshape the energy system.

Major considerations that have to be taken into account are:

- The replacement of oil from renewable energies for domestic electricity production.
- The effect of **subsidies** on electricity retail prices and how they are currently preventing the competitiveness of RES. Increasing electricity prices would directly impact energy consumption behavior, boosting energy **efficiency** measures and affecting the competitiveness of **distributed RES** (behind-the-meter solutions) and **isolated smart grids**.
- A new driver for electricity consumptions but highly depending on political decisions is the possibility of a rising **tourism industry** in Saudi-Arabia. Especially at the Red Sea coast area, large potential for tourism is projected. Linked to this are the plans for Neom, a new city in the Northwest of Saudi-Arabia.

B. Demand

Based on the load forecasting of National Grid SA, the main driver for electricity demand in the past decades was the constant economic growth and linked to this the growing Saudi and non-Saudi population. Not only did the total population grow but also the per capita electricity consumption [8]. Besides the classical drivers new sources of demand are about to impact future load.

GDP, Population & special events:
As for today, the future load profile is driven by the **GDP, population development** and the recurring special events (school start, holy events such as Hajj, Ramadan, etc.). **Population growth** is linked to GDP development and thus also part of a political driver. A clear differentiation should be considered between the population development of local population and expats, as expat population is also affected by the political decisions in the country. A debate is ongoing on the number of expats in the future as the aim is to employ more Saudi population.

Air conditioning
Air conditioning is a major driver of electricity demand and responsible for the high variation of winter and summer load profiles. The development of new cooling technologies and concepts could significantly reduce the demand for air conditioning [9] (higher efficiency, better isolation, district cooling sites). New technologies could decouple the air conditioning from the electricity grid using gas as a fuel instead.

Desalination of sea water
Water is mainly produced in thermal processes using conventional power plants and electricity is a by-product of this process (must-run generation). Today 25% of domestic oil production is used for water and electricity production and the need for water increased tremendously in the past years with high growth rates. As this trend is likely to continue, the domestic oil demand for water production may significantly grow. Which is why the use of electricity for desalination (reverse osmosis technology) is considered [10], [15].

Therefore, based on the technology adopted, the water production should be seen either as must-run generation or demand in the future scenarios. Furthermore, different solutions can be considered, such as renewables or even nuclear power plants. It is therefore important that the demand for water production and respective technologies are closely monitored and properly introduced in the scenario process.

Electric vehicles:
A fast growing international trend is the use of electric vehicles [11] in the transportation sector. In Saudi Arabia, the electrification of the transport sector can be linked to the reduction of the domestic use of oil. The role of electric mobility in the future in Saudi-Arabia is highly affected by two main parameters,

a) Evolution of domestic fuel prices, namely whether they will increase from the current low levels and
b) Removal of “range anxiety”, relating to the deployment of charging infrastructure through the country and the evolution of batteries technology to support long-distance travels typical for a country such as Saudi-Arabia.

C. Supply:

Today’s electricity is supply is completely based on fossil fuel combustions consuming large shares of the domestically produced oil. Ambitious plans exist to shift from burning oil to gas combustion and the use of renewable energies [2].

Conventional Power Plants
The current power system relies completely on conventional gas and oil powered power plants contributing with equal shares to the electricity production [14]. The current trend is to replace oil by gas [2] which implies in increase of the current gas production. In combination with renewables, gas has the role to provide backup capacity, and therefore an increase in gas production could be prevented. Another type of power plant currently under consideration is nuclear power plants [4]. However, as nuclear power plants are inflexible and used as baseload capacity, their deployment together with RES should be carefully planned, as it could lead to problems with the flexibility of the system.

Fuel pricing:
In countries with high oil and gas deposits the price for fossil fuels is decoupled from international market prices. A key question for Saudi Arabia and other GCC countries is whether to use “domestic” or “international” prices.

By using domestic prices the opportunity costs are neglected that could be generated by exporting those fossil fuels. The impact of opportunity costs should be especially considered with respect to the increasing demand of electricity that forces the country to massively increase oil and gas production. In particular, it might create a scarcity of exports if exploiting oil and gas fields can’t keep up with the demand growth and existing long-term contracts. In such cases, fossil fuels might need to be imported to cover demand. Low domestic fuel prices also prevent the country from increasing efficiency and supporting the use of new technologies.

Renewables:
The kingdom of Saudi-Arabia has a vast potential for renewable energies [12]. Prices for all kinds of renewables (PV, CSP, Wind, etc.) are following a downward trend [1] which makes them competitive to conventional power plants (considering international market prices for fossil fuels). This is especially valid for large scale power plants but as well for residential systems (PV + battery storage) [17]. Depending on electricity prices and political decisions the renewables could be deployed very quickly in the kingdom.

D. Grid:

The electricity grid design is strongly dependent on how the supply-side of a future energy system will be designed and on considerations to interconnect with neighboring countries.

Grid in energy scenarios:
Different strategies with regards to the deployment of renewable energies have different effects on the grid design. A centralized large-scale installation of renewable power plants implies a need for new transportation capacities on the transmission grid whereas a decentralized distribution of renewables impacts also the distribution grid [13].

In order to reach higher shares of installed RES, **interconnections for export of electricity** should be considered in order to balance residual load. It needs to be considered that the export potential to other GCC countries is limited, due to similar power supply, consumption, RES potential and demand patterns. In this respect, as discussed in several studies, in high-RES scenarios, power exports should be considered in continental scale from the Middle East to Europe.

