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Towards a Sustainable Energy Future: The Case for Smart Grids in Jordan

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ABSTRACT

The implementation of a smart grid in Jordan offers many potential advantages, such as improved reliability and efficiency of the power grid, expanded integration of renewable energy sources, enhanced control and monitoring capabilities for the utility, as well as cost savings and economic benefits. However, significant challenges must be addressed, such as high implementation costs, technical requirements, privacy and security concerns, regulatory and legal challenges, and potential job displacement. This research paper provides an overview of the current state of Jordan's energy sector, an explanation of smart grid technology, as well as an analysis of the advantages and disadvantages of implementing a smart grid in Jordan. The paper also reviews case studies of successful smart grid implementations in other countries and offers recommendations for future research and policy decisions. Overall, the research suggests that while there are significant challenges to be addressed, the potential benefits of a smart grid in Jordan are substantial, and the country should continue to explore this technology to enhance its energy infrastructure as well as reduce its environmental impact.

Keywords: smart grid, renewable energy, microgrids, advanced metering infrastructure, energy management systems, demand response, distribution automation.

INTRODUCTION

Background information on Jordan's energy sector

Jordan is a small country in the Middle East that is bordered to the south by Saudi Arabia, the east by Iraq, and the north by Syria [Jordan location – Bing]. For its energy requirements, the nation is significantly dependent on imported fossil fuels, which has resulted in a high cost of electricity and a sizable trade deficit [The International Trade Administration]. The government-owned National Electric Power Company (NEPCO), which is in charge of producing, transmitting, and distributing power to Jordan's roughly 11 million residents [Population of Jordan], dominates the country's electricity market. Jordan has worked recently to strengthen its renewable energy sector despite having few indigenous energy resources. By implementing massive solar and wind projects, the nation has already made significant strides toward its objective of producing 31% of its electricity from renewable sources by 2030 [The International Trade Administration]. However, there are considerable difficulties in integrating these sporadic renewable energy sources into the system, which could be resolved by establishing a smart grid. An energy network with a smart grid monitors and regulates the flow of electricity between generators, customers, and grid operators using digital communications technology [Fang et al. 2012]. The introduction of a smart grid in Jordan may assist to alleviate some of the issues the nation's electrical industry is now facing while also offering several advantages to utilities and consumers. The opportunities and risks of constructing a smart grid in Jordan were examined in this research paper, along with an evaluation of the viability and potential of such a project.

Definition and explanation of smart grid technology

An upgraded energy network known as a "smart grid" makes use of digital communication and control technology to raise the dependability, efficiency, and flexibility of the grid [Fang et al. 2012]. Smart grids allow for two-way communication and the flow of information between various grid components, in contrast to conventional energy grids, which are designed to transmit power in a one-way flow from generators to consumers as shown in Figure 1. This allows for more accurate control over electricity supply and demand. Smart grid technology includes a range of hardware and software components, such as sensors, meters, communication networks, and advanced analytics tools. These components work together to provide real-time data on electricity consumption, grid performance, and renewable energy generation, allowing utilities to manage the grid and respond to changes in demand or supply [Alonso et al. 2020]. The ability of a smart grid to incorporate renewable energy sources, such as solar and wind power, is one of its main advantages. Smart grids can assist utilities in more efficiently balancing the supply and demand of electricity by giving real-time data on energy production and consumption. This decreases the need for backup power sources and increaases grid stability. By allowing users to more effectively monitor and manage their energy usage, such as by altering their consumption patterns to take advantage of off-peak prices, smart grids can also help to lower total energy consumption [Taha 2020 Oct 1]. Jordan's energy system might become more effective and reliable through the deployment of a smart grid, which would also have a number of advantages for consumers and utilities. The deployment of the smart grid, however, may also come with possible downsides and difficulties, which were covered in more detail later in this research study.

Purpose and scope of the research paper

The goal of this research paper was to evaluate the smart grid deployment in Jordan and to identify any potential benefits and drawbacks. The paper gave an outline of the current situation of Jordan's energy sector, emphasizing the difficulties the country has had in satisfying its demand for electricity. Following that, it examined the idea of a smart grid and its potential advantages, including improved effectiveness, dependability, and the integration of renewable energy sources. The paper also looked at some potential drawbacks of deploying a smart grid, namely its high implementation costs and security and privacy problems. It gave a general summary of Jordan's smart grid strategy, outlining its main players, scheduled for execution, and implementation-related difficulties. To compare Jordan's strategy with other countries that have deployed smart grids, the research also contains case studies from those countries. The major goal of the research paper was to examine the viability and

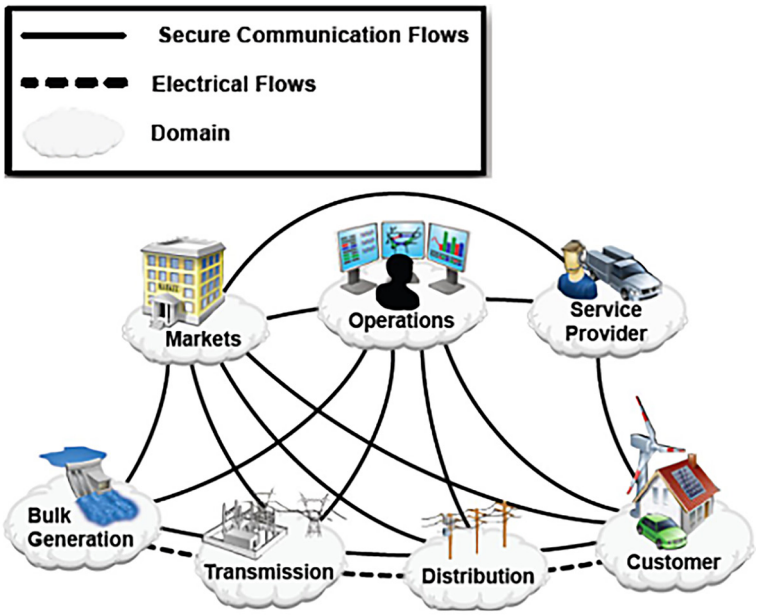

Figure 1. The NIST conceptual model for smart grid

potential of a smart grid in Jordan and to offer suggestions for further study and policy choices. The purpose of this study was to provide a better understanding of the potential effects of this technology on Jordan's electrical sector and the overall economy by examining the benefits and drawbacks of the adoption of the smart grid.

