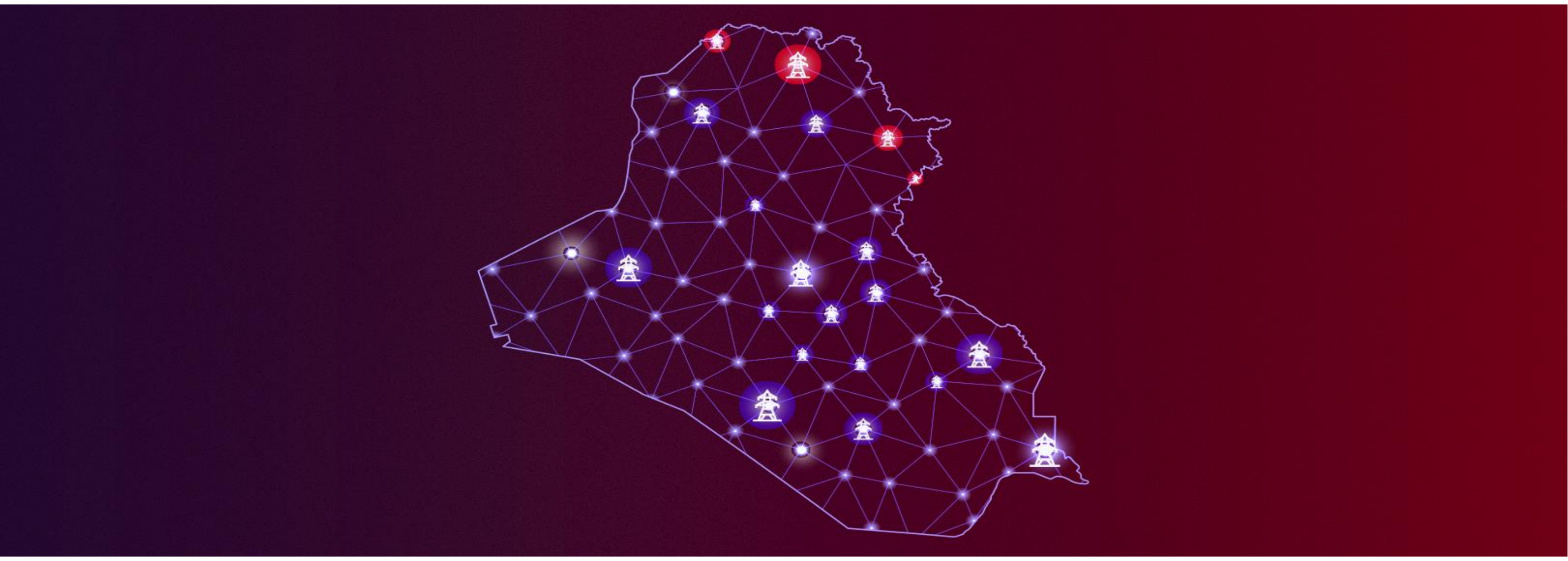
IRAQ'S ELECTRICITY CRISIS : COULD INTERCONNECTED SMART GRID BE THE ANSWER?

Roman Jamal | February 23, 2025



Executive Summary

Iraq faces a persistent energy crisis, marked by insufficient power generation, rising dependency on imports, and unsustainable practices like underutilization of Renewable Energy Sources (RES) and gas flaring. Private generators, extensively used, are neither eco-friendly nor scalable, while outdated transmission and distribution networks suffer from heavy losses. The Kurdistan Region of Iraq (KRI) and the rest of Iraq operate under disconnected ministries, limiting collaboration and efforts to interconnect the grids. Smart grid offers a strategic pathway to address these issues, by modernizing the power grid, reducing inefficiencies, and fostering interconnection between KRI, Iraq, and neighboring nations. However, progress is hindered by institutional and operational barriers and failed agreements with international partners. While the adoption of smart grids comes with its challenges, the long-term benefits far outweigh the initial hindrances. A renewed focus on actionable strategies and a commitment to overcoming these barriers are essential for realizing Iraq's energy transformation.

List of Abbreviations

AT&C -Aggregate Technical and Commercial Losses

BTU - British Thermal Unit

GoI - Government of Iraq

GHG - Greenhouse Gas

GW - Gigawatt

IEA - International Energy Agency

IEI - Iraq Energy Institute

ISIS - Islamic State of Iraq and Syria

KRG - Kurdistan Regional Government

KRI - Kurdistan Region of Iraq

kV - Kilovolt

LPC - Local Provisional Council

Mcm/d - Million Cubic Meters per Day

MoE - Ministry of Electricity

MoF - Ministry of Finance

MoI - Ministry of Interior

MoO - Ministry of Oil

MW - Megawatt

MWh - Megawatt Hour

NDC - Nationally Determined Contributions

PPA - Power Purchase Agreement

IPP - Independent Power Producer

RES - Renewable Energy Sources

SOE - State-Owned Enterprise

T&D - Transmission and Distribution

WASG - Wide Area Synchronous Grid

O & M - Operation and Maintenance

EPRI - Electric Power Research Institute

Introduction

Energy lies at the heart of a nation's development, acting as the agent that drives the economy. As one of humanity's most transformative inventions, electricity, the most relied upon form of energy, shapes modern life in profound ways. However, while many nations harness its potential to advance their societies, Iraq faces a crippling electricity crisis. This crisis stems from a pronounced imbalance between supply and demand, as the country's generation capacity cannot keep up with the rapidly growing demand which the International Energy Agency (IEA) forecast to be doubled by 2030.[1]

At the root of the complication is Iraq's overwhelming dependence on fossil fuels for power generation, a strategy going increasingly out of step with the worldwide shift toward more sustainable energy sources. The reliance on a volatile resource leaves Iraq vulnerable to fluctuations in global oil and gas prices, which directly impact its fiscal revenues. However, the challenges do not end here, inefficiencies in the Transmission and Distribution (T&D) sector are becoming an undesired contributor to the crisis. Aggregate Technical and Commercial (AT&C) losses have become a bottleneck in the power supply chain because efforts predominantly focused on expanding generation capacity, rather than upgrading and expanding the T&D networks.

The Iraq Energy Institute (IEI) estimated that over $8-10 billion in investment will be required between 2020 and 2025 to modernize the T&D infrastructures.[2] These funds will be allocated to replace overaged power lines, rehabilitating substations, and install smart energy meters, a cornerstone of smart grids. A smart grid is a network that combines energy distribution and digital communication technology, enabling a two-way flow of data.[3] The performance of Iraq's electricity sector is further degraded due to incompetencies within State-Owned Enterprises (SOEs). SOEs are formed by the governments to run commercial projects on their behalf, and while 62% of SOEs under the Ministry of Oil (MoO) reported profitability, only a meager 4% of the SOEs under the Ministry of Electricity (MoE) turned a profit in 2020.[4] These cumulative impacts have plagued Iraq with frequent power outages, especially during Iraq's sweltering summers when demand is at its peak, causing public frustration and unrest.

