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USAEE Case Competition 2016

Case Competition Authors
Dr. Parth Vaishnav
Nathaniel Horner
Dr. Eric Hittinger

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TO: USAEE Case Competition Teams
FROM: Case Competition Committee
DATE: 1 April, 2016
SUBJECT: 2016 USAEE Case Competition Problem Packet

In this problem, your student team will act as a group of energy economics consultants. Your company has just received a request for a quick piece of analysis, which has been assigned to your team.

Prepare your response exactly as you would prepare it in the real world. The judges will evaluate the responses from the position of the fictional customer, so producing a piece of work that is valuable to the fictional customer should be your goal. The fictional customer has outlined their interests and goals in the following documents. You are permitted to respond however you like to the customer, but are advised to keep the customer's stated and implied objectives in mind as you work the problem.

Your main text is limited to 8,000 words (including captions, but excluding references), with each figure and table counting as 200 words (for a figure or table, you count the figure or table itself as 200 words and must also count the words in the caption towards the total of 8,000). Your References or Works Cited section does not count towards your 8,000 word limit. You may add an unlimited amount of appendices to the main document. These appendixes may be an appropriate place to go into greater detail about your modeling and assumptions. Note that the customers (and the judges) want a concise analysis and may not read the appendices.

If for some reason you feel compelled to explain why you have adopted a particular strategy in your analysis or presentation that you believe should not go in your written response, you may include a separate one-page explanatory memo. However, we do not anticipate that such a memo will be needed and you should not prepare one unless you believe it to be essential.

Some of the documents and data are invented. You are to treat them as real, but you may not invent facts or documents yourself.

We ask that you not discuss your solution with anyone outside your group during the project period. While it does require creative thinking, the problem does not require advanced methods (though such methods are allowed), and outside consultation shouldn't be necessary. You are allowed to ask me questions about the problem or case competition rules (parthv@cmu.edu). In general, additional information will not be provided for the problem itself. As in real life, the customer may not have provided you will all of the information that you want and you may need to calculate, estimate, or look up relevant data. Any responses that I provide to one group will be emailed out to all groups.

This document contains the most important materials, including documents from and relating to the fictional customer. The remainder of the packet consists of materials that may or may not be of use to you as you work on the problem. There is a significant amount of material, and it is meant to simulate a literature review that you might do when confronting this problem. Our advice is NOT to try to read all this material, but rather to quickly skim the abstracts and

then pick and choose to read things in greater depth as you need data and insights to frame and work through the problem in your own way. The collection of documents in this packet is meant to save you some trouble, but is not meant to be limiting: you may use any outside written and web resources or other materials that you find to be useful to your solution.

When your written response is complete, send copies in pdf to both parthv@cmu.edu and usaee@usaee.org. Your written response is due by April 21, 2016 at midnight ET.

The panel of judges will be a mix of industry, academic, and consulting representatives and will select the top three teams based on the judging criteria described below. The top three teams will be informed by June 30 and must have at least one member attend the USAEE/IAEE North American Conference in Tulsa, OK, to present their solution. Student teams are allowed to modify or improve their solutions in the period before the conference presentation. At the presentation, each team will be given 15 minutes to present their solution, followed by questions from the judges and audience.

Judging Criteria (as provided to the judges):

Judges should evaluate each response from the perspective of the fictional customer and should ask themselves to what degree the response improves the customer's understanding of the issue and to what degree the response helps the customer make decisions about the issue.

The student responses must meet a few minimum criteria to be considered for the top three positions: the student response must address each of the client's questions in some way, and the quality of presentation (writing, organization) must meet minimal standards for professional communication.

In a project as cohesive as a consultant report, it is difficult to separate the different factors that go into a successful response. To provide some structure to grading, judges will use the following weight ranges for each of the four general criteria.

Responsiveness to the customer need (recognition of the key issues and responsiveness to the stated questions) - 30-40%
Quality of analysis (did the right analysis, did the analysis right, provided support for arguments and conclusions) - 25-35%
Originality and insight (demonstrates creative thinking and extends understanding on the topic or presents a novel solution) - 15-25%
Presentation (quality of writing/figures, organization) - 10-20%

For each student response, judges should provide both a score (out of 100) and a few sentences of feedback focusing on the strengths and weaknesses of the response. Feedback will be shared with the teams after the case competition presentations, while the numerical scores will be used by the judges to select the top three teams. After assigning scores individually, the judges will meet to choose the top three responses based on individual scores and comments.