ADVANTAGES OF IMPLEMENTING A SMART GRID IN JORDAN

Improved reliability and efficiency of the power grid

One of the key advantages of implementing a smart grid in Jordan is the potential for improved reliability and efficiency of the power grid. Efficiency is significantly impacted by the smart grid. It increases overall efficiency by fusing modern information and communication technology with existing power infrastructures. The goal of the smart grid is to increase the grid's efficiency and dependability while lowering costs across the board for production, transmission, distribution, and consumption. Consumers now have better access to information on consumption and tariffs, which enables them to manage their use more proactively. In its efforts to achieve energy efficiency, the smart grid also effectively uses electric vehicles, renewable energy sources, and clever pricing strategies. In terms of the energy economy, dependability, load balancing, and customer happiness, the smart grid has surpassed conventional power grids. The major differences between the smart grid and the traditional power grid are shown in Table 1 [Anjana and Shaji 2017]. A smart grid provides two-way communication and information flow between various grid components, enabling real-time monitoring and control of electricity supply and demand [Fang et al. 2012]. enable utilities to control the grid and adapt to fluctuations in supply or demand, which lowers the risk of blackouts and other reliability issues. Integrating renewable energy sources like solar and wind power into the grid is also made possible by smart grids. This can assist in evolving energy security, decrease dependence on fossil fuels, reduce emissions of greenhouse gases, and help achieve Jordan's plan in 2030 [Population of Jordan, Hossain et al. 2016, Erickson 2017]. Smart grids can assist utilities in more successfully balancing the supply and demand of electricity by giving real-time data on energy production and consumption, which lowers the need for backup power sources and increases grid stability [Taha 2020 Oct 1]. Therefore, Jordan's electrical industry may benefit greatly from higher efficiency and dependability of a smart grid, which will reduce the likelihood of blackouts and improve the overall grid performance.

Table 1. Major differences between the smart grid and the traditional power grid

Traditional grid	Smart grid
Mechanized	Digitized
One-way communication	Two-way communication
Centralized power generation	Distributed power generation
Small number of sensors	Large number of sensors
Less security and privacy issues	Subject to security and privacy issues
Fewer user choices	More user choices

Increased integration of renewable energy sources

Increased integration of renewable energy sources into the grid is a potential benefit of setting up a smart grid in Jordan. As shown in Figure 2, Jordan has a lot of potential for producing renewable energy, especially solar and wind energy, which might help the country lessen its reliance on fossil fuels and improve its energy security. Jordan is blessed with an abundance of solar energy, as evidenced by the country's yearly daily average solar irradiation, which is among the greatest in the world and ranges between 4 and 8 kWh/m^2. This is equivalent to 14 002 300 kWh/m^2 in total annually, with an average sunshine length of more than 300 days per year [Alrwashdeh et al. 2018]. However, given the fluctuation of energy production from sources like solar and wind power, integrating renewable energy sources into the grid can be difficult [Anvari et al. 2016]. By providing real-time data on energy production and consumption, smart grids can assist utilities in more efficiently balancing the supply and demand of electricity [Fang et al. 2012]. One of the solutions to this problem is demand response (DR) which is a technique that allows energy users to adjust their electricity consumption habits on the fly in response to time-of-use electricity price signals or real-time dispatching instructions to lower critical-peak demand and distribute power consumption over different time periods. It is a

crucial way for modern energy systems to handle variable load demand and unreliable power generation. Demand response can have a large impact on the power system's peak load, increase the use of renewable energy, and lower the costs associated with traditional power unit adjustments and start-up/shutdown during off-peak hours [Huang et al. 2019]. Additionally, smart grids make it possible to handle dispersed energy resources like rooftop solar panels and battery storage systems more successfully. Smart grids can help consumers optimize their energy use by giving real-time data on energy production and consumption [Miceli 2013]. For instance, consumers can store excess energy during times of low demand and use it during times of high demand [Smart Grids – Analysis – IEA]. An increasing use of renewable energy sources of a smart grid might have a large impact on Jordan's energy sector, lowering reliance on fossil fuels, enhancing energy security, and assisting the shift to a low-carbon economy.

Enhanced control and monitoring capabilities for the utility

The improved control and monitoring capacities of the utility are another benefit of setting up a smart grid in Jordan. Traditional electrical grids only allow for a one-way flow of electricity, making it difficult to monitor or regulate how the power is distributed. A smart grid, on the other hand, facilitates two-way communication and the flow of information between various grid components, enabling utilities to more effectively monitor and control the distribution of power. This reduces the possibility of blackouts and other reliability issues by enabling utilities to respond to changes in supply or demand more quickly [Anwar et al. 2019 Dec 8]. Additionally, utilities may more efficiently plan for future investments owing to the real-time data on energy generation and consumption that smart grids give. With a greater understanding of energy use patterns, utilities can spot underused grid segments and allocate money to infrastructure where it is most required [Nafi et al. 2016]. Therefore, Jordan's power sector might gain significantly from the improved control and monitoring capabilities offered by a smart grid, increasing the grid efficiency and dependability, lowering the danger of blackouts, and assisting in the efficient management of energy resources.

