Optimization of Data Center Siting in Saudi Arabia for Future Energy Mix Planning

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Abstract

Efficient planning is necessary to ensure sustainable energy utilization with the rapid expansion of data centers and the increasing need for a reliable digital infrastructure. This project is intended to optimize the siting of data centers in Saudi Arabia by evaluating suitable locations and evaluating potential energy mix scenarios using the PLEXOS modeling platform. In the first phase of the project, a first PLEXOS model skeleton was developed and the data sets required were collected and organized, including electricity demand, power generation technologies, renewable energy resources and energy mix data. These early results lay the groundwork for future model implementation, scenario analysis and optimization. The project is expected to support informed decisions for the sustainable deployment of data centers aligned with Saudi Vision 2030

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1 Introduction

The rapid expansion of digital services, cloud computing, and artificial intelligence has significantly increased the demand for data centers worldwide. As critical digital infrastructure, data centers require a continuous and reliable electricity supply to ensure uninterrupted operation. However, their high energy consumption makes site selection and energy planning essential for minimizing operational costs, improving energy efficiency, and supporting sustainability goals.

Saudi Arabia is experiencing a rapid digital transformation, driven by Vision 2030 and increasing investments in cloud computing, smart cities and digital infrastructure. The Kingdom is also accelerating digital transformation of government and private sector services including e-government platforms, healthcare systems, financial services and smart city applications. These initiatives are creating ever more digital data and demand for secure, reliable and locally hosted data centre infrastructure. The expected expansion of data centers all over the Kingdom has made the identification of suitable locations with reliable and sustainable energy sources an important planning challenge. The selection of a suitable site is a function of many factors, including electricity demand, available generation resources, renewable energy potential, and the existing energy mix.

The project aims to optimize data center siting in Saudi Arabia by combining energy system analysis with the PLEXOS energy modeling platform. The project is evaluating potential sites and exploring different energy mix scenarios to support decision making. In the first phase of the project, the initial PLEXOS model skeleton was built, and the necessary datasets (electricity demand, generation technologies, renewable energy resources and energy mix data) were compiled and organized. These activities set the stage for subsequent model implementation, simulation, and optimization.

2 Methodology

This study applies an optimisation-based approach to determine the optimal siting region of a data centre in Saudi Arabia, considering the future energy mix and regional power system characteristics. The methodology consists of the following key steps:

2.1 Data Collection

Taking advantage of national open data such as KAPSARC, Saudi Energy, SERA and the Ministry of Energy. The needed data for building the PLEXOS model was collected based on the year 2024-2025, including: (2024-2025 Saudi regional Energy Consumption, Energy mix per region, Heat Rates, variable operation and maintenance (VOM), fixed operational maintenance (FOM) and Saudi Energy Tariff for cloud computing). As well as a report with all needed information of

a well-known Data Centre (Meta Data Centre) which is based in Canada.

Table 1 Energy mix per region data.

REGION/ TYPE	SOLAR (MW)	WIND (MW)	OIL (MW)	GAS (MW)	TOTAL
EAST	400	0	11,062	15,942	27404
MIDDLE	3111	0	14,371	24,156	41638
WEST	5,160	416	16,724	9100	31400
NORTHERN	500	400	0	0	900

2.2 Regional Classification

Saudi Arabia was divided into six operational regions (Nodes): Central (COA), Eastern (EOA), Western (WOA), Southern (SOA), North Eastern (NEOA), and North Western (NWOA). Each region (Node) was characterized by its specific hourly demand profile, available conventional and candidate generation technologies, and local renewable energy potential (solar PV and wind).

2.3 Model Development in PLEXOS

The basic Foundation of the model was built and uploaded to the cloud. Then shared with the Group members. In addition, four generators were created for the available energy mix (Oil, Gas, Solar, Wind), and their properties.

2.4 Regional Demand Data Development

The electricity demand data were prepared for each region using the provided Regional Load Template. The annual demand profile and corresponding hourly load data were organized according to the required year, month, day, and hourly structure. This step was performed to establish the detailed demand profiles required for the regional representation of the Saudi Arabian power system in PLEXOS.

