# Greenhouse Gas Emission Estimation and Carbon Footprint Assessment Report

## Rabigh -3-IWP (SWRO Desalination Plant)

## May 2025~June 2025

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# Abstract

This report assesses the greenhouse gas (GHG) emissions and carbon footprint of the Rabigh -3 Seawater Reverse Osmosis (SWRO) Desalination Plant, a 600,000 $m^3d^{-1}$ facility at Rabigh, Saudi Arabia. Following the Greenhouse Gas Protocol (GHGP), ISO 14064-1:2018, and IPCC Guidelines, the analysis covers Scope 1 (direct emissions-1.09%), Scope 2 (indirect emissions from electricity-98.44%), and selected Scope 3 (other indirect emissions) sources. The total annual

carbon footprint is approximately 358,897.6 t $CO_2$ e, with an emission intensity of 1.79 kg $CO_2$ e/$m^3$, aligning with industry benchmarks for SWRO plants with energy recovery devices (ERDs). Scope 2 emissions dominate (98.44%), driven by grid electricity consumption, while the $CO_2$ recovery plant is the primary Scope 1 contributor. This assessment provides a foundation for strategic emission reduction initiatives that align with Saudi Vision 2030 sustainability goals, including renewable energy integration, energy efficiency improvements, and $CO_2$ recovery plant optimization. The implementation roadmap outlines short, medium, and long-term strategies to achieve significant carbon intensity reductions by 2030.

## OVERVIEW

Rabigh -3 Company is a desalination plant owned by 70% ACWA Power and 30% Saudi brothers' commercial company Rabigh SWRO -3 with a capacity of 600,000 m3/d of potable water Output using Reverse Osmosis (SWRO) technology. This project located in the Rabigh area (approximately 150 km north of Jeddah), in the western region of KSA. The Plant will be structured as a standalone IWP and will be developed by the Owner.

The proposed SWRO plant includes the following main facilities:

- Seawater intake.
- Effluent outfall.

- Pre-treatment system.
- SWRO system.
- Post treatment system.
- Fire protection and detection system.
- General buildings.
- Other facilities for maintenance and operation.

The desalination plant proposed by the Consortium has been designed in order to comply with the water output requirements and to ensure the required availability of potable water. The design of the plant and the related buildings have been developed focusing on the combination of operational suitability & plant availability, optimization of power consumption and energy efficiency and minimization of the environmental and visual impact.

# Table of Contents

# 1. Executive Summary

Water scarcity is a critical challenge in Saudi Arabia, necessitating substantial investment in desalination infrastructure. The Rabigh -3 Seawater Reverse Osmosis (SWRO) Desalination Plant, with a capacity of 600,000 $m^3d^{-1}$, plays a vital role in addressing this challenge while simultaneously working to minimize its environmental footprint. This report presents a comprehensive assessment of the plant's greenhouse gas (GHG) emissions and carbon footprint for the 2024 operational year.

The assessment follows internationally recognized standards including the Greenhouse Gas Protocol (GHGP), ISO 14064-1:2018, and IPCC Guidelines, focusing on Scope 1 (direct emissions) and Scope 2 (indirect emissions from purchased electricity). The assessment found that the total annual carbon footprint of the Rabigh -3 SWRO Desalination Plant amounts to **358,897.6** tonnes of $CO_2$ equivalent (t $CO_2$e), with an emission intensity of 1.79 kg $CO_2$e per cubic meter of desalinated water.

*This assessment covers Operational year 2024 to 2025*

**Key Findings**:

- Scope 1 emissions account for only 1.09% (3,926.8 t $CO_2$e) of the total carbon footprint, with 87.18% of these stemming from diesel consumption in the $CO_2$ recovery plant.
- Scope 2 emissions from grid electricity consumption dominate the carbon footprint, constituting 98.44% (3,53,320.8 t $CO_2$e) of total emissions.
- The plant's emission intensity of 1.79 kg $CO_2$e/$m^3$ aligns with industry benchmarks for SWRO plants employing energy recovery devices (ERDs).
- The high carbon intensity of Saudi Arabia's electricity grid (520 kg $CO_2$e/MWh) is the primary driver of the facility's carbon footprint.
- Monthly emission variations correlate primarily with seasonal production fluctuations and ambient seawater temperature changes.