Potential for cost savings and economic benefits

Another advantage of a smart grid installation in Jordan is the potential for financial savings and advantages. Even while the initial costs of implementing a smart grid can be high, there may be various long-term cost savings and financial benefits. For instance, a smart grid can help reduce energy waste and increase energy usage

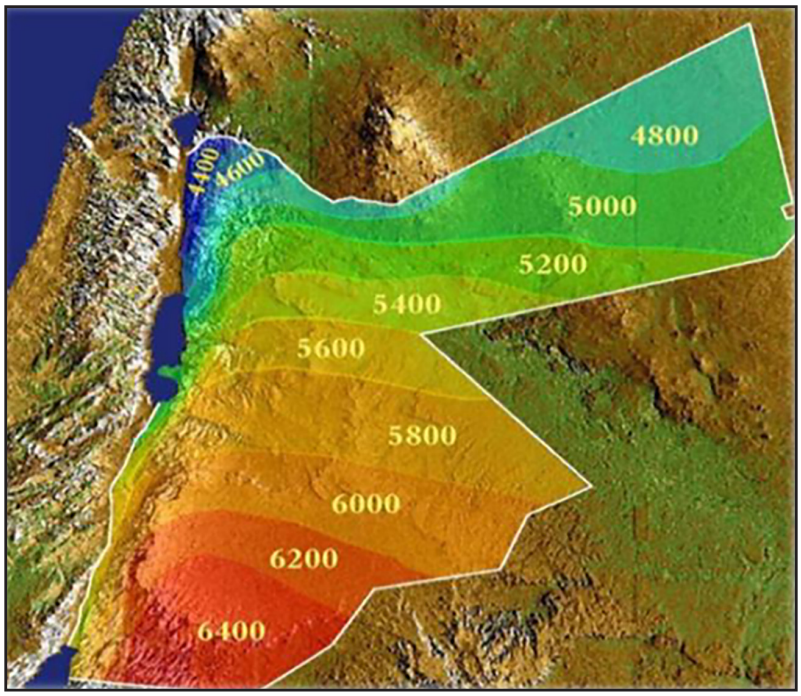

Figure 2. Global solar radiation map of Jordan in Wh/m^2/day

efficiency, which can lower consumers' overall energy costs. Smart grids can help consumers use energy more sensibly by providing real-time data on production and consumption, potentially enabling them to cut their energy expenses and save money. Smart networks also have several long-term cost savings and economic advantages. The requirement for costly to operate and maintain diesel generators as backup power sources may be reduced by smart grids. By more effectively balancing the supply and demand of electricity, smart grids can help to reduce the overall demand for backup power sources, which can save money for utilities and consumers. A smart grid could also open new business prospects in Jordan, particularly in the field of renewable energy. A smart grid might aid in the creation of new jobs and the stimulation of the nation's economy by promoting the system's integration of renewable energy sources. Therefore, the potential of a smart grid for cost savings and economic gains might have a large positive impact on Jordan's power industry and the country's overall economy [SmartGrid.gov].

Benefits for consumers, such as greater energy management and cost control

The introduction of a smart grid in Jordan might potentially help consumers by improving cost and energy management. Real-time data on energy production and consumption is provided by smart grids, which can help consumers better understand their energy usage and make wise decisions about how to control it [Salman 2017]. Customers can, for instance, use real-time data to pinpoint times of high energy consumption and modify their behavior accordingly, such as shutting off appliances during times of peak demand. Customers may be able to lower their energy costs as a result and possibly save money. Through the deployment of smart meters, which allow for remote monitoring and management of energy usage, smart grids can also provide consumers with more control over how much energy they use. Setting energy usage goals or utilizing timers to regulate when appliances are switched on and off, this can help consumers manage their energy use more effectively. Using rooftop solar panels or other distributed energy resources, smart grids can allow users to produce their own electricity. Smart grids can assist users in making the most use of these resources by giving real-time statistics on their production and consumption, and they may even enable them to resell any unused electricity to the grid [Li et al. 2023 Jan 11]. In the end, a smart grid might provide the consumers in Jordan with a number of benefits, including better energy management and cost control, increased reliance on renewable energy sources, and the capacity to generate their own electricity.

DISADVANTAGES OF IMPLEMENTING A SMART GRID IN JORDAN

High implementation costs and capital expenditures

One of the main disadvantages of implementing a smart grid in Jordan is the high implementation costs and capital expenditures required to upgrade the existing electricity infrastructure. The installation of smart meters, sensors, communication networks, and other advanced technologies can be expensive, and the costs can be particularly high in the areas with limited existing infrastructure or challenging terrain Particularly for smaller utilities or those with limited financial resources, the high costs of installing a smart grid might be a substantial obstacle to adoption. Additionally, the price of establishing a smart grid can be passed on to customers, which might result in temporary price increases for electricity. With the upkeep and management of a smart grid, there can be additional continuing expenses. Because of their complexity, smart grids call for specific technological know-how as well as regular maintenance and updates that can be expensive for utilities to handle. To ensure the long-term viability of the energy system, it is crucial to carefully assess and manage the high implementation costs and ongoing capital expenditures linked to the installation of a smart grid in Jordan [Kirmani et al. 2022].

Technical challenges and infrastructure requirements

The technological difficulties and infrastructure need that come with such a complicated system are other drawbacks of constructing a smart grid in Jordan. Sensors, communication networks, and data management systems are just a few of the cutting-edge technology that smart grids rely on. These technologies must be carefully integrated and controlled to ensure optimal

operation. In some circumstances, Jordan's current infrastructure would not be adequate to support the installation of a smart grid, necessitating pricey renovations and new technology expenditures. For instance, it may be difficult and expensive to establish communication networks and other infrastructure in remote or rural locations. Technical difficulties, such as managing intermittent energy output and ensuring the stability of the electricity system, might arise from the grid integration of renewable energy sources. Implementing a smart grid in Jordan can provide considerable infrastructure and technological obstacles, necessitating careful planning, financial investment, and technical know-how to guarantee the system's dependability and performance [Kirmani et al. 2022, Bouhafs et al. 2012].