2.5 Regional Load Allocation

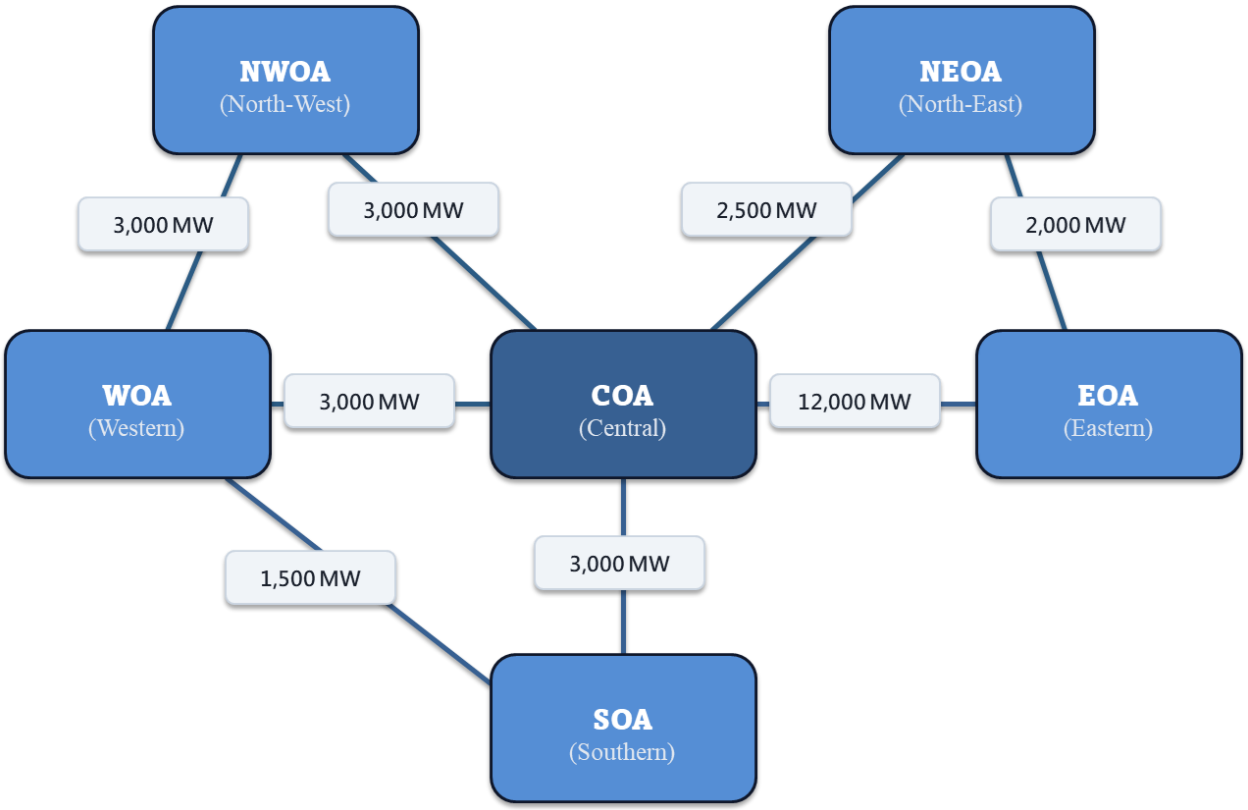
The total electricity load of the Kingdom was distributed among the different regions based on the specified Load Participation Factor for each region. These factors were applied to the national demand profile to estimate the corresponding electricity demand for each region while maintaining consistency with the overall system demand. This approach provides a regional representation of the load that can be incorporated into the PLEXOS model.

2.6 Transmission Corridors and Interconnections

To capture how electricity moves between regions, the model includes eight main transmission corridors connecting the six regional nodes. As shown in the network layout, the Central Operating Area (COA) functions as the central hub of the grid, with power lines linking it to all surrounding regions alongside specific inter-regional connections.

Key aspects of the transmission setup include:

- Central Links: The main power link is between the Eastern and Central regions (EOA–COA) with a transfer capacity of 12,000 MW, allowing large amounts of power to flow into the central demand area.
- Other corridors linking COA to the West, South, and Northern regions (WOA, SOA, NEOA, and NWOA) handle between 2,500 MW and 3,000 MW.
- Direct Regional Connections: Specific lines also connect neighboring regions directly such as WOA–SOA (1,500 MW), EOA–NEOA (2,000 MW), and WOA–NWOA (3,000 MW) to allow direct power transfers without routing everything through the center.



2.7 Generator Data Preparation

Generator data were compiled and organized for each region to support the development of the regional generation model. The collected information included the generator name, generation technology/type, and associated region. The generator information was structured according to the required PLEXOS input format to facilitate the subsequent integration of generation resources into the model.

Furthermore, a comprehensive dataset comprising approximately 66 power generation plants across the Kingdom was integrated. This dataset encompasses critical technological, operational, and financial parameters for each plant, including Capacity (MW), Heat Rate, Fixed Operation and Maintenance (FOM), Variable Operation and Maintenance (VOM), Minimum Stable Level (MSL), Minimum Up Time (MUP), and Minimum Down Time (MDT).

To fulfill the specific input requirements of the PLEXOS modeling platform, two key operational parameters were mathematically derived from the raw dataset:

Total Start Cost ($): Calculated by multiplying the total Capacity (MW) of the plant by its specific Startup Cost ($/MW).

Run Up / Run Down Rate (MW/min): Derived by multiplying the plant's Capacity (MW) by its Ramp Rate (% Capacity/Min). For the purpose of this system modeling, the Run Up and Run Down rates were assumed to be symmetrical and assigned identical values.

These derived parameters are crucial for accurately simulating generator flexibility, operational constraints, and unit commitment costs within the optimization model.

To illustrate the practical implementation of the dataset, Figure 1 displays the regional hierarchical structure of the power plants within the PLEXOS modeling environment, taking the Eastern Operating Area (EOA) as a primary example.