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المملكة العربية السعودية
وزارة المياه والكهرباء
MINISTRY OF WATER & ELECTRICITY

NRG Economic Consultants
28790 Chagrin Blvd., Suite 350

Cleveland, OH 44122

April 1, 2016

Dear Mr. Estudiante,

We seek your assistance in doing a first order analysis of the costs and benefits of a major energy transition for the Kingdom of Saudi Arabia (KSA).

As you know, KSA currently generates just over half of its electricity from oil, and the rest from natural gas. In fact, electricity generation is a significant source of demand for oil – each year, KSA consumes about 1 million barrels per day (bbl/d) to produce electricity, or about 10% of total production and about 30% of total domestic consumption.[1,2]

If this oil could be sold instead, it would be worth $10 billion a year at an oil price of $30 per bbl. This would be substantially more than what the government of KSA spends, for example, on infrastructure and transport each year.

The Kingdom is blessed with an abundance of solar energy, and one way to replace oil as a source of electricity is to rely instead on various forms of solar energy. There has been discussion[3] within the government of floating a small stake in the national oil company, Saudi Aramco, with a view to bringing in external expertise and governance. Even the sale of a 5% stake in Aramco could bring in hundreds of billions of dollars.[4]

The Ministry of Water and Electricity is considering investing some of that investment to replace, as much as possible, all fossil fuel generation with solar photovoltaic generation. We would like to

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[1] http://www.eia.gov/todayinenergy/detail.cfm?id=18111
[2] http://www.bp.com/content/dam/bp/excel/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-workbook.xlsx
[3] The Economist, "Sale of the Century?," *The Economist*, January 9, 2016, http://www.economist.com/news/briefing/21685475-possible-ipo-saudi-aramco-could-mark-end-post-war-oil-order-sale.
[4] Kevin Baxter and Summer Said, "Could Saudi Aramco Be Worth 20 Times Exxon?," *The Wall Street Journal*, January 8, 2016, http://www.wsj.com/articles/saudi-aramco-confirms-ipo-study-1452254819.

completely stop using oil for electricity generation, and use natural gas only to balance demand and supply.

We would like you to give us a systematic, if approximate, understanding of what the costs and benefits of making such a transition would be. In general terms, we want to understand the costs and benefits of this transition and have a sense of the optimal system design if KSA committed to this path. In particular, we would like to have rough estimates of the following.

- How much solar capacity would we have to build to meet current and future demand? What would be the best way of building out this capacity? That is, assuming the project starts building now, how much capacity should it build and add every year? What would the cost, in terms of present value, of such a build out be? How should we determine the upper limit on solar capacity and what should that limit be?
- Where should this capacity be built? How much transmission would need to be built? What would the size of the losses be?
- How much natural gas-fired generation would be needed to ensure that demand is met now and the future? How much natural gas would be needed? Would new generation capacity have to be built? What would this cost? Would gas production or imports have to be increased (current imports are zero)? If so, what would this cost?
- What would the benefits of such a transition be? An obvious advantage would be that we would have more oil available for export. What would this be worth? Switching mainly to solar would also likely reduce the Kingdom's CO_2 emissions. Is there a way in which this benefit could be monetized?
- What non-pecuniary issues should we consider? What impact will creating a potentially very large demand for solar power have on local industry and skills? How should the government go about maximizing the benefits generated in terms of helping the economy diversity away from fossil fuels.

We note that your answers to these questions will depend on a number of quantities that are highly uncertain. In your response to us, we would appreciate it if you gave some thought to how this uncertainty affects your analysis: under what circumstances would your recommendations be different? How much would they change in response to changes in your assumptions?

I have attached a few relevant memos. The first memo by Nadim Haaziq al-Harbi discusses what the demand for electricity currently is, and how it is likely to evolve. The second memo by Tom Wood will help you get familiar with some information about the costs of the system. Finally, I have attached a note from Abu Yousef al-Fadl, the advisor to the Minister, which lays out some of the broader policy goals he hopes you can speak to in your assessment. We have also tried to put together a series of reports and datasets that we think you will find helpful.

We trust that your brief report, which we expect to receive in three weeks' time, will help add some clarity to our decision.