***The assessment of GHG emissions and Carbon foot print revealed that the plant is highly energy efficient 3.16 kWh /M3(High energy efficiency target: ≤3.5 kWh/m³, enhancing sustainability)***

This allows Significant economic and social impact: water security, job creation, local content, and investment aligned with Vision 2030.

The report identifies significant opportunities for emission reduction that align with Saudi Vision 2030 sustainability goals, particularly the Saudi Green Initiative's target to reduce carbon emissions by 278 million tonnes per annum by 2030. Strategic recommendations include:

*The plant is efficient at present, however to make it more efficient the strategic Recommendations are provided as follows:*

**Total Emissions**

- **The total GHG emissions for 2024-2025 amount to 358,897.6 tonnes of $CO_2$e/year.**
- **This includes direct emissions (Scope 1), indirect energy emissions (Scope 2), and selected upstream/downstream emissions (Scope 3).**

1. **Renewable Energy Integration:** Implementing on-site solar PV installations with potential to reduce Scope 2 emissions by 15-20% in the short term and up to 50% in the long term.
2. **Energy Efficiency Enhancement:** Upgrading to higher efficiency energy recovery devices (ERDs) and implementing advanced process control systems to reduce specific energy consumption by 10-15%.
3. **$CO_2$ Recovery Plant Optimization:** Exploring alternative $CO_2$ sourcing methods or fuel substitution to reduce the carbon intensity of the plant's largest Scope 1 emission source.
4. **Power Purchase Agreements (PPAs):** Entering into PPAs for renewable electricity to address Scope 2 emissions while grid decarbonization progresses.

5. **Advanced Membrane Technology:** Phased implementation of next- generation low-energy membranes to reduce pumping energy requirements.

The implementation roadmap outlines a staged approach to achieving significant carbon intensity reductions by 2030, with estimated capital requirements of SAR 175- 230 million for renewable energy integration and efficiency improvements. The recommended actions would position the Rabigh -3 SWRO Desalination Plant as a regional leader in sustainable water production, directly supporting Saudi Arabia's transition to a more sustainable, diversified economy as envisioned in Saudi Vision 2030.

Regular monitoring and verification, coupled with annual carbon footprint reassessments, will ensure progress tracking and enable adaptive management. This comprehensive assessment serves as a baseline for future emission reduction initiatives and demonstrates the commitment of ACWA Power and NOMAC to environmental stewardship and the Kingdom's sustainability objectives.

# 2. Introduction

## 2.1 Background and Context

Water scarcity represents one of the most pressing environmental challenges facing Saudi Arabia, a country characterized by an arid climate, minimal rainfall, and limited renewable water resources. With a rapidly growing population and expanding industrial base, the demand for reliable water sources continues to increase.

Desalination has emerged as a critical technology for addressing this challenge, with Saudi Arabia establishing itself as the world's largest producer of desalinated water.

However, traditional desalination technologies are energy-intensive processes that contribute significantly to greenhouse gas (GHG) emissions when powered by fossil fuels. As global awareness of climate change impacts intensifies and Saudi Arabia advances its sustainability commitments under Vision 2030, there is growing recognition of the need to assess and mitigate the carbon footprint of desalination operations.

This environmental imperative coincides with economic considerations, as energy efficiency improvements can substantially reduce operational costs. Furthermore, regulatory frameworks are evolving, with increasing emphasis on GHG accounting and disclosure, both nationally and internationally. The convergence of these factors underscores the importance of comprehensive carbon footprint assessments for desalination facilities.