The Government of Iraq (GoI)'s intended plans include the integration of renewable energy solutions and the establishment of interconnected grids with neighboring countries to improve power availability. However, achieving these goals require addressing critical gaps within Iraq's borders. Without an interconnected grid across Iraq and KRI the country risks experiencing imbalanced distribution and uneven power allocation, particularly as generation volume increases with the grid interconnections. At the same time, expanding generation is futile if the adequate delivery of services to end-users is dysfunctional. Currently, the federal and regional electricity authorities operate independently of each other, mirroring the disconnection in the physical grid. Additionally, the fluctuating nature of RES needs a more resilient and smarter power grid.

To understand the multifaceted challenges facing Iraq's electricity sector, an evaluation of ongoing initiatives, and the exploration of transformative solutions are necessary. This includes the potential conversion of the grid into an interconnected smart network supported by advanced smart grid technologies. Additionally, the institutional and structural alignment required to enable this transition, along with the obstacles Iraq may face in adopting smart grid technology and its broader implications, are examined.

Major Obstacles in Iraq's Power Sector

Power Generation

Electricity, while ubiquitous, is only generated in specific locations, and it cannot be stored and used at a later time. Consequently, the supply of generated electricity should always align with instantaneous demand. Efficient electricity generation hinges on two critical factors: 1- adequate infrastructure to ensure sufficient production capacity, and 2- a reliable and consistent supply of fuel and resources to sustain operations. Most of Iraq's power plants rely on natural gas and oil as primary feedstocks for power production. However, these facilities have suffered from declining efficiency and output. This is evident in Figure 1, which illustrates the reduction in average gas and diesel power plant production capacity in 2023 compared to 2022, alongside a sharp rise in electricity imports counteractively.

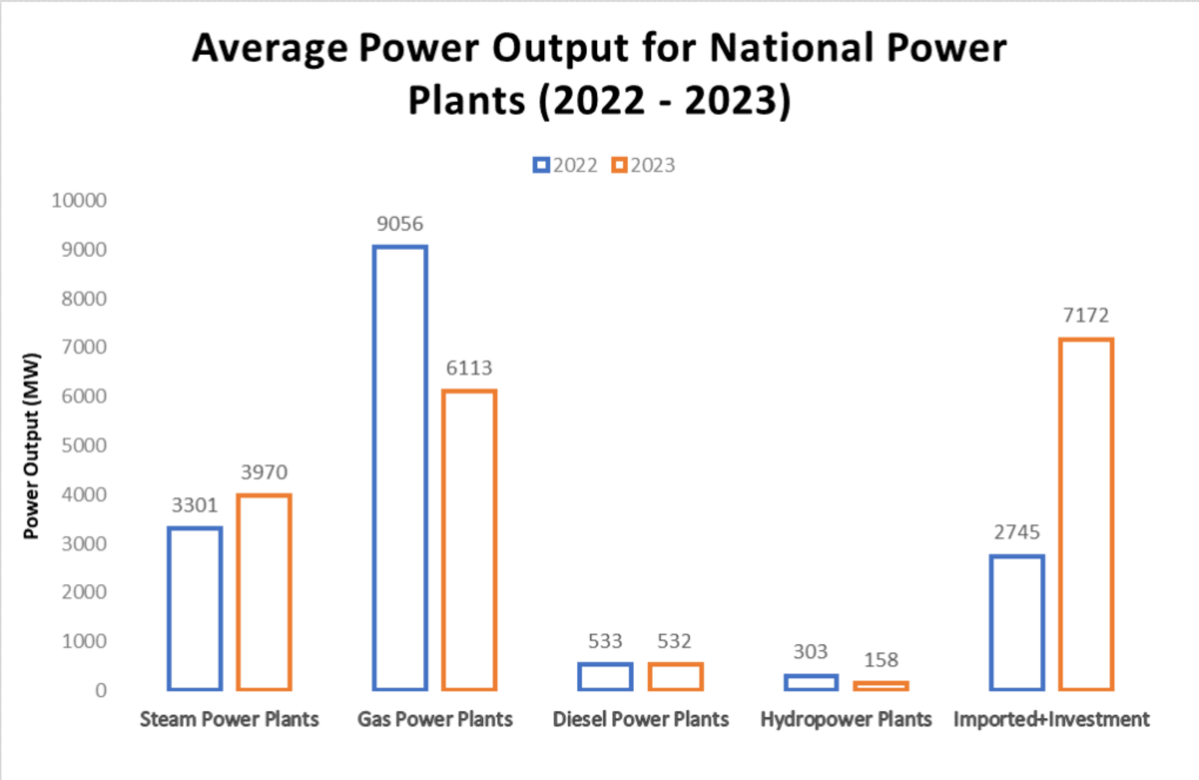


Figure 1: Power Plants Production in Iraq (2022 vs. 2023) **Source:** MoE (Iraq)

Iraq has increasingly resorted to importing electricity and natural gas from neighboring Iran, a practice initiated in 2017. While this approach temporarily alleviates power shortages, it introduced new problems. Most notably, the financial burden of reliance on Iranian-generated energy, which comes at a premium. For instance, Iraq pays $8 per million British thermal unit (BTU) for Iranian natural gas[5], whereas the estimated cost of producing domestic gas is less than $2 per million BTU. This dependency was further solidified in March 2024, when Iraq's MoE and the state-owned National Iranian Gas Company, signed a five-year agreement[6] for the supply of up to 50 mcm/d of gas.

Iraq's decision underscores its vulnerability, the surge in global natural gas prices, triggered by the war in Ukraine caused the subsequent European energy crisis, which foreshadows a similar fate that could befall Iraq's already precarious power sector. Moreover, the potential to diversify gas imports, such as sourcing from Qatar[7], remains constrained by Iraq's infrastructural limitations. Reconfiguring the existing structures to accommodate new supplies of natural gas would require substantial investments and extended timelines. Meanwhile, global demand for natural gas continues to rise, compelling major exporters, including Qatar, to prioritize fulfilling existing contracts, over new ones.

A critical setback in Iraq's power generation sector is the inefficiency in utilizing associated gas and resorting to gas flaring instead. Gas flaring is the burning of the associated gas during oil extraction. Iraq flares about 16 billion cubic meters each year, a wasted resource capable of providing energy to an approximating three million houses.[8] However, Iraq's limited infrastructure for gas separation and processing precludes the reduction of gas flaring. Additionally, gas flaring remains cheaper than capturing, processing, and marketing the gas for local power generation. In addition to economic barriers, reducing gas flaring has faced opposition from political sentiments. Disputes over oil and revenue sharing between the Kurdistan Regional Government (KRG) and GoI have yielded conflicting policies and priorities, greatly impeding cooperation and investments in flaring reduction and the utilization of associated gas for electricity generation in the disputed territories.[9]

The sector remains burdened by the aftermath of the war against the Islamic State of Iraq and Syria (ISIS), which inflicted extensive damage on Iraq's power plants. The war resulted in the complete destruction of eight power plants and remarkable damage to twenty-five others, with the total damage estimated at $7 billion.[10] This damage has not been fully addressed, and such losses cannot be overlooked.