Privacy and security concerns for consumer data

The privacy and security issues that come with gathering and managing significant volumes of consumer data could be another drawback of adopting a smart grid in Jordan. Real-time data on energy production and consumption, which can contain sensitive information, are gathered and analyzed in order for smart grids to function. This data is susceptible to hacking or unauthorized access, which could result in privacy violations and security lapses. Additionally, worries regarding customer privacy and monitoring may arise because of the greater connectivity and data sharing brought on by smart grids. It is crucial that utilities as well as policymakers set clear norms and standards for data privacy and security, including safeguards to preserve consumer data and avoid unwanted access, to allay these worries. To only allow authorized users access to data, could involve the use of encryption, secure communication protocols, and stringent access controls. While the gathering and analysis of consumer data is a crucial part of a smart grid, it is crucial to manage privacy and security issues properly to preserve customer data and keep the public's confidence in the system [Hasan et al. 2023].

Regulatory and legal challenges

The difficulties in installing a smart grid in Jordan due to regulations and laws governing such a complicated system are another possible drawback. The creation of new laws and policies is necessary for the installation of a smart grid to guarantee the system's efficient and secure operation. Legal issues pertaining to data privacy, consumer protection, and liability may also arise; these issues need to be handled carefully to ensure that the system complies with applicable local laws and regulations [Hasan et al. 2023]. Jordan, which has a special political and regulatory context, can provide extremely complicated regulatory and legal obstacles when attempting to install a smart grid. To facilitate the development of a smart grid, it might be necessary to create new rules and laws, which could necessitate strong political will and collaboration from decision-makers and stakeholders. To guarantee that the system runs successfully and complies with local rules and regulations, policymakers and stakeholders must carefully plan as well as coordinate the implementation of a smart grid in Jordan due to the regulatory and legal obstacles that can be involved.

Potential for job displacement and workforce changes

The possibility of job relocation and workforce changes is another potential drawback of adopting a smart grid in Jordan. The adoption of a smart grid might alter the workforce requirements for the energy industry, either resulting in job losses or the requirement for retraining and the creation of new skills [Reed and Stanchina 2010]. For example, the greater use of technology and the automation of some jobs may reduce the demand for manual labor while generating new employment opportunities in such fields as data analytics and IT assistance. It is crucial for utilities and legislators to create strategies for workforce development and transition to address these issues as well as make sure that employees have the education and training needed to succeed in a rapidly evolving energy industry. This can entail funding for education and training initiatives as well as initiatives to promote employee retraining and job placement services. While the adoption of a smart grid has the potential to improve the productivity and dependability of Jordan's energy sector, it is crucial to carefully analyze and handle any potential effects on the workforce to ensure a fair and just transition to the new system [Li et al. 2022].

SMART GRID IMPLEMENTATION IN JORDAN

Overview of Jordan's current energy infrastructure

Now, Jordan's energy system is mainly reliant on imported fossil fuels, especially oil and natural gas. Around 94% of the nation's energy requirements are imported, which has raised serious questions about energy security and exposed it to changes in the world energy markets [Abu-Rumman et al. 2020]. The Northern, Central, and Southern regional systems make up Jordan's electricity grid, which is run by the National Electric Power Company (NEPCO). Around 73% of the nation's electricity is generated by thermal power plants, which supply the grid with the other 26% coming from renewable energy sources like wind and solar and 1% from other sources as shown in Figure 3 [Ministry of Energy and Mineral Resources (MEMR), Annual reports 2021]. While the government has set an ambitious target to raise the amount of renewable energy in the country's energy mix, Jordan has achieved considerable strides in the development of its renewable energy sector in recent years. The entire installed capacity of projects using renewable energy to produce electric power is around 2445.7 MW, and it consists of: 947.6 MW renewable energy projects owned by subscribers to cover their consumption by using net metering and wheeling schemes and 1498.1 MW projects where the electric power generated is sold to electrical companies. The electricity generation projects using renewable energy during the years 2015–2021 are shown in Table 2. The country also has the ambitions to build more renewable energy capacity in the upcoming years [Ministry of Energy and Mineral Resources (MEMR), Annual reports 2021]. Despite these initiatives, Jordan's energy infrastructure continues to confront many difficulties, such as a shortage of energy storage capacity, outdated equipment, as well as substantial transmission and distribution losses.

Steps taken towards the implementation of a smart grid in Jordan

To build a smart grid, Jordan has taken several initiatives, such as creating an action plan and starting pilot projects to test out various smart grid technologies. Action Plan of Jordan Energy Strategy 2020–2030 highlighted the nation's goals for creating a smart grid infrastructure. The plan outlined several crucial areas for action, such as the creation of smart grid standards and laws, the incorporation of renewable energy sources, and the introduction of improved metering infrastructure [The Executive Action Plan of Jordan Energy Strategy 2020–2030 2020]. Jordan has started a few pilot projects to test smart grid technologies in actual environments in addition to the action plan. For instance, NEPCO started a pilot project in the northern part of the country in 2020 to evaluate a demand response program. To track energy consumption and offer consumers incentives to use less energy during times of high demand, the initiative required installing smart meters in homes and businesses [The