Sincerely,

Mohammed al Suwami

VP, Strategic Planning

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Electricity & Cogeneration Regulatory Authority (ECRA)
Riyadh, Saudi Arabia

17 Mar 2016

Mohammed al Suwami
VP, Strategic Planning
Ministry of Water & Electricity (MOWE)
Al Khobar, Saudi Arabia

RE: Notes on KSA electricity generation sector

Dear Mr. al Suwami:

After we spoke on the phone regarding the Ministry's upcoming report on a possible solar power future for the KSA, I have put together some quick thoughts that may be of help to the NRG consultants.

The Ministry's analysis of solar feasibility could not be more timely. KSA has a voracious and rapidly growing demand for electricity, with domestic electricity consumption doubling between 2001 and 2012.[1] As KSA's power sector regulator, ECRA has published weekly and annual peak load data,[2] which will provide some insight into the regional distribution of this growth. Additionally, I have attached hourly regional load data for the eastern, central, southern, and western operating areas for 2014.

As you know, virtually all of this load is met with fossil-based generation, split approximately evenly between natural gas and petroleum-based fuels. There is not much excess generation capacity: reserve margins have been as low as 3% in recent years. The majority state-owned Saudi Electricity Company (SEC) and its subsidiaries comprise 3/4 of the country's generation. As of 2013, just over half of the 76 power plants in KSA were less than ten years old, while around a quarter were over 25 years old.[3] Note that the fuel mix varies quite a lot by region, with lots of gas in the East and a disproportionate amount of diesel in the South. Some resources that might help NRG characterize the Saudi power sector include ECRA's own annual statistical reports and web data portal,[4] materials from SEC,[5] the overviews by the IEA[6] and US EIA,[7] a

[1] EIA International Data Browser: http://tinyurl.com/hz2jtny
[2] http://www.ecra.gov.sa/en-us/DataAndStatistics/NationalRecord/PeakLoad/Pages/Home.aspx
[3] http://www.ecra.gov.sa/en-us/MediaCenter/DocLib2/Lists/SubCategory_Library/ecra_ebook20131.pdf
[4] http://www.ecra.gov.sa/en-us/DataAndStatistics/NationalRecord/pages/NationalRecord.aspx
[5] https://www.us-sabc.org/files/public/PowerGen2012Presentation.pdf
[6] http://www.iea.org/ieaenergy/issue7/saudi-energy-mix-renewables-augment-gas.html

more economics-focused look on the various potential reforms,[8] and utilities sector trade publications.[9]

Going forward, the country is betting big on solar as one option to meet this growing demand, planning to have 41 GW installed by 2032.[10] KSA also plans on 17 GW of new nuclear capacity additions by 2040.

Generally, a country's electricity demand grows in step with its population and its wealth. While there are forecasts of peak demand going out a few years,[11]it may make sense to construct longer term forecasts based on population[12] and wealth.[13] In addition to simple extrapolation, there are several additional aspects of the KSA power sector worth considering.

First, well over half of electricity demand is from building air-conditioning--some estimates are as high as 70%. The country's total electricity consumption was on par with Mexico in 2011 but was three times as much on a per capita basis. Thus, building energy use is a potential area for demand-side mitigation.

Second, KSA has a large and growing amount of desalination capacity to provide water for the growing population--currently the Kingdom accounts for 20% of global desalination capacity. There are several desalination technologies in use, which can generally be grouped into thermal and reverse-osmosis. The thermal technologies are more energy-intense; as a result, Saline Water Conversion Corporation (SWCC) is the country's second-largest power producer behind SEC. Therefore, opportunities for joint planning regarding these two crucial utilities exist, since thermal desalination plants can also be grid-connected cogeneration facilities.

Third, there is a growing discussion for partial privatisation of state-owned assets, and several steps have been taken to liberalise the power sector by divesting portions of SEC. The structure of the industry will have a large effect on which energy policy incentives are most likely to achieve the goals.

Finally, much of the region faces a conundrum that is similar to KSA's: moving power generation away from oil will create a need to import natural gas[14] or cease lucrative exports of it.[15] This may create an opportunity for the Kingdom to export surplus clean electricity production to these countries.