Transmission and Distribution of Electricity

After electricity is generated in Iraq, it is transmitted through an extensive network consisting of 6,253 km of 400 kV grid and 17,777 km of 132 kV lines. These transmission lines connect to the distribution grid through 889 fixed and 277 mobile 33/11 kV substations.[11] Despite incremental improvements in the distribution network's capacity, problems are still persistent for Iraq's MoE. The obsolescence of the T&D infrastructures has led to severe overloading of various equipment. Local capabilities in developing major transmission equipment, such as high voltage lines and transformers, remain extremely limited.[12] Although systemic losses are known to be high, the absence of proper metering systems makes it difficult to accurately quantify such losses. Furthermore, rampant illicit connections, widespread electricity thefts, low and ineffective tariff collection practices have led to alarmingly low-cost recovery ratios and elevated subsidy levels.

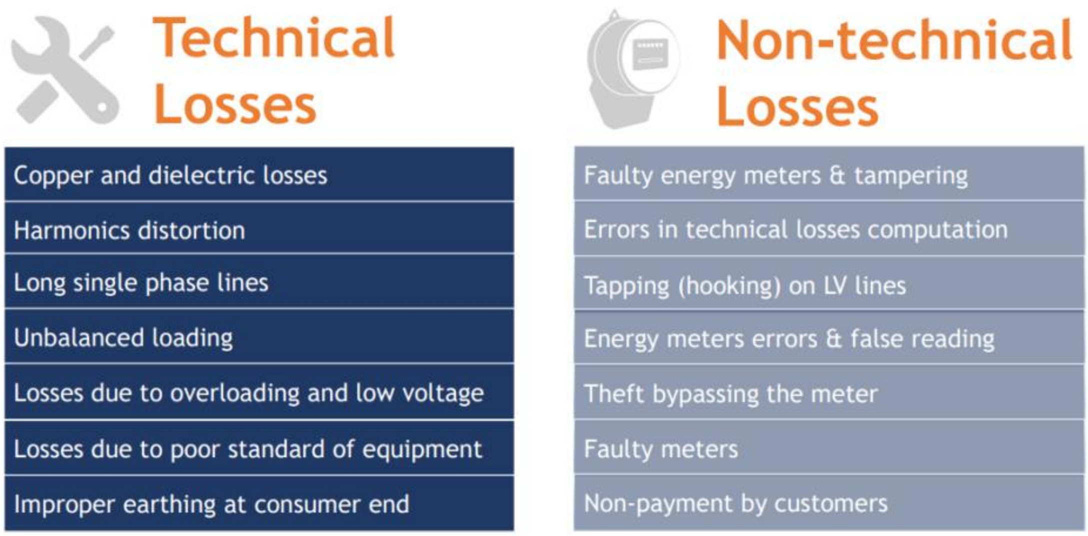


Figure 2: AT&C losses in Iraq Electricity Sector **Source:** Harry Istepanian

While Iraq's grid extends from Mosul to Basrah, over one-fifth of the network remains inoperative due to years of conflict and inadequate maintenance. High demand and concentrated loads are acute in central Iraq, especially around Baghdad province, where additional non-technical losses of electricity such as theft, exacerbates the issue. The Western and Northern parts of Iraq suffer from poor connectivity and require enormous network expansions.

The T&D infrastructure is fragile, a result of decades of poor maintenance, corruption, and conflict. The total losses are among the highest in the region, ranging between 40% and 50%

and even reaching 55% in 2023, as illustrated in Table 1. In comparison, neighboring Saudi Arabia maintain losses of less than 7%.[13]

Companies	Governorates	Energy Received from Transmission Companies (MWh)	Energy Generated from Diesel (MWh)	Internal Consumption (MWh)	Losses (MWh)	Percentage of Losses	Energy Sold to Consumers (MWh)
Baghdad	Al-Rusafa	8,980,202	-	1,532	5,222,264	58%	3,756,406
	Al-Karkh	16,421,833	-	-	9,347,012	57%	7,074,821
	Al-Sadr	10,724,467	-	10,232	6,538,998	61%	4,175,237
Middle	Upper Euphrates	1,616,412	-	-	362,634	22%	1,253,778
	East of Al-Anbar	2,237,867	-	-	918,089	41%	1,319,778
	Central Anbar	2,675,976	-	-	1,417,913	53%	1,258,063
	Diyala	6,459,127	-	-	2,653,386	41%	3,805,741
	Wasit	5,164,263	-	-	2,807,093	54%	2,357,170
North	Nineveh	10,016,928	-	7,641	4,828,220	48%	5,181,067
	Kirkuk	7,111,154	-	1,162	3,815,590	54%	3,294,402
	Salah Al-Din	6,899,685	-	2,079	4,208,258	61%	2,689,348
Middle Euphrates	Babylon	7,090,252	4	5,378	3,673,049	52%	3,411,829
	Karbala	6,698,633	11.5	1,043	4,578,342	68%	2,119,260
	Najaf	6,755,680	2	744	2,997,311	44%	3,757,627
	Al-Diwaniyah	4,448,845	-	2,187	2,754,399	62%	1,692,259
South	Basrah	10,287,636	-	24,710	5,160,862	50%	5,102,064
	North of Basrah	10,163,779	-	32,208	6,281,488	62%	3,850,083
	Thi Qar	5,348,189	-	12,141	2,847,604	53%	2,488,444
	North of Nasiriyah	3,219,455	-	6,839	1,723,265	54%	1,489,351
	Maysan	5,680,696	-	32,893	3,444,495	61%	2,203,308
	Al-Muthanna	3,360,504	-	6,693	1,703,522	51%	1,650,289
Total		141,361,583	17.5	147,482	77,283,794	55%	63,930,325

Table 1: Net Power Delivered to End-Users in Iraq for 2023 **Source:** MoE (Iraq)

Addressing non-metered consumption and electricity theft is paramount for ensuring the sustainability of any investment strategy in the power sector. This necessitates the accelerated upgrading of the distribution network, coupled with deployment of smart grid technologies like smart meters. The GoI needs to recognize that resolving the electricity crisis and implementing reforms cannot be achieved without investments in the modernization and rehabilitation of the electricity T&D networks.