Figure 1: *PLEXOS system tree illustrating the regional classification of generators, highlighting the Eastern Operating Area (EOA)*

Furthermore, Figure 2 demonstrates the successful integration of the calculated operational and financial parameters into the PLEXOS properties interface, taking the Ras Al-Khair SWCC power plant as an applied example

Figure 2: *PLEXOS properties tab displaying the configured parameters (e.g., Start Cost, Run Up/Down Rates, and Min/Max Capacity) for the Ras Al-Khair SWCC power plant*

In addition to baseline generating assets, regional expansion candidate generators were integrated to allow the model to dynamically evaluate long-term capacity expansion options under future load growth scenarios. The modeling and parameterization of these candidate units were established as follows:

- **Asset Benchmarking:** Operational, technical, and cost parameters—including technology type, heat rate, and variable operating costs—were mirrored directly from each region's highest-capacity existing power plant.

- **Capacity Sizing:** The candidate capacity for each region was set to twice the capacity of the corresponding reference generator.

- **Regional Minimum Thresholds:** Specific capacity baselines were enforced according to regional demand scale:

    - **Large-Demand Regions (EOA and COA):** Configured with a minimum expansion capacity threshold of **10 GW**.
    - **Smaller-Demand Regions (NEOA, NWOA, and SOW/SOA):** Configured with a minimum expansion capacity threshold of **5 GW**.

- **Endogenous Build Optimization:** All expansion candidate generators were initialized with zero existing units (Units = 0), enabling the PLEXOS optimization solver to endogenously trigger new capacity additions based on capital investment costs, transmission limits, and system reliability requirements.

Table 2 *Summary of Regional Expansion Candidate Generators and Baseline Benchmark Parameters.*

Region	Candidate Generator Name	Reference Plant	Reference Capacity (MW)	Configured Capacity (MW)	Primary Fuel	Technology
EOA	Expansion Candidate Generator EOA	Ghazlan	4,256	10,000	Crude Oil	ST
COA	Expansion Candidate Generator COA	PP9	5,980	11,960	Crude Oil	OC
WOA	Expansion Candidate Generator WOA	Shoaiba CC	6,531	13,062	HFO	CC
SOA	Expansion Candidate Generator SOA	Jazan IGCC	3,600	7,200	HFO	CC
NEOA	Expansion Candidate Generator NEOA	Waad Alshamal ISCC	1,390	5,000	Gas	CC
NWOA	Expansion Candidate Generator NWOA	Tabuk	744	5,000	HFO	OC

2.8 Energy Storage Modeling

Battery Energy Storage Systems (BESS) were integrated into the model to provide essential flexibility, peak shaving, and energy shifting capabilities across different operating regions. A total storage fleet of **9,950 MW** rated discharge power and **42,300 MWh** rated energy capacity was modeled across phased deployment timelines from 2024 through 2029.

Key characteristics of the modeled storage fleet include:

- **Duration Sizing:** All planned BESS units feature multi-hour storage durations, ranging primarily between 4-hour (e.g., 500 MW / 2,000 MWh) and 5-hour configurations (e.g., 500 MW / 2,500 MWh), optimized for daily renewable integration and evening peak support.
- **Regional Allocation:** The storage assets are distributed strategically across the nodes, with substantial initial allocations in the Southern (SOA), Central (COA), and

Western (WOA) operating areas to alleviate local network congestion and enhance grid reliability.

As outlined in Table 3, the storage assets are phased across regional nodes between 2024 and 2029.

Table 3: *Summary of Modeled Battery Energy Storage Systems (BESS) by Operating Area*

Operating Area (Node)	Total Power (MW)	Total Energy Capacity (MWh)	Target Commissioning Window
SOA (Southern)	2,950	12,300	2024 – 2027
WOA (Western)	3,500	15,000	2027 – 2029
COA (Central)	3,000	13,000	2027 – 2029
EOA (Eastern)	500	2,000	2029
Total Fleet	**9,950**	**42,300**	**2024– 2029**

2.9 Fuel and Emission Parameters

Thermal generators in PLEXOS were modeled using four fuel types to capture variable operational costs and total system emissions: Heavy Fuel Oil (HFO), Crude Oil, Natural Gas, and Diesel.

- **Fuel Pricing and Merit Order:** Fuel commodity costs determine the variable generation costs and plant dispatch sequence. Heavy Fuel Oil has the lowest base price at 0.60 US$/MMBtu, followed by Crude Oil at 1.144 US$/MMBtu and Natural Gas at 1.250 US$/MMBtu, while Diesel serves as the highest-cost peaking fuel at 2.410 US$/MMBtu.

- **Emission Rates:** Specific carbon factors were applied to evaluate greenhouse gas output across simulated dispatch intervals. Natural Gas exhibits the lowest carbon intensity at 59.10 kg/MMBtu, while liquid fuels produce higher emissions, reaching 77.50 kg/MMBtu for Crude Oil and peaking at 85.90 kg/MMBtu for Heavy Fuel Oil.