E. New Technologies:

Future scenarios should consider new technological trends and their impacts. The most relevant trends for Saudi-Arabia have been identified being Power-To-X technologies, the trend towards a digitalized power system and the use energy storage systems.

Power-to-X
Highly relevant for the GCC region and a source of flexibility for RES integration are trends towards sector coupling. Linking electricity generation with other sectors such as cooling, fuel generation (Power-to-gas or Power-to-fuel) and transportation (electric vehicles) provide options to economically use excess renewable generation. The concept of power-to-X is to transform electricity for example into synthetic gas (i.e. converting electricity to hydrogen through electrolysis and further to methane) or fuels in order to store them or to use them directly in other industry processes. Synthetic fuels can also be transported (for exports) and stored in the domestic gas network. Today power-to-X is still very costly due to high losses in the transformation process.

However, it is a unique option for long-term (seasonal) storage of excess electricity from renewables which would otherwise be curtailed. This option is therefore highly linked to high-RES scenarios. The technology might improve in the future and provide attractive options for the GCC countries to export not only fossil energies but synthetic fuels [16]. In European long-term energy scenarios those options are already incorporated.

Battery Storage

Battery storage might be an important technology for managing short- to mid-term fluctuations of RES production. The price drop of batteries for household uses could for example trigger private PV-rooftop battery systems and directly influence the demand for distribution grid developments.

New technologies and Digitalization

The term digitalization refers to the trends of having an interconnected energy system where consumption, storage and supply are automatically optimized. Practically, higher digitalization will lead to more decentralization of the system development and operation [13]. Especially in a distributed small scale renewable energy system with a large number of electricity producers, artificial intelligence and block chain technology might be considered as disruptive technologies for the electricity sector. In this respect, three key trends were identified regarding the implementation of digitalization, namely

- PV costs reduction,
- Costs for batteries / local storage and
- local intelligence (AI/block chain)

The development of these trends should be monitored in order to see the role of prosumer-based systems in the future.

VI. Conclusions

The paper presents how energy scenario methodology can be deployed for the GCC energy landscape, using the KSA study case as key example. The approach is based on the analysis of 5 main drivers that allow mapping all future uncertainties influencing the development of the power system, namely political framework, demand, supply, grids and new technologies. The analysis shows that the large-scale incorporation of variable renewable sources imposes a need for use of such scenario-based approaches in order to better plan the development of the generation system and to assess the robustness of the new grid investments.

VII. References

[1] IRENA (2018): Renewable Power Generation Costs in 2017.

[2] Kingdom of Saudi Arabia (2016), Saudi Vision 2030, Available Online: https://vision2030.gov.sa/

[3] Renewable Energy Project Development Office (2019), Saudi Arabia’s Ministry of Energy, Industry and Mineral Resources Launches Round Two of Renewable Energy Programme. Available online: https://www.powersaudiarabia.com.sa/web/attach/news/Press-release_29.01.2019_REPDO_EOI_RoundTwo.pdf

[4] King Abdullah City for Atomic and Renewable Energy (no year): The Vision. Available online: https://www.energy.gov.sa/en/FutureEnergy/Pages/vision.aspx

[5] ENTSO-E (2018): Overview of the proposed Gas and Electricity Scenario Building Storylines. Available online: https://entsog.eu/sites/default/files/entsog-migration/publications/TYNDP/2018/180702_WGSB_Scenario%20Building%202020_Consultation_Document.pdf

[6] Elia (2017): Electricity Scenarios for Belgium towards 2050. Available online: http://www.elia.be/~/media/files/Elia/About-Elia/Studies/20171114_ELIA_4584_AdequacyScenario.pdf

[7] 50hertz (2016): 50Hertz Energiewende Outlook 2035 (Abschlussbericht). Available Online: http://www.youblisher.com/p/1457252-Abschlussbericht-50Hertz-Energiewende-Outlook-2035

[8] CEIC: Electric Power Consumption: per Capita from 1971 to 2014. Available Online: https://www.ceicdata.com/en/saudi-arabia/energy-production-and-consumption/sa-electric-power-consumption-per-capita

[9] IEA (2015): Energy Efficiency Standards and Mandates. Available online: https://www.iea.org/policiesandmeasures/pams/saudiarabia/name-147402-en.php

[10] IEEE Spectrum (2018): Saudi Arabia Pushes to Use Solar Power for Desalination Plants. Available online: https://spectrum.ieee.org/green-tech/solar/saudi-arabia-pushes-to-use-solar-power-for-desalination-plants

[11] IEA (2018): Global EV Outlook 2018.

[12] King Abdullah City for Atomic and Renewable Energy (no year): Renewable Resource Atlas. Source: https://rratlas.kacare.gov.sa/RRMMPublicPortal/

[13] MIT Energy Initiative (2016): Utility of the future.

[14] Electricity & Cogeneration Regulatory Authority (2017): Annual statistical booklet for electricity and seawater desalination industries.

[15] Caldera, U.; Afanasyeva, S.; Bodganov, D. and Ch. Breyer (2016): Integration of reverse osmosis seawater desalination in the power sector, based on PV and wind energy, for the Kingdom of Saudi Arabia. In:Proceedings of the 32nd European Photovoltaic Solar Energy Conference, June 20-24, Munich, Germany

[16] Agora Verkehrswende, Agora Energiewende and Frontier Economics (2018): The Future Cost of Electricity-Based Synthetic Fuels.

[17] LAZARD (2018): LAZARD’s levelized cost of storage analysis – Version 4.0.