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[7] http://www.eia.gov/beta/international/analysis_includes/countries_long/Saudi_Arabia/saudi_arabia.pdf
[8] https://www.ifri.org/sites/default/files/atoms/files/note_arabie_saoudite_vf.pdf
[9] http://www.utilities-me.com/article-4048-saudi-arabias-unstoppable-utilities-market/
[10] http://www.pv-magazine.com/news/details/beitrag/solar-power-key-for-saudi-future--says-energy-chief_100016969/
[11] http://www.ecra.gov.sa/en-us/MediaCenter/DocLib2/Lists/SubCategory_Library/ecra_ebook20131.pdf
[12] http://esa.un.org/unpd/wpp/
[13] http://www.mckinsey.com/global-themes/employment-and-growth/moving-saudi-arabias-economy-beyond-oil
[14] https://www.ifri.org/sites/default/files/atoms/files/notedelifrimdbkuwaitalternativesforpower.pdf
[15] https://www.eia.gov/beta/international/analysis.cfm?iso=OMN

For these reasons, it's important to note a solar transition is not the only option for addressing growing demand: energy efficiency, nuclear power, grid connections with other countries in the region, and ending or reducing energy subsidies all form part of KSA's current thinking on its future energy strategy.

Some key questions I think the NRG analysts might want to look into include (but shouldn't be limited to):

- How diurnal and seasonal demand trends fit with solar availability, and how much fossil generation is needed to provide solar backup
- How a future energy strategy interacts with a future water strategy, including--perhaps--recommendations for joint energy-water development
- How solar cost-effectiveness and reliability compares with other options
- How privatisation vs. continued state monopoly of the power sector will affect the implementation and effectiveness of proposed energy development policies

I very much look forward to reading the final report.

Regards,

Nadim Haaziq al-Harbi
Assistant Director for Infrastructure Coordination
Electricity Cogeneration and Regulation Authority

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KAPSARC
مركز الملك عبدالله للدراسات والبحوث البترولية
King Abdullah Petroleum Studies and Research Center

Mohammed al Suwami
VP, Strategic Planning
Ministry of Water & Electricity (MOWE)
Al Khobar, Saudi Arabia

RE: Notes on KSA's proposed transition to solar PV

Dear Mr. al Suwami:

We are delighted that you are helping estimate the cost of a big move to solar energy in KSA. With this memo, I would like to familiarize you with some information that might help you.

We have data on the size of the solar resource available in different places in Saudi Arabia. The data consist of two components, called the Direct Normal Irradiance (DNI), which is the amount of radiation that is coming from the direction of the sun and the Diffuse Horizontal Irradiance (DHI), which is radiation produced by an unclear atmosphere or clouds. You can add these components to produce an estimate of the amount of solar energy available at any given time. The data on solar insolation are available here[1] and information on how to combine these values is available here.[2]

Note that south-facing panels (i.e., azimuth = ψ = 180 degrees) for which the angle of tilt of the panel (ß) is equal to the latitude (ø) will produce the most power.

My instinct would be to assume that we use fairly standard crystalline silicon panels, which have efficiencies of 10-15%. Of course, if you think that as we add capacity over time, we will switch to more efficient technologies, that would we worth considering. The current cost of utility scale solar, including capital and running costs, is discussed by the Lawrence Berkeley National Lab (LBNL) here.[3]

You will also have to give some thought to where to site the panels. One option is to site them all in one place and run high voltage direct current (HVDC) lines to tie the new generation to the existing grid. I found some recent estimates of the cost of HVDC lines and stations here.[4] Another might be to build the solar farms close to demand centers (e.g., cities) and simply build transmission to connect them to the existing (AC) transmission infrastructure. The LBNL report gives you some estimates of these costs. Here[5] is a source with a helpful summary of the relative losses of both types of transmission over different distances.

[1] http://rredc.nrel.gov/solar/new_data/Saudi_Arabia/
[2] http://www.pveducation.org/pvcdrom/properties-of-sunlight/making-use-of-TMY
[3] https://emp.lbl.gov/sites/all/files/lbnl-1000917_0.pdf
[4] http://www.nature.com/nclimate/journal/vaop/ncurrent/extref/nclimate2921-s1.pdf
[5] http://energy.gov/sites/prod/files/2013/05/f0/HVDC2013-Tang_0.pdf

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The calculations you perform based on Nadim's memo and on this one will give you some idea of how much natural gas will be needed to balance the system. The Kingdom does not have any stated plans to import natural gas.[6] It would be helpful if you produced some analysis of the rate at which production would have to ramp up to cope with demand. Note that a significant proportion of KSA natural gas production is associated gas.[7]

We will also need your take on how far into the future the Kingdom's existing capacity of gas-fired generation (35GW of gas turbine and 8.6GW of combined-cycle gas turbine)[8] will be adequate, what the future build-out rate will be, and what that would cost.[9]

I hope very much that you will find this information useful, and look forward to reading your report.