The baseline prices and emission parameters applied in the model are summarized in Table 4

Table 4: *Baseline Fuel Prices and Emission Production Factors.*

Fuel Type	Price	Emission Factor	Price	Emission

	(US$/MMBtu)	(kg/MMBtu)	($/GJ)	Factor (kg/GJ)
Heavy Fuel Oil (HFO)	0.600	85.90	0.569	81.417
Crude Oil	1.144	77.50	1.084	73.456
Natural Gas	1.250	59.10	1.185	56.016
Diesel	2.410	78.00	2.284	73.930

2.10 Data Center Demand Integration

To evaluate the grid impacts of large-scale digital infrastructure and assess spatial siting trade-offs, dedicated data center loads were incorporated into the model across all six regional nodes (COA, EOA, NEOA, NWOA, SOA, and WOA).

Empirical Sizing Benchmark: A uniform continuous capacity of 120 MW was selected based on reported operational demands of major hyperscale facilities (e.g., Meta's Altoona facility averaging ~142 MW), modeled as a non-flexible baseload profile (100% capacity factor) [1].

Spatial Siting Methodology: Standardizing the capacity across all regions provides a neutral baseline to compare network hosting capacity, transmission constraints, and local generation costs.

Network Stress Testing: Adding 120 MW to each regional node evaluates local grid stability and renewable energy utilization without overloading the regional network infrastructure.

Table 5 summarizes typical hyperscale data center electricity demands used to benchmark the modeled load capacity.

Table 5: Operational Electricity Demand Benchmarks for Hyperscale Data Centers [1].

Company	Data Center / Location	Electricity Consumption (MWh)	Average MW
Google	Council Bluffs, Iowa	3,915,416	446.97
Meta	Altoona, Iowa	1,243,306	141.93
Apple	Mesa, Arizona	488,000	55.71

3 Scenarios & Results

3.1 Scenario Definition and Baseline Rationale

To systematically evaluate the impact of large-scale data center (DC) integration on the Saudi electricity system, a comparative simulation framework was established in PLEXOS consisting of a benchmark baseline and six distinct regional deployment scenarios.

Baseline Scenario Rationale

- **Reference Benchmark:** The Baseline (No DC) case represents standard grid operations without additional data center loads. It reflects projected domestic demand growth, planned generation unit commitments, and existing transmission capacities.
- **Control Counterfactual:** Simulating this scenario establishes the baseline system marginal prices (5,274 USD/MWh), total system emissions (170.47 Mt CO2), and regional import/export dynamics required to isolate the exact marginal impact of newly added loads.

Regional Siting Scenarios To determine the optimal geographic location for future data center capacity, six regional scenarios were constructed by allocating the incremental data center demand into individual operating zones:

- **Central Operating Area (COA):** High domestic load center with major urban demand.
- **Eastern Operating Area (EOA):** Heavy industrial baseline with high local generation capacity.
- **North-East Operating Area (NEOA):** Developing regional corridor.
- **North-West Operating Area (NWOA):** Emerging zone with high planned renewable penetration.
- **Southern Operating Area (SOA):** Interconnected peripheral region.
- **Western Operating Area (WOA):** High population center with strategic coastal connectivity.

Evaluating these cases under identical operational constraints allows direct comparison of transmission congestion (Delta LMP), system-wide marginal costs, regional power balances, and carbon footprint variations across Saudi Arabia.

3.2 Regional Power Balance and Interconnection Flows

The integration of concentrated data center loads across different regions shifts the net power exchange dynamics across the transmission network. Figure 3.1 illustrates the annual net export (positive values) and net import (negative values) for each operating area across the evaluated siting scenarios.

Key Observations and Flow Dynamics:

Heavy Exporters and Import Sinks: Across all scenarios, the Eastern Operating Area (EOA) functions as the primary power deficit/import sink (importing between -83.5 TWh and -89.4 TWh), while the Southern (SOA) and Western (WOA) operating areas serve as dominant net power exporters, supplying over +30 TWh to +36 TWh to the national grid.

Central Area Transition: The Central Operating Area (COA) maintains a positive net export position (+13.3 TWh to +19.8 TWh) under standard baseline and western/southern siting

cases, supporting inter-regional power flow.

Impact of Localized Siting:

Siting data centers in the Eastern Operating Area (EOA) maximizes its net import deficit to its peak (-89.4 TWh), forcing additional reliance on long-distance transmission corridors from western and southern assets.

Siting loads in the North-West Operating Area (NWOA) shifts its local balance from near-equilibrium (+8.0 TWh) down to a net import position of -13.3 TWh, absorbing local generation and requiring power transfers from adjacent zones.