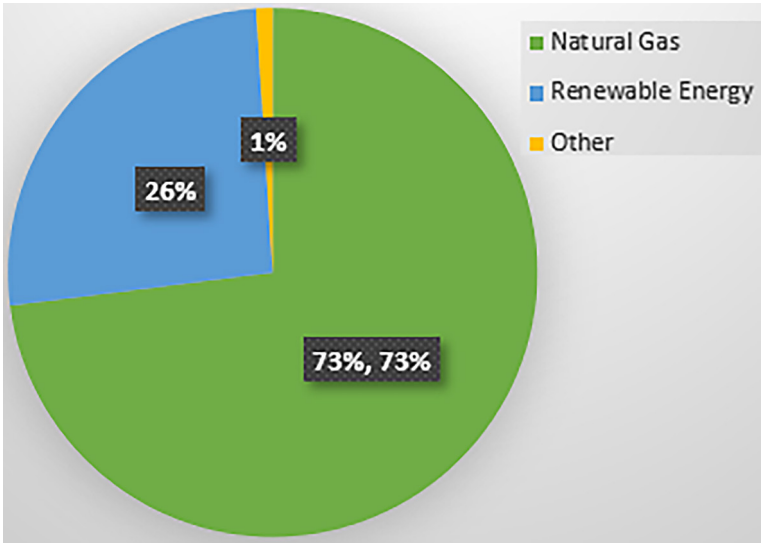

Figure 3. Structure of primary energy sources in Jordan in 2021

Table 2. The electricity generation projects using renewable energy during the years 2015–2021

2015	2016	2017	2018	2019	2020	2021
Azraq project/ Spanish grant 2.5 MW	Hussein wind project/Gulf grant 66 MW	Hussein wind project/Gulf grant 14 MW	FRV solar project 50 MW	AM solar project 40 MW	Mass Jordan for renewable energy project 100 MW	Energy wind project in Tafila 51.75 MW
Azraq project/ Spanish debt swap grant 2 MW	Energy projects/Direct offers at a capacity 204 MW		Dutch empire solar company project 50 MW	Risha solar project 50 MW	Baynounah solar project 200 MW	Daehan wind project in Tafila 51.75 MW
Jordan wind company project 117 MW			Local company for water and energy project 51 MW	Safawl green energy project 51 MW	Shobak company wind project 45 MW	Philadelphia project 50 MW
			Sheikh Zayed solar energy complex project/ Gulf grant 92 MW	Azraq solar project/ European Union grant 5 MW		
			Air Force project 10 MW	Al-Fujeij wind energy project 89 MW		
			Green energy for renewable energy project 86.1 MW			

Executive Action Plan of Jordan Energy Strategy 2020–2030 2020, Renewables Readiness Assessment: The Hashemite Kingdom of Jordan 2021]. Jordan is still developing its smart grid infrastructure, but the country has made significant strides in creating a plan and launching pilot projects to test out new technologies. As a result, Jordan is well-positioned to continue growing and expanding its smart grid capabilities in the years to come [The Executive Action Plan of Jordan Energy Strategy 2020–2030 2020].

Details of Jordan's smart grid plan

The Action Plan of Jordan Energy Strategy 2020–2030, which outlines a framework for creating a contemporary, adaptable, and efficient electricity grid that can support the integration of renewable energy sources and enhance the overall dependability as well as quality of electricity supply, serves as the foundation for Jordan's smart grid plan.

The plan includes several key components as shown in Figure 4, including:

- Advanced metering infrastructure (AMI): Jordan is implementing advanced metering infrastructure into place across the country, allowing for real-time monitoring of energy use and giving consumers more specific data on their energy usage. Additionally, utilities will benefit from improved energy demand management and real-time grid event response owing to the AMI system [The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020].
- Distribution automation: To provide more effective and dependable electricity distribution across the grid, Jordan is also attempting to automate and upgrade its electrical distribution infrastructure. This will involve the installation of sensors and other monitoring tools that can track grid conditions in real-time and spot any faults or issues before they result in outages [Renewables Readiness Assessment: The Hashemite Kingdom of Jordan, 2021].
- Integration of renewable energy: Jordan is attempting to include additional renewable energy sources, such as wind, solar, and biomass, into its electrical infrastructure. The management of the unpredictability and intermittency of these sources as well as their effective and efficient integration into the grid will depend heavily on smart grid technologies [Ministry of Energy and Mineral Resources (MEMR), Annual reports 2021, The Executive Action Plan of Jordan Energy Strategy 2020–2030 2020, Renewables Readiness Assessment: The Hashemite Kingdom of Jordan, 2021].
- Demand response: Jordan is looking at the possibility of demand response plans, which would allow utilities to better control electricity demand during peak hours and ease grid stress. This would entail the use of smart meters and other monitoring technology to offer real-time information on energy consumption,

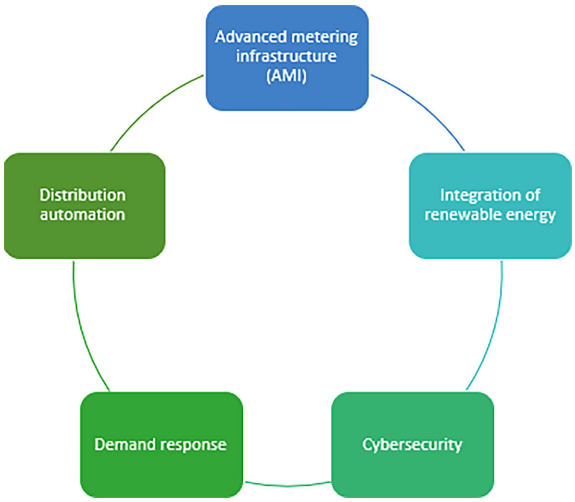

Figure 4. The key components of Jordan's action plan

as well as the creation of incentive and pricing mechanisms to encourage consumers to use less energy during peak hours [The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020, Renewables Readiness Assessment: The Hashemite Kingdom of Jordan, 2021].

- Cybersecurity: Jordan is also making an effort to creat strong cybersecurity safeguards to defend the smart grid system from online threats and intrusions. This will entail the creation of standards and guidelines for the security of the smart grid as well as the introduction of tools and procedures that can identify threats and take appropriate action [National Cyber Security Strategy 2018–2023, 2018].

The goal of Jordan's smart grid plan is to modernize the electrical system, increase its efficiency and dependability, facilitate the integration of renewable energy sources, and provide consumers with more control over how much energy they use. The idea is a huge advancement for Jordan's energy industry and has the potential to have a positive impact on both the economics and environment of the entire country.