Private Generators

In response to the power deficit, the Local Provincial Councils (LPCs) and the private sector have been persuaded by the GoI and KRG to deploy diesel generators at the neighborhood level. These generators aim to supplement grid supply and mitigate power shortages. In KRI most of these generators are privately owned. As of 2021, KRI had a total of 3,108 generator sites.[14] In Iraq, Baghdad alone has an astounding 13,000 neighborhood generators. While most generators in KRI are brand-name models procured from globally renowned companies, many generating sets in the other regions of Iraq are locally assembled using repurposed truck diesel engines coupled with imported generator components.[15] Although this local assembly process is cost-effective, these diesel generators are often substandard and lack proper enclosures, leaving critical parts like fans exposed, as shown in Figure 3.

Figure 3: Private Generators in Iraqi Neighborhoods **Source:** KIRKUK NOW

Another alarming issue displayed in Figure 3, is the proximity of the fuel storage tanks to the generators. Generators require fuel storage tanks and while 99% of generator owners maintain fuel storage, 17% of them lack safe storage practices. The generators contribute to environmental degradations through fuel combustion, releasing toxic gases like carbon dioxide. The widespread reliance on these generators has placed Iraq among the top five countries with the most diesel generators per capita globally.[16] Residential units are connected to these neighborhood generators through unconventional practices violating many safety standards and leading to floating voltages at consumer premises.[17]

The GoI has begun formalizing its relationship with the private sector by offering subsidized cheaper fuel for private generators. However, subsidized fuel has not lowered the cost of electricity from private generators to be cheaper than the national grid electricity. Therefore, subsidized rates ranging between $4 and $8 per ampere per month are still deemed unaffordable compared to the cost of the national electricity.[18] When diesel generators are operating, people consume much less energy, as tariff collection is based on consumption, indicating that most consumers are price sensitive. Private generators prove inadequate during extreme weather conditions and peak demand periods such as summers. These generators can only account for limited loads as the public cannot afford higher consumption, and they fail to support air conditioning or other energy-intensive appliances in moments of great necessity.

Clean Energy Solutions

Iraq should keep pace with the evolving global energy landscape. Investing in RES and implementing sustainable mitigation practices such as reducing gas flaring will complement Iraq's Nationally Determined Contributions (NDCs) and climate change commitments. Electricity Law No. 53 of 2017 regulates the adoption of renewable energy activities by the MoE. Under this Law, institutions and individuals can generate renewable power for personal use, with access to connection with the national T&D grid or sell electricity to MoE through Power Purchase Agreements (PPAs).[19] This framework has prompted many companies to approach the MoE with solar project proposals.

Iraq owns great renewable energy potential, with high solar irradiance, and viable wind speeds, particularly in the Southern and Western regions[20] as highlighted in Figure 4.

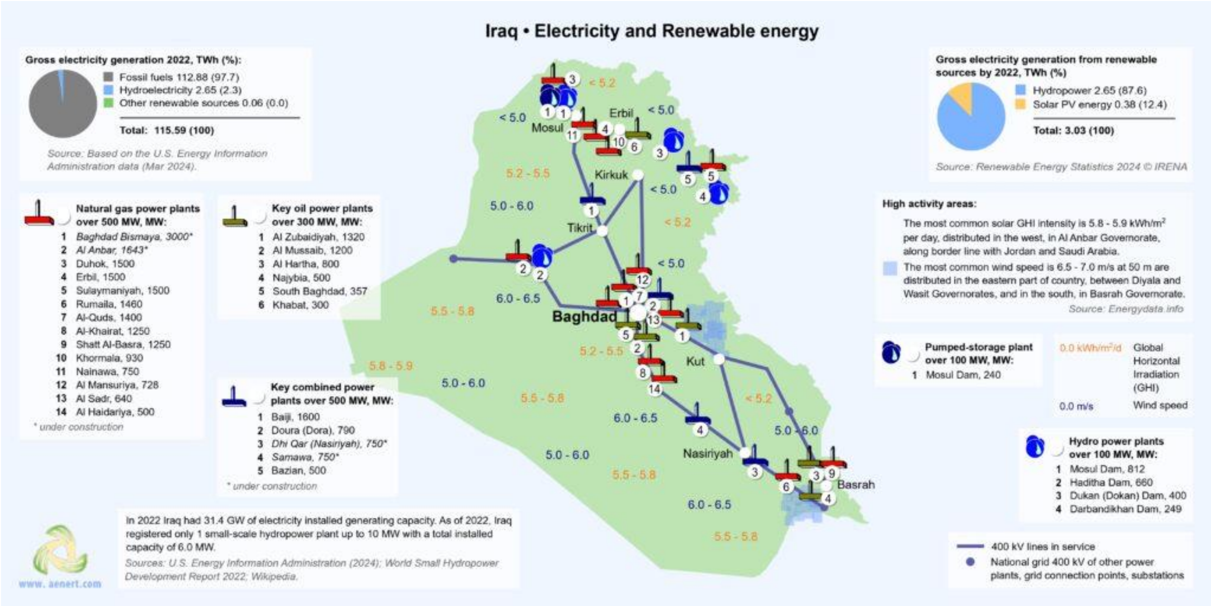


Figure 4 : Electricity and Renewable Energy in Iraq **Source** : aenert

Figure 4 illustrates that only 2-3% of Iraq's net generated electricity comes from RES, with negligible contributions from solar and wind power, despite their potential to electrify a huge part of the country.

When integrating RES with Iraq's national grid, many promising RES project sites are in remote areas, requiring extended grid connections or advanced battery storage solutions. Renewable energy investments must be backed by flexible resources, including energy storage, demand response mechanisms and interconnection extents, to mitigate seasonality of RES. Iraq's underdeveloped and insufficient grid further restricts the integration. Without comprehensive planning and effective energy distribution, RES projects risk perpetuating existing grid inefficiencies. RES projects increasingly rely on Independent Power Producers (IPPs) and long-term PPAs. However, due to these entangled challenges, many regional IPPs have prioritized RES projects in neighboring Middle Eastern countries over Iraq.

Organizational Structure of Iraq's Power Sector

The electricity system in Iraq is operating by two distinct entities, with the KRG managing its own sector independently from federal Iraq. Both federal Iraq and KRI have a state-owned sector administered by their respective MoE, which maintain a complete dominance over transmission and distribution. A key distinction lies in electricity generation. In KRI, generation is predominantly carried out by IPPs including the Erbil, Sulaymaniyah, and Duhok power plants, which are contracted to the regional MoE. Conversely, the federal MoE primarily operates its own generation facilities, with limited engagements from IPPs[21] such as, Maisan, Rumaila, and Besmaya Phase II.

The federal MoE's financial operations are heavily dependent on the government budget allocated by the Ministry of Finance (MoF). Most policies and procedures related to energy projects require MoF approval before financing is facilitated by the Central Bank. This centralized financial dependency often leads to delays in implementing initiatives. The regional MoE is primarily funded by the KRG through allocating a portion of the budget for the region's power sector. Multiple government entities are responsible for the contemporary issues in the electricity services. While the MoE receives most of the blame, the broader issue is the lack of effective coordination among the relevant ministries. For instance, in Iraq, collaboration between the MoE and the MoF is needed to secure the appropriate financial allocations. Similarly, the Ministry of Interior (MoI) should work on protecting the grid from attacks and acts of sabotage. The MoO and the MoE should cooperate to ensure the utilization of domestic resources in the most efficient way.