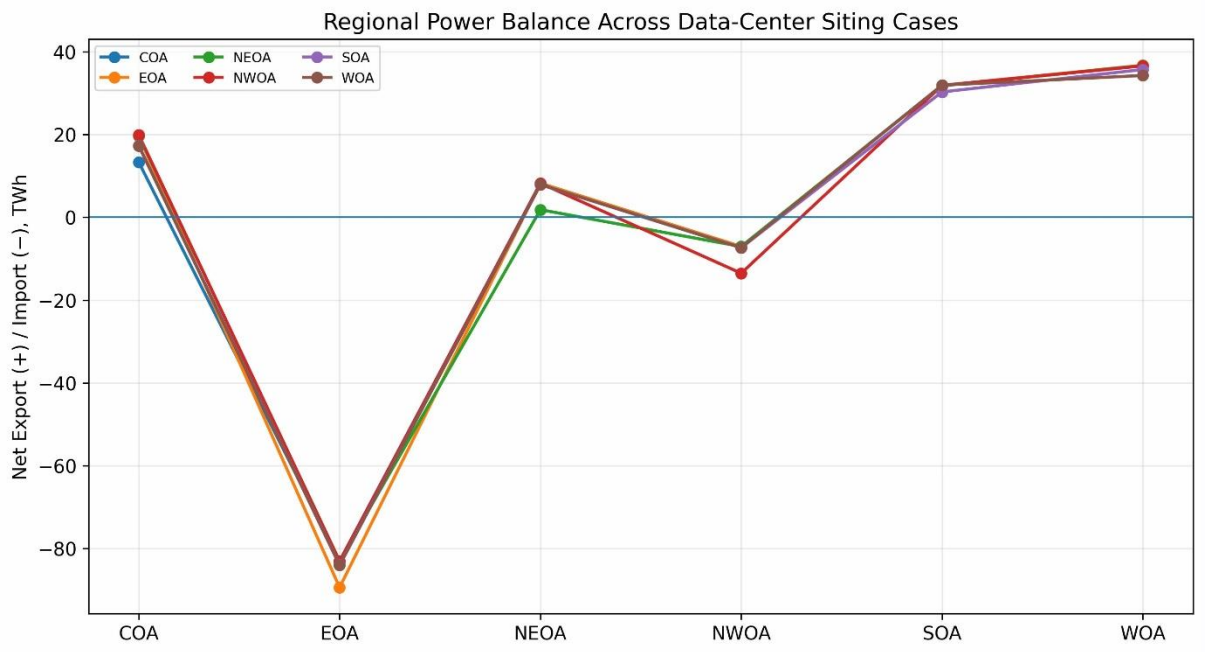


Figure 3.1: Simulated regional net power export and import balances across Saudi operating areas for each data center siting scenario.

3.3 Transmission Congestion and Nodal Price Variations

Transmission congestion occurs when power transmission lines reach their physical thermal capacity limits, causing locational marginal price (LMP) divergences across network nodes. The transmission congestion index is measured by the nodal LMP price spread (maximum LMP minus minimum LMP) across the network. Figure 3.2 illustrates the congestion index across all evaluated siting scenarios.

Key Findings and Bottleneck Dynamics:

- **Optimal Siting Locations:** The Western Operating Area (WOA) achieves the lowest transmission congestion at 1,793.5 USD/MWh, even outperforming the Baseline scenario (1,808.8 USD/MWh). This indicates that co-locating data center demand in the Western region absorbs localized surplus generation directly, relieving stress on export transmission corridors. The Southern Operating Area (SOA) closely follows with a low congestion level of 1,809.1 USD/MWh.

- **High-Congestion Corridors:** Siting data centers in the Central (COA), North-East (NEOA), and North-West (NWOA) areas results in severe transmission congestion, with the LMP price spread climbing steeply to 1,934.4 USD/MWh (an increase of over 125 USD/MWh relative to the Baseline). The Eastern Operating Area (EOA) exhibits comparable congestion at 1,932.4 USD/MWh.
- **Transmission Bottlenecks:** Placing massive continuous loads in COA, NEOA, NWOA, or EOA forces expensive remote generation dispatch across constrained inter-regional corridors, significantly magnifying transmission price differentials across the Kingdom.