Key stakeholders and their roles in the implementation process

The implementation of Jordan's smart grid plan involves several key stakeholders as shown in Figure 5, including:

- The Ministry of Energy and Mineral Resources (MEMR): The MEMR is in charge of creating and carrying out Jordan's energy policies, including the smart grid plan. The MEMR is in charge of making sure the plan is carried out successfully and efficiently and plays a key role in coordinating the many stakeholders involved in the implementation process [The Executive Action Plan of Jordan Energy Strategy 2020–2030 2020, (Ministry of Energy and Mineral Resources)].
- The Electricity Distribution Company (EDCO): The EDCO will be essential in implementing the smart grid plan and is in charge of overseeing the distribution of electricity throughout southern Jordan. To ensure that the smart grid is successfully incorporated into the current electricity infrastructure, the EDCO will be in charge of deploying advanced metering infrastructure, distribution automation technologies, and other smart grid components across the nation. The EDCO will also work closely with other stakeholders to this end [Renewables Readiness Assessment: The Hashemite Kingdom of Jordan 2021, EDCO].
- Jordan Electric Power Company (JEPCO): The JEPCO is in charge of overseeing Jordan's central electricity generation and transmission, and it will be crucial to the success of the smart grid project. In order to make sure that the grid is able to manage the unpredictability

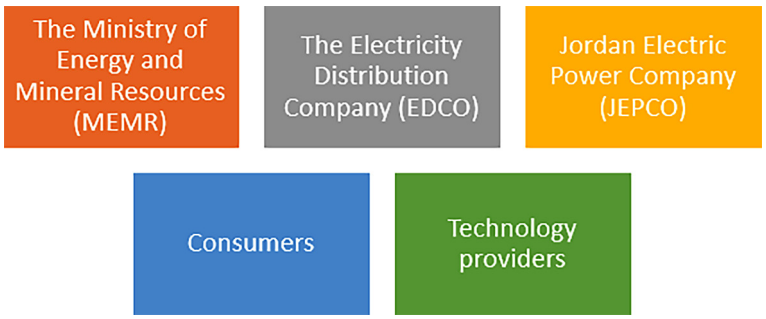

Figure 5. Key stakeholders

and intermittency of these sources, the JEPCO will be in charge of integrating renewable energy sources into the electrical grid. To do this, the company will collaborate closely with EDCO and other stakeholders [Renewables Readiness Assessment: The Hashemite Kingdom of Jordan 2021, JEBCO].

- Consumers: Customers will be crucial in implementing the smart grid concept. Smart meters and other monitoring equipment will need to be installed and used by consumers, who will also need instruction on how to use them in order to successfully manage their energy usage. Demand response programs will also be available to consumers, and they will need to be encouraged to use less energy during peak hours.
- Technology providers: The execution of the smart grid plan will involve a number of technology suppliers, such as the firms that offer advanced metering infrastructure, distribution automation technologies, renewable energy technologies, and cybersecurity solutions. To make certain that the technologies used are dependable, efficient, and compatible with existing infrastructure, these firms will collaborate closely with the MEMR, EDCO, JEPCO, and other stakeholders [National Cyber Security Strategy 2018–2023, 2018].

All these parties will need to work closely together and coordinate for Jordan's smart grid plan to be implemented successfully. They will also need to be fully committed to the plan's goals and objectives.

Timeline and milestones for implementation

With a target date of 2030 for full deployment, Jordan's smart grid plan is expected to be implemented over a number of years in phases. Some of the major dates and deadlines for the implementation are shown in Figure 6 [The Executive Action Plan of Jordan Energy Strategy 2020–2030 2020]:

- Phase 1 (2020–2021): A feasibility assessment and a road map for the plan's implementation were part of the initial phase of the smart grid plan. For the smart grid strategy to be successful, the MEMR and other stakeholders worked to identify essential technologies, infrastructural needs, and regulatory frameworks.
- Phase 2 (2021–2025): The rollout of distribution automation technology (DAT) and advanced metering infrastructure (AMI) across the country is part of the second phase of the smart grid strategy. During this phase, EDCO and other partners will seek to implement sensors and other automation technology on the grid itself, as well as smart meters and other monitoring equipment in residences and commercial buildings. In this stage, the electricity system will also incorporate renewable energy sources like solar and wind power.
- Phase 3 (2025–2030): Demand response programs and other consumer-facing energy management tools are integrated as part of the final stage of the smart grid plan. Consumers will be able to adapt their consumption habits in response to the changes in electricity costs and availability during this phase because they will have access to real-time information about their energy usage. Advanced cybersecurity measures will also be implemented at this phase to safeguard the smart grid against online dangers [The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020, National Cyber Security Strategy 2018–2023, 2018].

Jordan's smart grid implementation will be a difficult and complex process that calls for tight cooperation and coordination between all stakeholders. However, the advantages of a smart grid, such as higher efficiency, reliability, and greater

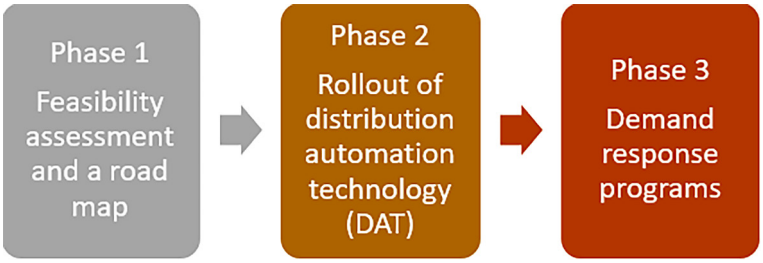

Figure 6. Timeline for implementation

integration of renewable energy sources, make this endeavor well worth the expenditure.

Challenges faced during implementation and how they were addressed.