The business model for both electricity sectors is defective, as it is almost entirely government- owned and has deficient investment inflow. Consumers usually fail to take responsibility for paying for the electricity they consume, largely owing to a weak tariff collection system. Despite issuing invoices, there is minimal engagement with consumers regarding tariff collections, further distancing the sector from international practices. The federal MoE has estimated that over 160,000 connections remain unmetered, while these connections are either legal or equipped with outdated, faulty meters.[22] Moreover, there is limited interconnection between the federal and the KRG network. Although Iraq imports electricity from KRI, grid connections between the two are limited. The hierarchical structure of both MoE exacerbates the issue, both ministries simultaneously act as a policymaker, operator, regulator, and supplier.[23] Therefore, the lack of collaboration between the two electricity sectors is a byproduct of their institutional independence.

The privatization of the electricity sector was once seen as the solution to the longstanding challenges, and since 2012, an increasing number of private firms have entered the sector. However, infrastructural damage and growing demand remained constant issues. Despite the improvement brought by privatization, it has been unable to fully resolve the sector's deeper systemic issues. Figure 5 presents a detailed visual representation of Iraq's electricity sector's organizational structure, including key governmental and private entities such as the federal MoE, KRG MoE, IPPs, and the federal transmission and distribution companies.

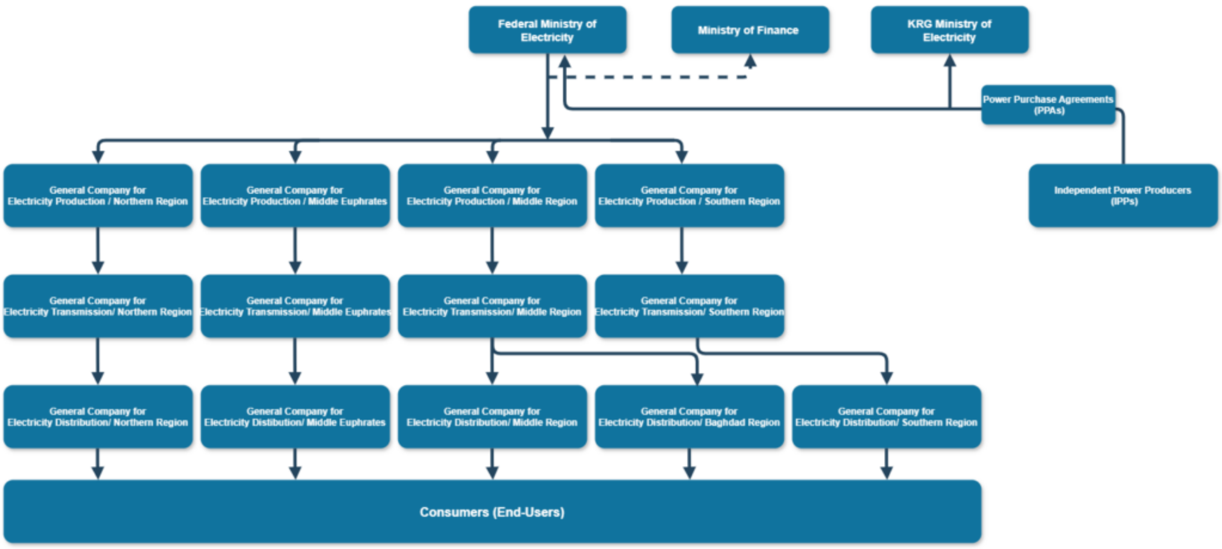


Figure 5 : Organogram of the Main Stakeholders of Iraq's Electricity Sector

The disconnection between the two electricity networks poses many challenges beyond the ongoing contention over resources in the disputed territories. The lack of integration causes inefficiencies, resource underutilization, and supply vulnerabilities. For instance, an interconnected grid allows for smoother demand management. Through robust interconnection between European countries, Europe's energy network efficiently manages varying peak times and demands[24], ensuring a steady electrical flow throughout the year. Lessons from this model, could benefit Iraq and the KRI. Resources like RES can be shared strategically, leveraging the strength of both regions. The current insufficient grid interconnectivity often results in wasted capacity in one region while another endures blackouts, hindering progress toward a sustainable power sector.

Plans and Initiatives for The Power Sector

Despite several agreements and plans, the majority remain unfulfilled. Examining these plans reveals the MoE's acknowledgment of electricity sector's problems and its consideration of interconnection and smart grid adoption, even though these efforts have yet to materialize. The repeated failure to implement most of these plans is testament to the inefficiency of addressing electricity issues in a timely manner.

A source of this predicament is the frequent change in government. With each new administration, established plans are abandoned in favor of new proposals, resetting efforts, and delaying implementation, often beyond the tenure of a single government. Former Prime Minister Mustafa Al-Kadhimi acknowledged this in 2021, noting that resolving Iraq's electricity crisis requires years of consistent action.[25] Al-Kadhimi emphasized that investing in domestic gas production, repairing power transmission and distribution networks, and establishing electricity interconnections with neighboring countries could have mitigated crises.

Timeline of the Major Electricity Sector Agreements

2017-2018

Iran Gas Exports

Iran began exporting gas to Baghdad power plants in 2017 and to Basrah in 2018.[26]

2019

Roadmap for the Electrification of the New Iraq

Iraq signed a $15 billion contract with Siemens for the execution of the project.The Plans aim to reduce energy losses, integrate smart grids, rehabilitate existing power plants, and add 11 GW of generation capacity.[27]

2021

PowerChina Rumaila Plant and TotalEnergies Gas Capturing Project

- PowerChina connected the Rumaila gas-fired combined-cycle power plant to the national grid.[28]
- The gas capturing project includes a deal to construct infrastructures to reduce gas flaring through recovering flared gas from Basrah oil fields.The recovery gas will be fed to the power plants for electricity generation.[29]

2022

Qatar-Iraq Interconnection, Jordan-Iraq interconnection, and Gulf Interconnectivity

- Iraq and Qatar signed an agreement to enhance energy cooperation and diversify Iraq's energy supply.[30]
- Iraq and Jordan laid the groundwork for an interconnection project between the two countries.[31]
- Iraq announced an agreement with Gulf states for electricity interconnection.[32]

Turkmenistan Gas Agreement and Turkish Electricity Imports

- Iraq signed a deal with Turkmenistan for the delivery of 20 million cubic meters of gas daily, via Iran's pipeline network.[33]
- A significant power line was inaugurated, linking Türkiye and Iraq for Turkish electricity imports.[34]

2024

Smart Grids and an Interconnected Network

Balancing electricity production and consumption on a real-time basis is essential for a reliable power system. The complexity of the electricity grid stems from managing faults, providing redundancy to prevent blackouts and re-routing electricity when equipment is out of service, whether planned or otherwise. Making the grid smarter through software, sensors, and communication devices addresses these and many more challenges effectively as depicted in Table 2.