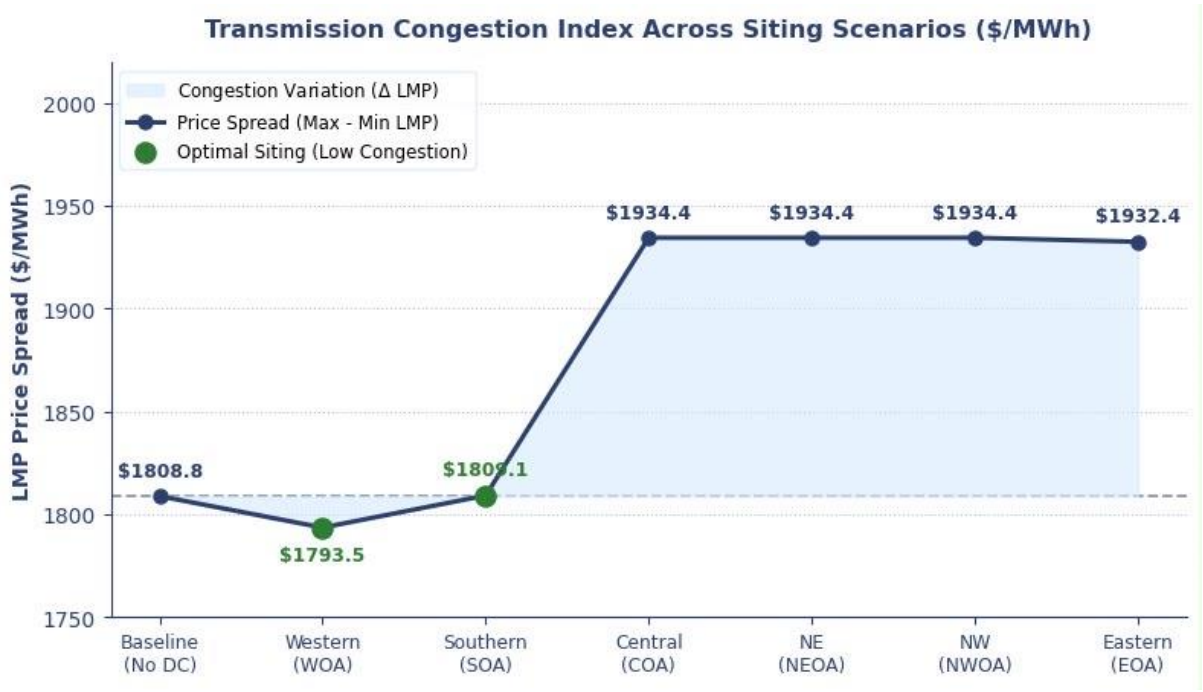


Figure 3.2: Transmission congestion index and LMP price spread (Max - Min LMP) across regional data center siting scenarios.

3.4 Total System Carbon Emissions Trajectory

Evaluating the environmental footprint of data center expansion is critical for ensuring alignment with Saudi Vision 2030 and national net-zero decarbonization goals. Figure 3.3 illustrates the total annual carbon emissions (Mt CO_2) and the incremental emissions induced across the different siting scenarios compared to the benchmark.

Key Emissions Insights:

- **Baseline Reference:** The Baseline scenario (No DC) establishes the minimum system emissions level at 170.47 Mt CO2.
- **Low-Carbon Siting Advantages:** Siting data centers in either the Western Operating Area (WOA) or Southern Operating Area (SOA) results in the lowest system emissions increase, capping total carbon output at 172.47 Mt CO2 (an incremental addition of only 2.00 Mt CO2). This efficiency stems from the immediate integration of local low-carbon and flexible generation assets without incurring transmission-loss penalties.
- **High-Emissions Siting Penalties:** Locating data centers in the Central (COA), Eastern (EOA), North-East (NEOA), or North-West (NWOA) areas drives total emissions up to 172.95–172.96 Mt CO2 (an incremental addition of nearly 2.49 Mt CO2). This higher environmental cost is driven by the dispatch of less efficient thermal assets and increased line losses required to wheel power across long distances.

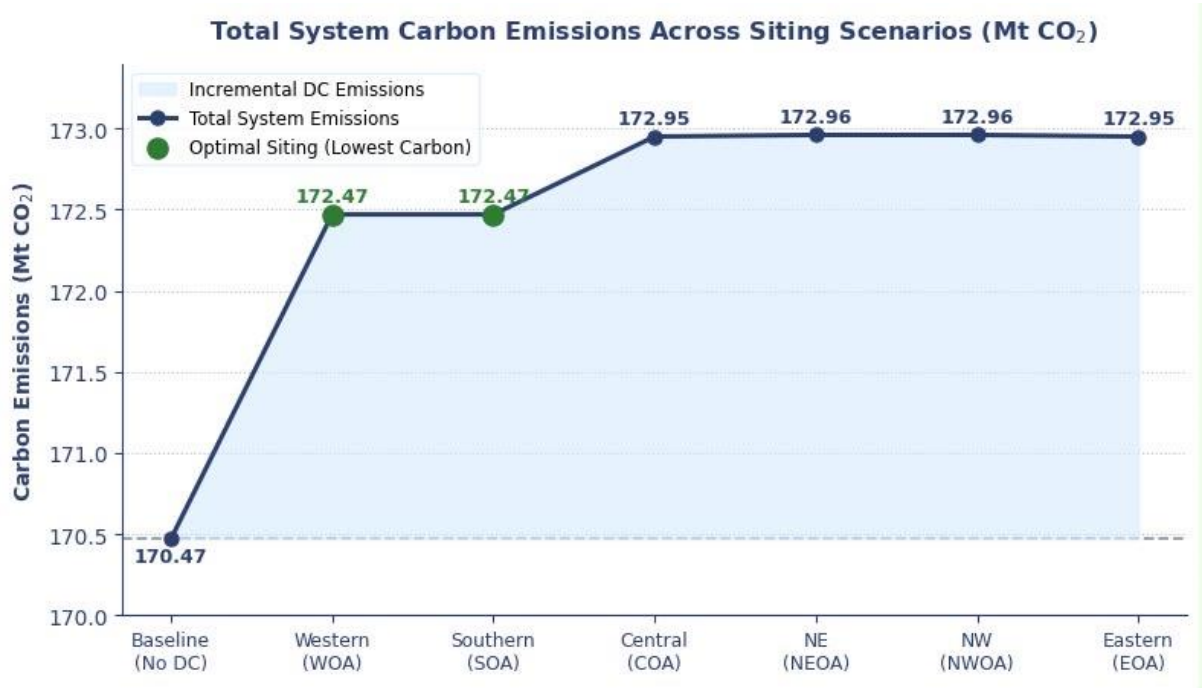


Figure 3.3: Total system carbon emissions and incremental emission variations across regional data center siting scenarios.