A smart grid is being implemented in Jordan, however, there are several challenges as shown in Figure 7 that must be overcome for the system to be successfully installed and run. These are a few of the issues and how they are being resolved:

- Funding: The high cost of installation and maintenance is one of the greatest challenges to deploying a smart grid. The Jordanian government has obtained funds from a number of sources, including international donors and investors from the private sector, to solve the issue. To use the financing and knowledge of the private sector, the government has also created regulations to promote public-private partnerships in the energy industry [The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020].
- Technical challenges: The installation of new hardware, such as sensors, communication devices, and automation systems, is necessary for the adoption of a smart grid. Significant technological know-how and cooperation between numerous parties are needed for this. To solve this, the government created a technical committee to supervise the implementation of the smart grid plan and guarantee that the infrastructure is set up and run in a secure, dependable, and safe manner [The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020, The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020].
- Regulatory obstacles: The implementation of a smart grid necessitates modifications to the current legislative framework to account for new business models and technological advancements. The government has created a regulatory committee to study and revise the current laws, including grid codes, license requirements, and tariff structures, to address this [The Executive Action Plan of Jordan Energy Strategy 2020–2030, 2020].
- Consumer education: Consumer engagement and participation are essential for a smart grid to succeed. The government must start a public awareness campaign to inform people about the advantages of a smart grid and how to use the new technology and tools that will be made accessible to them to address this.
- Cybersecurity: The introduction of a smart grid raises the danger of cyber threats, such as hacking, data breaches, and other cyberattacks. A cybersecurity committee has been set up by the government to oversee the creation and application of cybersecurity measures, including the adoption of global standards and best practices [National Cyber Security Strategy 2018–2023, 2018].

The government, utilities, consumers, and the corporate sector must work together and in concert if a smart grid is to be implemented successfully in Jordan. Jordan can attain a more dependable, efficient, and sustainable energy system by addressing the challenges and implementing workable solutions.

CASE STUDIES OF OTHER COUNTRIES THAT HAVE IMPLEMENTED SMART GRIDS

Review of successful smart grid implementations in other countries

Several countries have successfully deployed smart grid technologies, offering useful lessons and best practices to Jordan's smart grid plan.

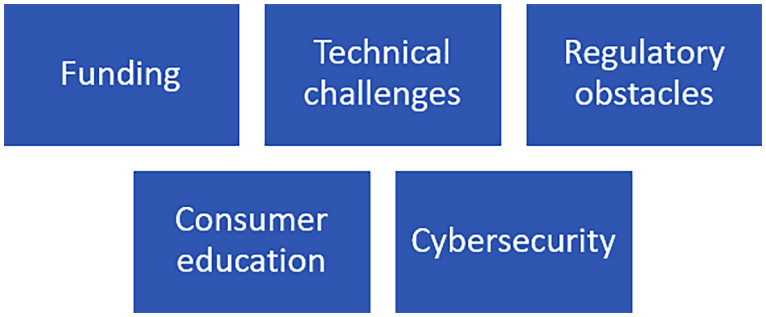

Figure 7. The challenges of implantation of smart grid

Successful applications of the smart grid include the following:

- United States: With numerous successful deployments all around the country, the US has been a global leader in smart grid technology. The Pacific Gas and Electric (PG&E) smart grid project in California is one noteworthy instance. Using smart meters, demand response programs, and distributed energy resources, this initiative has increased grid dependability and decreased energy consumption [Oliver and Sovacool, 2017].
- South Korea: One of the most cutting-edge smart grid systems in the world is found in South Korea, which has made considerable investments in technology. Initiatives for the nation's smart grid have emphasized enhancing grid stability, incorporating renewable energy sources, and advancing energy efficiency [Choi and Do 2016].
- Germany: The goal of Germany's Energiewende (energy transition) initiative, which includes the installation of a smart grid, is to convert the nation's energy system from fossil fuels to renewable energy sources. The implementation of smart meters, demand response programs, the expansion of infrastructure for charging electric vehicles, and the integration of renewable energy sources are all part of Germany's smart grid strategy [Lösch and Schneider 2016].
- Japan: After the Fukushima nuclear disaster in 2011, enhancing grid stability and reliability has been the main emphasis of Japan's smart grid programs. To increase grid resilience and include renewable energy sources, Japan's smart grid plan calls for the installation of cutting-edge sensors and automation technologies [Mah 2020].

These case studies show how smart grid technologies may significantly improve the sustainability, efficiency, and dependability of energy systems. Jordan can find best practices and deployment methods for its own smart grid system by researching the successful deployment of smart grids in other countries.

Key takeaways and lessons learnt from other implementations

There are numerous major takeaways and lessons learnt from the case studies of other countries that have adopted smart grids that can be helpful for Jordan's smart grid implementation as shown in Figure 8:

- Clear aims: Successful smart grid installations have incorporated clear objectives that are in line with the nation's energy demands and policies. To lessen its reliance on fossil fuels, South Korea, for instance, implemented the smart grid programs that were aimed at enhancing grid stability and incorporating renewable energy sources [Choi and N 2016].
- Solid regulatory framework: The success of a smart grid implementation depends on a robust regulatory environment. This entails establishing precise standards and norms for smart grid technologies as well as ensuring utility companies and other interested parties abide by them. Energy efficiency and the integration of renewable energy sources have been successfully promoted by Germany's legislative framework for its smart grid plan [Lösch and Schneider 2016].
- Strong stakeholder involvement and communication: Successful smart grid installations have involved strong stakeholder engagement and communication with utilities, consumers, and government organizations. This entails informing customers of the advantages of smart grid technologies as well as resolving their worries about data security and privacy. Through community engagement and education, PG&E's smart grid project in California was successful in attracting consumers [Oliver and Sovacool 2017].
- Collaboration and partnerships: For the implementation of the smart grid to be successful, cooperation and collaboration between utilities, governmental organizations, and other stakeholders have been essential. To develop and implement cutting-edge sensors and automation systems to improve grid resilience, for instance, Japan's smart grid strategy required tight cooperation between utilities, governmental organizations, and private sector businesses.