Benefit Category	Benefit Sub-category	Benefit
Economic	Improved Asset Utilization	Optimized Generator Operation Deferred Generation Capacity Investments Reduced Ancillary Service Cost Reduced Congestion Cost
	T&D Capital Savings	Deferred Transmission Capacity Investments Deferred Distribution Capacity Investments Reduced Equipment Failures
	T&D O&M Savings	Reduced Distribution Equipment Maintenance Cost Reduced Distribution Operations Cost Reduced Meter Reading Cost
	Theft Reduction	Reduced Electricity Theft
	Energy Efficiency	Reduced Electricity Losses
	Electricity Cost Savings	Reduced Electricity Cost
Reliability	Power Interruptions	Reduced Sustained Outages Reduced Major Outages Reduced Restoration Cost
	Power Quality	Reduced Momentary Outages Reduced Sags and Swells
Environmental	Air Emissions	Reduced CO_2 Emissions Reduced SO_x, NO_x, and PM-10 Emissions
Security	Energy Security	Reduced Oil Usage Reduced Wide-scale Blackouts

Table 2: Smart Grid Benefits **Source:** EPRI

Smart grid system allows utility providers to optimize electricity generation, transmission, and distribution, while consumers gain insights into their energy usage. Smart grids can expand the limitations of the traditional power systems as illustrated in Figure 6.

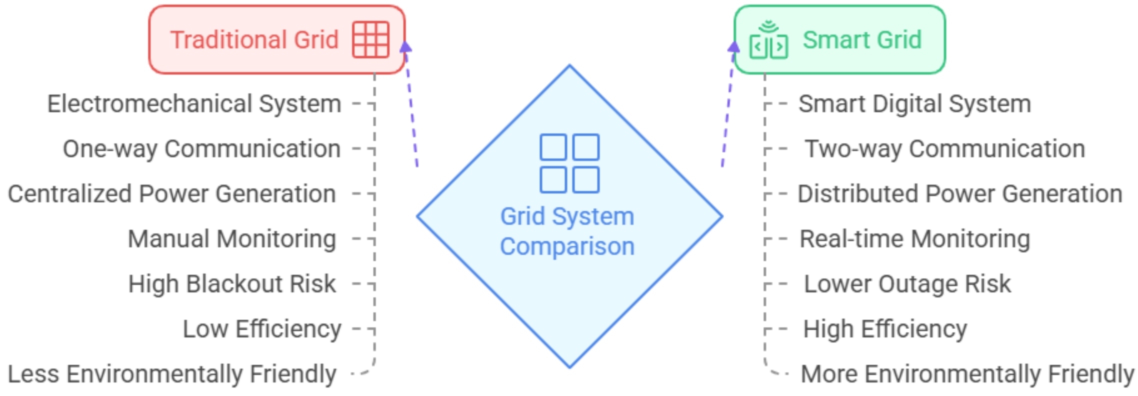


Figure 6: Advantages of Smart Grids over Traditional Grids

For Iraq, replacing the existing distribution network infrastructure is costly and difficult. Instead, a cost-effective alternative is to incorporate smart grid components into the current grid. Therefore, smart grids, are deemed far more effective for Iraq over any other alternative because it can help utilities optimize the distribution network and minimize the high transmission losses, reducing the need for new power generation sources or additional infrastructure investments. Additionally, smart meters can play a pivotal role by streamlining tariff collections, providing Iraq with much-needed fund for grid modernization. While KRG installed a considerable number of smart meters, many were faulty and failed to fulfill their primary purpose of aiding tariff collection. In the traditional grid, consumers do not have a keen understanding of the quantity of power being used or how much it should cost depending on the time of the day/year. Smart grids can take away the obfuscations by making better decisions on how to use electricity in daily lives.

Model Case: A UK distribution system operator's pilot project demonstrates the potential benefits of smart grids. The project aims to improve energy management, optimize network loads, and reduce carbon emissions, saving customers millions of pounds while cutting greenhouse gas (GHG) emissions.[35] This is an instance of smart grid mutual benefit for consumers and the environment that is particularly relevant for Iraq, which faces similar challenges and stands to benefit from such technologies.

In Iraq, the smart energy transition has gained momentum with the backing of Prime Minister Muhammad Shia' al-Sudani. The electricity minister outlined a structured plan for smart grid implementation, including integrated smart meters for accurate real-time readings, reducing electricity theft, and improving transparency and service quality.[36] Another aspect of the plan involves converting overhead lines to underground systems, reducing outages and energy losses while ensuring a stable supply.

The world is witnessing the start of the decentralization of energy production. Smart grid technologies will empower consumers to become active participants in the energy market, enabling them to produce, store and sell energy. While decentralization of electricity production favors the adoption of RES, it is more suitable for Iraq to equip a centralized interconnected distribution network to support this approach. There are many reasons weakening the financial abilities of Iraqi citizen to have self-producing energy equipment and systems. However, once these barriers are overcome, Iraq will be well-positioned to utilize smart grid for decentralized generation, provided that a robust interconnected grid is already established across the country. An interconnected smart grid is expected to reduce the carbon footprint of Iraq's power system by enhancing the management of the power system with high penetration of alternative energy sources.

The 2021 power crisis in Texas underscores the risks of a disconnected grid, when its failure during a severe snowstorm, left 4.5 million[37] households and businesses without power. Iraq should try to prevent such power system failures and prioritize the development of interconnected grids on a national and international scale. A world map of Wide Area Synchronous Grids (WASG) shown in Figure 7, highlights large scale grid interconnections such as Europe with Middle East and North Africa. Smart grid and interconnections are complementary technologies that can work in tandem. For example, Türkiye's connection to the European grid in 2010[38] was achieved through using smart grid technology. Iraq and KRI's disconnected grids, although not displayed on the map due to data unavailability, operate at the same frequency and are compatible for interconnection.