3.5 Economic Impact: System Marginal Price and Generation Costs

The economic viability of regional data center integration is evaluated through two key metrics: the Average System Marginal Price (SMP) and the Total System Generation Cost.

Figure 3.4 and Figure 3.5 illustrate the comparative economic performance across all siting scenarios.

System Marginal Price Dynamics:

- **Benchmark Cost:** The Baseline scenario (No DC) maintains an average SMP of 5,274 USD/MWh.
- **Economically Favorable Siting:** Integrating data centers into the Western Operating Area (WOA) yields the lowest wholesale market price impact at 5,304 USD/MWh (a modest increase of 30 USD/MWh over the baseline). The Southern Operating Area (SOA) follows closely at 5,330 USD/MWh.
- **Marginal Cost Escalation:** Siting loads in the Central (COA), North-East (NEOA), North-West (NWOA), or Eastern (EOA) regions drives the average SMP up to 5,405–5,406 USD/MWh (an increase of over 130 USD/MWh). This escalation reflects the frequent commitment and dispatch of expensive peaker units to meet remote localized demand.

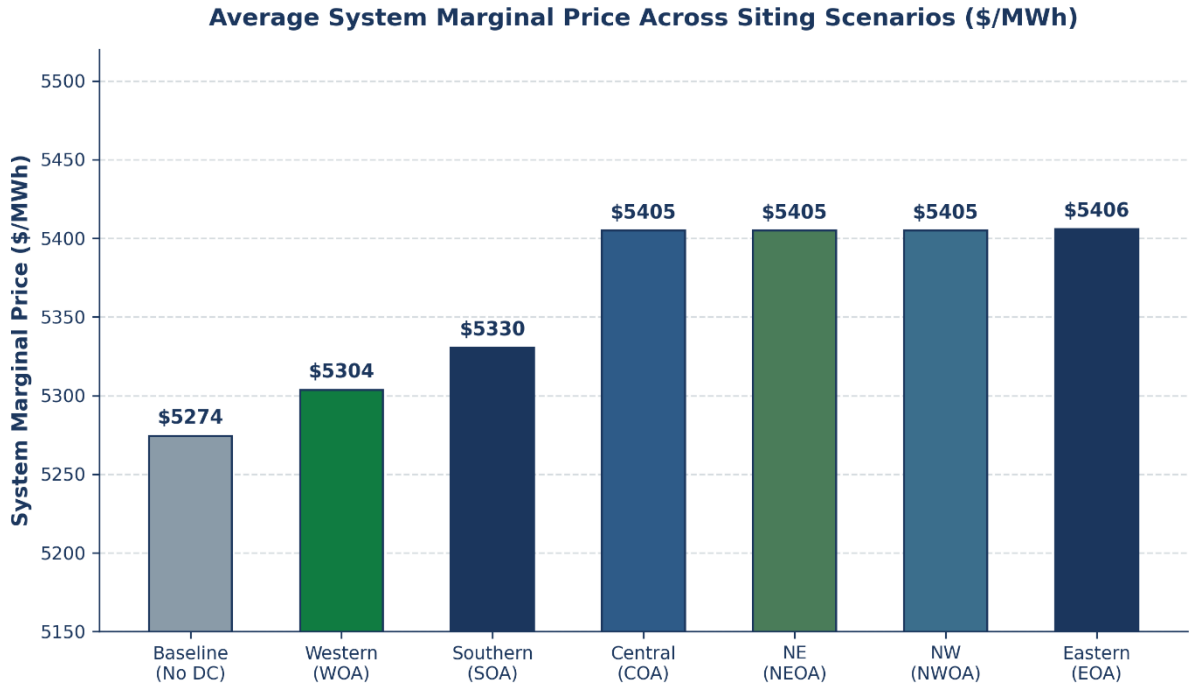


Figure 3.4: *Average system marginal price (SMP) across regional data center siting scenarios.*

Total Generation Cost Analysis:

- **Baseline Expenditure:** Total system generation cost in the Baseline (No DC) scenario stands at 825.2 Billion USD.
- **Cost Minimization in Western and Southern Zones:** The Western deployment scenario achieves the lowest overall system generation cost among all DC integration cases at 851.2 Billion USD, followed by the Southern scenario at 851.7 Billion USD.
- **System-Wide Cost Penalty:** Allocating data center loads across COA, NEOA, NWOA, or EOA results in identical maximum system costs of 861.8 Billion USD. Siting outside the Western and Southern zones imposes an unnecessary operational premium of approximately 10.1 to 10.6 Billion USD on the national grid due to transmission losses and inefficient thermal generation dispatch.