Jordan can create a successful smart grid implementation strategy that is in line with its energy policy and needs, incorporates strong communication and collaboration with stakeholders, and takes these important takeaways and lessons learned into consideration.

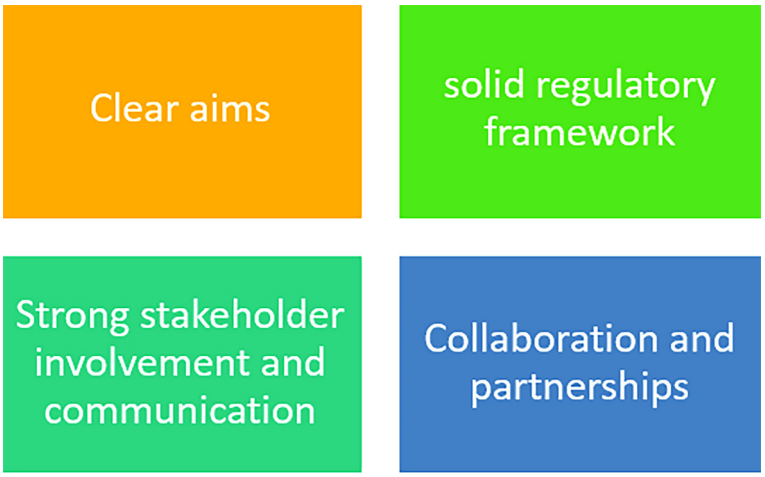

Figure 8. Lessons learnt from the case studies of other countries

Comparison of other implementations to Jordan's plan

There are certain similarities and variations between Jordan's plan and other nations' smart grid initiatives that should be recognized. Similarities include the fact that many of the successful implementations have had precise goals and objectives that match the nation's energy demands and policies. This is also true for Jordan, which intends to boost the integration of renewable energy sources, strengthen the dependability and efficiency of its power system, as well as enhance utility management and monitoring capabilities Strong regulatory frameworks and cooperation between utilities, governmental organizations, and other stakeholders have also been essential to effective implementations. With the creation of a smart grid strategy and the inclusion of important stakeholders in the implementation process, Jordan has also taken strides in this direction. However, there are also other ways that Jordan's strategy differs from past successful ones. For instance, while Jordan's plan covers a variety of goals, some countries have concentrated on particular components of the smart grid, such as grid stability or the integration of renewable energy sources. Furthermore, while Jordan's strategy mostly depends on already-existing technologies, some effective implementations required major investments in research and development to create cutting-edge technologies [The Executive Action Plan of Jordan Energy Strategy 2020–2030 2020, Oliver and Sovacool 2017, Choi and N 2016, Lösch and Schneider 2016, Mah 2020]. Overall, there are many commonalities and areas Jordan can learn from, even though there are considerable variations between his concept and other successful smart grid installations. Jordan can create a more effective and efficient plan for implementing the smart grid by taking into account the accomplishments and difficulties experienced by other countries.

CONCLUSIONS

The deployment of a smart grid in Jordan, including its benefits and drawbacks, the country's smart grid plan, and case studies of other nations' successful implementations, have all been covered in this research study. The benefits of establishing a smart grid in Jordan include increased energy management and cost control for consumers, improved reliability and efficiency of the power grid, increased integration of renewable energy sources, as well as improved control, and monitoring capabilities for the utility. The implementation of a smart grid in Jordan is not without drawbacks, though, including high implementation costs and capital expenditures, infrastructure requirements and technical difficulties, privacy and security issues involving consumer data, regulatory and legal difficulties, and the potential for job displacement and workforce changes. Despite these obstacles, Jordan has created a strategy for a smart grid and involved important parties in its implementation. The nation can also gain knowledge from past successful implementations in other nations, which have strong regulatory frameworks, defined aims and objectives, and cooperation between utilities, government agencies, and other stakeholders. We advise Jordan to keep making investments in and giving the installation

of a smart grid top priority considering our findings. Increased integration of renewable energy sources, a more dependable and efficient power system, and advantages for both the utility and the consumer could result from this. We advise Jordan to keep working on building regulatory frameworks, resolving infrastructure and technical requirements, and addressing privacy and security issues to overcome the difficulties involved with implementing a smart grid in the nation. Efforts should also be made to reduce job displacement and support workforce changes. Jordan may successfully adopt a smart grid and benefit from this technology by addressing these issues and learning from successful implementations in other nations. On the basis of the conducted analysis, it can be concluded that setting up a smart grid in Jordan is feasible and has the potential to have a positive impact on the country's energy industry. The nation has already begun the process of creating a plan for a smart grid and including important stakeholders. Jordan also has the potential to gain from a smart grid because of its rising energy demand, ambitious renewable energy targets, and geographical location that enables the integration of renewable energy sources like solar and wind power. Even if there are difficulties with adopting a smart grid in Jordan, including as high prices and technical constraints, they can be overcome with careful planning, stakeholder cooperation, and legislative frameworks that encourage the advancement of technology. The feasibility and prospects of a smart grid in Jordan are favorable, and we advise the country to keep funding and giving this technology a high priority. Future research and policy choices can be made in several different areas because the deployment of a smart grid in Jordan is a complicated and protracted process. Firstly, the economic and environmental advantages of implementing a smart grid in Jordan, including possible cost savings, carbon emission reductions, and improved energy efficiency, can be evaluated through more thorough studies. Secondly, Policy choices should be taken to address the legal and regulatory issues, such as potential employment displacement and worries about data security and privacy, that are related to the installation of a smart grid. Thirdly, research might be done to evaluate the possibility of public-private collaborations in the creation and deployment of the smart grid. The Jordanian government should last but not least, continue to involve important parties in the implementation process, such as energy utilities, regulators, and consumers, to make sure that the advantages of a smart grid are maximized and that any problems are dealt with effectively.

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