Sincerely,

Tom Wood
Research Associate
KAPSARC

[6] https://www.oxfordenergy.org/wpcms/wp-content/uploads/2013/03/MEP_4.pdf
[7] https://www.worldenergy.org/data/resources/country/saudi-arabia/gas/
[8] http://www.ecra.gov.sa/en-us/MediaCenter/DocLib2/Lists/SubCategory_Library/ecra_ebook20131.pdf
[9] See, for example, https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf

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From the desk of:

Abu Yousef al-Fadl

Advisor to The Minister of Water and Electricity Abdullah bin Abdul Rahman Al Hussein

Dear Mr. al Suwami,

Thank you for taking the lead on the investigation into the feasibility of transitioning the electricity supply of the Kingdom away from oil and towards more renewable energy sources. The Minister is very interested in this topic and will be monitoring your output closely. This initiative would represent not only a change in the Kingdom's energy sources, but a shift in perception of KSA's role as an energy producer. KSA is a world leader in the production of oil and natural gas and a strong commitment to solar energy could make it also a leader in emerging new forms of energy production.

There are clear financial benefits to a strong commitment to solar energy, specifically the reduced consumption of oil, which could be sold on the market. The solar resource in the Kingdom is strong and very consistent, and we have plentiful space on which to locate large utility-scale plants.

Furthermore, the Kingdom has sufficient capital to invest in large energy projects. In fact, these large infrastructure projects can be viewed favorably because they act as endowments to the people of KSA, a way to invest in the future. In many ways, a large commitment to solar energy can be considered a diversification of investment. Resources that we commit to solar power help the Kingdom endure the inevitable swings in oil prices and prepare our country for an eventual day when our natural energy endowment no longer ensures our wealth and prosperity. Please ensure that your team performs some investigation into the value of this diversification in KSA's energy resources.

As you investigate this opportunity, please be assured that the economic case is not the only consideration that will be applied to this decision. The Minister is encouraged as well by the effect that this may have on our local electricity workforce. As it stands now, many of the Ministry's electricity employees are working to maintain the existing fleet of oil and natural gas powered generation, some of which is old or inefficient. A large investment in solar energy and new natural gas generation would allow us to upgrade our entire electricity infrastructure, retrain existing employees in state-of-the-art electricity system management practices, and broaden employment in the electricity sector. In addition to the job creation associated with installation of the solar facilities, we are interested in other updates to the electricity system that would be required with this plan, such as additional transmission, monitoring equipment, or new control centers. While these all have capital costs, they will

also produce new employment and should enable to more efficiently operate our electricity system.

In addition to the benefits from installation, the Minister is interested in the possibility of locating new solar panel factories within KSA in an effort to become the regional center for the solar industry. The Kingdom enjoys low energy prices, strong availability of capital, and would have a large guaranteed customer in the Ministry of Water and Electricity. A manufacturing hub located in KSA would produce significant local benefits in terms of employment in high-tech industry. We would appreciate some analysis of whether the proposed plan could justify the scale of this manufacturing effort and the amount and quality of employment that would be created by such a center. Furthermore, we would want to ensure the sustainability of such an effort – could we rely on eventual replacement of panels as an outlet for future production, or on selling to neighbors or the global market?

As a major contributor to the global energy supply, Saudi Arabia is sometimes portrayed as a major contributor to greenhouse gas emissions. Most of these critics are unaware that KSA is highly vulnerable to the effects of climate change and that we are actively considering our adaptation strategies. A serious effort to reduce our electricity-related emissions may also help our global image and demonstrate our commitment to addressing the causes of climate change.

The emissions reductions resulting from these efforts should be able to produce some value for us. It should be clear that our interest in this program would be enhanced if we could successfully find international support for the project, either through clean development support or through the offering of carbon offsets on the international market.

The KSA, as well as the Ministry of Water and Electricity, views this concept as more than just a direct financial investment. Certainly, our natural resources have produced wealth that has been invested globally. But a significant investment in solar electricity, especially using locally-produced hardware, would also be an investment in the future of KSA, in the form of employment, infrastructure, and emissions reduction. Please keep this in mind as you contemplate the real value of the proposed program.

Sincerely,

Abu Yousef al-Fadl
Advisor to The Minister of Water and Electricity