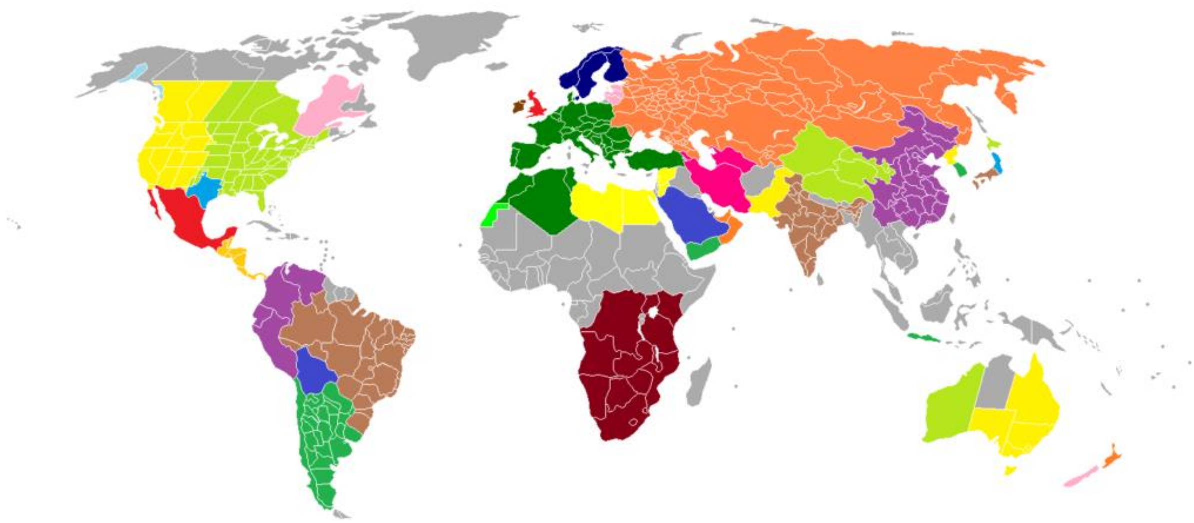


Figure 7: World Map of Interconnected Synchronous Grids **Source:** Wikimedia Commons

Iraq's Smart Grids: Financial Strains and Security Risks

To introduce smart grids into the Iraqi power system, various challenges will be faced, particularly concerns related to understanding the unique features and complexities of this network. Deploying smart grids requires significant upfront costs[39] due to the necessity of its advanced technologies such as smart meters, communication networks, and control systems. Moreover, the benefits of smart grids are not immediately evident, often requiring many years to be fully materialized. This postponed realization can complicate the justification of initial deployment costs for utilities. In developed countries, utilities are typically the primary financiers of smart grids due to their strong investment incentives, as smart grids enhance efficiency. In developing nations, governments usually take the lead in financing these projects, driven by the commitment to improve reliability of delivering services to their deprived communities.

Smart grids face security challenges with the rapid progression of communication technologies. The reliance on modern communication tools such as the internet for transmission and exchange of data, makes smart grids more susceptible to cyberattacks. The consequences of cyberattacks can vary from minor disruptions, such as inaccurate household billings, to catastrophic events, such as a total grid collapse. Cyberattack can take several forms, false data injection attacks aim to manipulate data potentially reducing users cost and misleading operators. Another form, man-in-the-middle attacks, as the name suggests, intercept and manipulate communication between grid devices, enabling attackers to extract sensitive information.[40]

There are also several design and logistical challenges that further complicate the integration of smart grids. Establishing communication infrastructure in remote or geographically challenging areas presents additional difficulties. The telecommunications sector in Iraq falls behind neighboring countries, the fiber optic cable infrastructures for service delivery to subscribers is still under development. Currently, internet services for users rely on Wi-Fi networks, which are prone to interruptions and come with excessive costs. These limitations obstruct the operation of smart grid, which requires a reliable, high-speed, and continuous communication network.

Despite these hurdles, Iraq should not abandon the vision of a nationwide smart grid. While the massive initial costs are inconvenient, the long-term benefits including improved efficiency, reliability, and seamless integration of renewable energy sources, are expected to overtake these expenses. In a cost-benefit analysis formulated in 2011, it was estimated that over the next 20 years, the benefits of the smart grid will exceed its costs.[41] A summary of the estimated costs is attached in Table 3.

	20-Year Total ($billion)
Net Investment Required	338-476
Net Benefit	1,294-2,028
Benefit-to-Cost Ratio	2.8-6.0

Table 3: The Findings from a Smart Grid Cost-Benefit Study (2011-2030) **Source:** EPRI

Furthermore, technological advancements are likely to reduce the component costs over time, and innovative refinancing strategies can help manage the financial burden of smart grid projects. Some international organizations have shown interest in supporting smart grid projects. The World Bank for instance has funded smart grid projects in Mexico and India.[42] Iraq could leverage similar funding opportunities to initiate the deployment of some smart grid technologies.

To mitigate the exposure of smart grids to cyberattacks, Iraqi policymakers must establish governance frameworks to ensure safe, rapid, and secure grid operations. Much like how the internet and smartphones, initially seen as technologies prone to security breaches, are now managed and secured through safeguarding terms and regulations. Data security and privacy should be central to smart meter regulations, requiring power plants, substations, and other utilities to adhere to strict guidelines. Fractions of the investments should target the fortification of the grid's security, ensuring that it remains resilient against cyberattacks.

Conclusion

In conclusion, it is difficult for the traditional grid to meet the evolving energy requirements with the continued rise in the global electricity demand. In this context, smart grids and interconnections are relevant innovations capable of addressing growing energy demand particularly for Iraq. They offer the potential to reduce losses and enhance the resilience of Iraq's national and international grid infrastructure.

The transition to smarter grid system starts with a few cautious steps before scaling up. For meaningful change to occur, the federal MoE, regional MoE and IPPs should foster strong communication and collaboration, engage customers effectively, and implement comprehensive management plans. Although smart grids present a few disadvantages, it is essential for resolving Iraq's electricity issues. Iraq's strategy should begin with the development of a centralized, interconnected smart grid. This can be scaled up by integrating multiple decentralized generation networks that utilize RES, culminating into an interconnected smart grid that transcends national borders.

References

1. IEA. "Iraq's Energy Sector A Roadmap to a Brighter Future." IEA, April 2019. Read More ↩
2. Iraq Energy Institute. "Residential Electricity Subsidies in Iraq: Exploring Options for Reform [Report]." Iraq Energy Institute, March 19, 2020. Read More ↩
3. SAP. "The Smart Grid: How AI Is Powering Today's Energy Technologies," n.d. Read More ↩
4. White Paper. "Privatization of State-Owned Enterprises," April 20, 2022. Read More ↩
5. Cameron. "Iraq's Perennial Electricity Problem and Its Implications for Social Stability." Gulf International Forum, June 10, 2022. Read More ↩
6. "Enabling Iraq's Energy Independence," November 28, 2024. Read More ↩
7. Cameron. "Iraq's Perennial Electricity Problem and Its Implications for Social Stability." Gulf International Forum, June 10, 2022. Read More ↩
8. Kapoor. "Iraq's Drive to Eradicate Gas Flaring Gains Momentum." Oil&Gas MIDDLE EAST, May 17, 2024. Read More ↩
9. Enabling Peace in Iraq Center. "Issue Brief: The Flaring of Natural Gas in Iraq." *Enabling Peace in Iraq Center*, July 5, 2024. Read More ↩
10. Government of Iraq, World Bank, and Mahdi Al-Alaq. "Damage and Needs Assessment of Affected Governorates IRAQ." *Iraq Reconstruction and Investment*, 2018. Read More ↩
11. التقرير الاحصائي السنوي" وزارة الكهرباء." *Ministry of Electricity*, October 14, 2024. Read More ↩
12. Mills, Robin, Maryam Salman, Al-Bayan Center for Planning and Studies, Friedrich-Ebert-Stiftung, Friedrich-Ebert-Stiftung, and Al-Bayan Center for Planning and Studies. *Powering Iraq: Challenges Facing the Electricity Sector in Iraq*. Interview by Friedrich-Ebert-Stiftung and Al-Bayan Center for Planning and Studies. Edited by Friedrich-Ebert-Stiftung and Al-Bayan Center for Planning and Studies, 2020. Read More ↩
13. Obeid. "Iraq Needs Renewables, but They Won't Solve Its Power Problems without Broader Reforms." Middle East Institute, February 21, 2023. Read More ↩
14. Kurdistan Region Statistics Office. "Electric Generators Survey in the Private Sector in Kurdistan Region 2021." *Industry Statistics Department*, 2024. Read More ↩