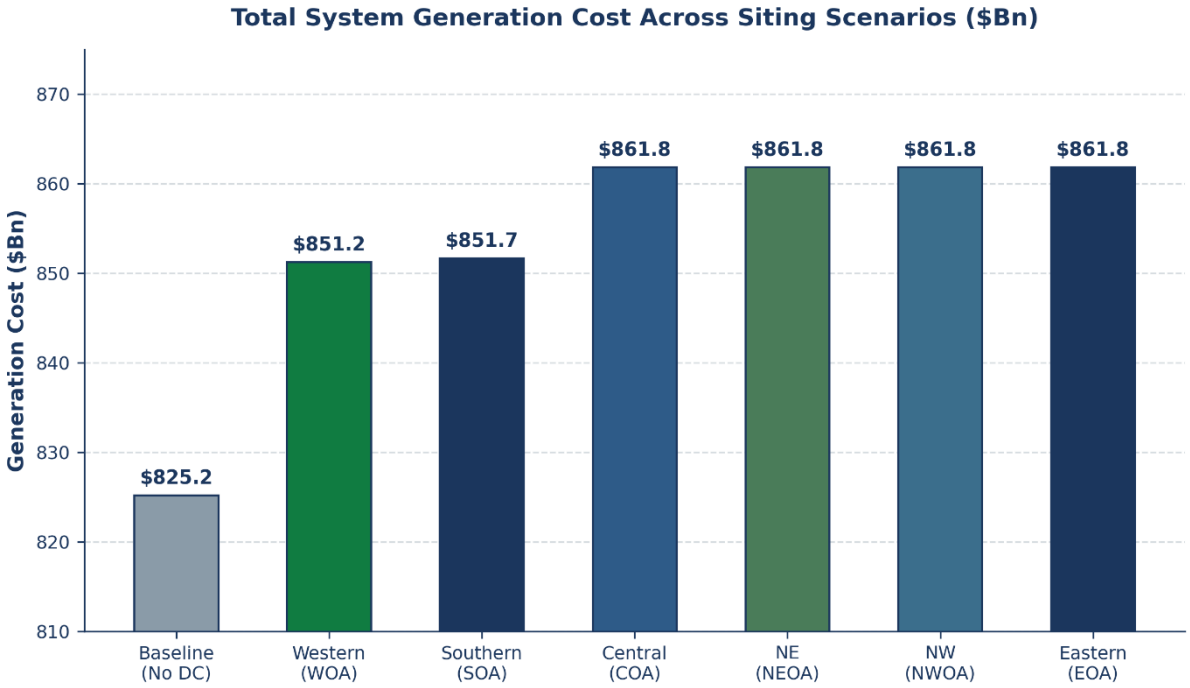


Figure 3.5: *Total system generation cost across regional data center siting scenarios.*

3.6 Siting Decision Synthesis and Key Recommendations

Across all evaluated operational, environmental, and economic metrics, the Western Operating Area (WOA) emerges as the optimal strategic location for large-scale data center deployment in Saudi Arabia.

Congestion Mitigation: Deploying data centers in the Western region achieves the lowest transmission congestion across the network (1,793.5 USD/MWh), outperforming even the Baseline case by absorbing local surplus generation directly and eliminating transmission bottlenecks.

Economic Efficiency: The Western scenario minimizes the system-wide economic burden, delivering the lowest Average System Marginal Price (5,304 USD/MWh) and the lowest Total Generation Cost (851.2 Billion USD)—saving over 10.6 Billion USD compared to Central, Eastern, or Northern siting alternatives.

Environmental Alignment: Co-locating data center infrastructure in the Western zone yields the lowest incremental carbon footprint (172.47 Mt CO2), fully supporting Saudi Vision 2030 decarbonization and energy efficiency mandates.

Therefore, prioritizing the Western Operating Area for digital infrastructure expansion maximizes national grid reliability, minimizes operational expenditure, and accelerates sustainable energy transition goals.

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Refrences

[1] OpenStreetMap Contributors, “OpenStreetMap,” OpenStreetMap Foundation, Open Database License (ODbL) 1.0.

[2] Saudi Electricity Regulatory Authority, Annual Statistical Booklet for Electricity, Saudi Arabia.

[3] Saudi Press Agency (SPA), “Saudi Arabia’s energy and electricity sector,” Saudi Press Agency. SPA

[4] Saudi Arabia Open Data Platform, “Open Data Platform,” Kingdom of Saudi Arabia. Saudi Arabia Open Data Platform

[5] F. M. Khan, B. F. Bargaan, and M. S. AlRasheed, “Operational Challenges Associated with Integration of One Solar & One Wind Plant in Weak Part of SEC Grid: A Case Study for Northern Operating Area,” Saudi Energy, 2024.

[6] Saudi Ministry of Energy, “Energy Mix Policies,” Kingdom of Saudi Arabia.

[7] A. de Vries-Gao, “The carbon and water footprints of data centers and what this could mean for artificial intelligence,” Patterns, vol. 7, no. 1, 2026.