15. Al-Wakeel. “Local Energy Systems in Iraq: Neighbourhood Diesel Generators and Solar Photovoltaic Generation.” *IntechOpen*, 2020. Read More ↩
16. Obeid. “Iraq Needs Renewables, but They Won’t Solve Its Power Problems without Broader Reforms.” Middle East Institute, February 21, 2023. Reaf More ↩
17. Al-Wakeel. “Local Energy Systems in Iraq: Neighbourhood Diesel Generators and Solar Photovoltaic Generation.” *IntechOpen*, 2020. Read More ↩
18. World Bank (PPIAF) and Ministry of Electricity. “Development of a Reform Roadmap for the Electricity Distribution Sector in Iraq.” *World Bank*, February 25, 2015. Read More ↩
19. Mills, Robin, Maryam Salman, Al-Bayan Center for Planning and Studies, Friedrich-Ebert-Stiftung, Friedrich-Ebert-Stiftung, and Al-Bayan Center for Planning and Studies. *Powering Iraq: Challenges Facing the Electricity Sector in Iraq*. Interview by Friedrich-Ebert-Stiftung and Al-Bayan Center for Planning and Studies. Edited by Friedrich-Ebert-Stiftung and Al-Bayan Center for Planning and Studies, 2020. Read More ↩
20. aenert. “Energy Industry in Iraq.” *Aenert*, December 16, 2024. Read More ↩
21. Ersoy, Sibel Raquel, and Julia Terrapon-Pfaff. “SUSTAINABLE TRANSFORMATION OF IRAQ’S ENERGY SYSTEM.” *FRIEDRICH-EBERT-STIFTUNG*, May 2021. Read More ↩
22. Altai, Theyab Abd, Lazim, and TH. Salim Alrikabi. “Analysis of the Problems of Electricity in Iraq and Recommendations of Methods of Overcoming Them.” ResearchGate, February 2022. Read More ↩
23. Aldarraji, Vega-Márquez, Pontes, Mahmood, and Riquelme. “Addressing Energy Challenges in Iraq: Forecasting Power Supply and Demand Using Artificial Intelligence Models.” *Science Direct*, February 29, 2024. Read More ↩
24. Commission Expert Group on electricity interconnection targets. “Towards a Sustainable and Integrated Europe: Report of the Commission Expert Group on Electricity Interconnection Targets,” November 2017. Read More ↩
25. RASANAH. “The Ramifications of Iraq’s Electricity Crisis and the Iranian Dimension.” *RASANAH*, July 15, 2021. Read More ↩

26. Khajehpour. “Deep Dive: The Significance of Iran-Iraq Energy Swaps.” Amwaj.media, July 29, 2023. Read More ↩

27. Salih. “Iraq’s Bid for Sustainable Economic Growth Starts with Electricity.” Siemens Energy, September 21, 2020. Read More ↩

28. People’s Daily. “POWERCHINA Aids Iraq Reconstruction, Development.” POWERCHINA, March 23, 2023. Read More ↩

29. Kareem. “Empowering Iraq: The $27 Billion Deal for Iraq’s Energy Sufficiency.” Foreign Policy Research Institute, September 12, 2023. Read More ↩

30. Shokri. “Strengthening Energy Security: The GCC-Iraq Electrical Interconnection Project.” Gulf International Forum, July 24, 2023. Read More ↩

31. Al-jnaidi. “Iraq Says Power Link with Jordan Ready.” AA, September 30, 2023. Read More ↩

32. SaudiPedia. “Electricity Interconnection Project with Iraq.” Saudipedia, December 6, 2024. Read More ↩

33. Shafaaq News. “Iraq’s Power Sector: Domestic Shortfalls and International Supply Constraints - Shafaq News.” *Shafaq News*, December 4, 2024. Read More ↩

34. Shokri. “Powering up: Turkey-Iraq Transmission Line Is Part of a Broader Strategic Shift.” Middle East Institute, August 7, 2024. Read More ↩

35. SAP. “The Smart Grid: How AI Is Powering Today’s Energy Technologies,” n.d. Read More ↩

36. Iraqi News Agency. “Electricity Minister Oversees Smart Grid Transformation Contracts for Central and Northern Iraq,” October 23, 2024. Read More ↩

37. Kluge. “Political, Economic, and Environmental Concerns for the Texas Power Grid – Michigan Journal of Economics,” October 31, 2024. Read More ↩

38. “Türkiye to Connect with the European Grid, Expanding Energy and Economic Opportunities,” September 2, 2010. Read More ↩

39. Günther, Reinhard. “The Economics: How Can Smart Grids Be Financed?” CLOU GLOBAL, April 27, 2023. Read More ↩

40. Khalel, Ismaeel, Hikmat Aziz, and Abdulrhman Al-Flaiyeh. "Smart Grid Application in the Iraqi Power System: Current and Future Challenges." *ResearchGate*, December 2022. Read More ↩

41. Feng, Zhang, and Gao, eds. *Real Options Analysis for Smart Grid*. *The 16th Annual International Conference*, 2015. Read More ↩

42. Günther, Reinhard. "The Economics: How Can Smart Grids Be Financed?" CLOU GLOBAL, April 27, 2023. Read More ↩

ABOUT

Nestled in the mountains of Sulaymaniyah, the Culture Capital of KRI, iNNOV8 Research Center pioneers cutting-edge research and innovation. We aspire for excellence as an independent research center by providing valid, valuable, and timely products to the public. We deliver impactful solutions and contribute to our industry’s vibrant and forward-thinking community. As an affiliate of CHANNEL8 Media Corporation, iNNOV8 also serves as the in-house research and public relations hub for the channel.

IRAQ'S ELECTRICITY CRISIS : COULD INTERCONNECTED SMART GRID BE THE ANSWER?

iNNOV8

CONTACT

CHANNEL8 BUILDING,

KURDSAT QTR., SULAYMANIYAH, IRAQ

+964-773-608-8885

INNOV8@CHANNEL8.MEDIA