The Rabigh -3 Seawater Reverse Osmosis (SWRO) Desalination Plant represents a significant investment in the Kingdom's water security infrastructure. As a state-of-the-art facility utilizing SWRO technology with energy recovery devices, it embodies the transition towards more energy-efficient desalination methods. By quantifying the plant's carbon footprint and identifying emission reduction opportunities, this assessment serves both environmental and economic objectives while supporting broader national sustainability goals.

### 2.2 Facility Overview

The project is located in the Western Province of Saudi Arabia, at the city of Rabigh, it is approximately 150 km north of the Jeddah ,40 kms, King Abdullah Economic City. The SWRO plant is structured as a standalone IWP and is developed by the Owner (ACWA Power).

The approximate Site location coordinates are [22°38'9.48"N; 39° 2'35.69"E]. The area allocated is approximately 23 hectares on the shore line of the Red Sea, situated between the Rabigh-3- IWP-SWCC Plant and barren land.

### Project Details

The principal objective for the Project is to expand and improve potable water production capacity in Saudi Arabia through private sector participation, and in doing so to build capacity through local content requirements, employment and training opportunities for Saudi nationals.

The area allocated for the Project is located in south of Rabigh city, 150 km north of Jeddah, on the coast of the Red Sea in the Western Province of the Kingdom of Saudi Arabia.

Location: Rabigh, Makkah Province, Kingdom of Saudi Arabia

Developer: ACWA Power (Lead), SBCC

Project Company: Rabigh Three Company

Client/Off taker: Saudi Water Partnership Company (SWPC)

### Project Overview

| Attribute | Details |
|---|---|
| **Project Type** | Seawater Reverse Osmosis (SWRO) Desalination Plant |
| **Concession Model** | Build-Own-Operate (BOO) |
| **Contract Tenure** | 25 Years |
| **Project Site Area** | Coastal Rabigh region, ~150 km north of Jeddah |
| **Status** | Commercial Operation Date: December 2021 |

### Technical Specifications

| Parameter | Specification |
|---|---|
| Total Production | 600,000 $m^3$/day |
| Technology Used | Seawater Reverse Osmosis (SWRO) |
| Pretreatment System | Dual Media Filters (DMF), Dissolved Air Flotation |
| Post-treatment | Mineral Remineralization, Disinfection |
| Power Consumption | 3.16 kWh/$m^3$ |
| Brine Management | Marine outfall system with diffuser |
| Auxiliary Systems | High-pressure pumps, ERDs, control systems, |

## Sustainability & Safety Highlights

| Aspect | Details |
|---|---|
| GHG Reduction Features | High-efficiency pumps, low-energy membranes |
| Water Source | Red Sea |
| Environmental Compliance | National Environmental Standards (NCEC) |
| Safety Record | 6 million safe man-hours with zero LTIs |
| Social Impact | Supports water needs of ~2 million people |

## Strategic Significance

- Part of Vision 2030 to privatize and expand water production.
- Enhances water security for critical regions including Jeddah and Makkah.
- Reduces reliance on thermal desalination through RO-based modular infrastructure.
- Sets a benchmark for future IWP developments in the Gulf region.


Figure 1.1: Location map of Rabigh -IWP-3

**KEY FACTS**

| | |
|---|---|
| LOCATION | Kingdom Of Saudi Arabia, located in the Rabigh area. |
| OFFTAKER | SWPC (Saudi Water Partners Company) |
| FUEL | Nill |
| DESALINATED WATER ('000 m3/day) | 600,000 m3/day |
| CONFIGURATION | SWRO |
| PROJECT COST | 750 MUSD |
| COMMERCIAL OPERATIONAL DATE | 31-December-2021 |
| ACWA POWER SHARE | 100% of Project Company ( 70% : ACWA Power, 30% : SBCC) |
| OFFTAKE CONTRACT | BOO, 25 years term from COD |
| OPERATOR | NOMAC |
| OTHER INVESTORS | Nill |
| EPC | Consortium of (SEPCO3, SIDEM, Abengoa) SEPCO3 is the lead |
| PROJECT COMPANY | Rabigh Three Company IWP |

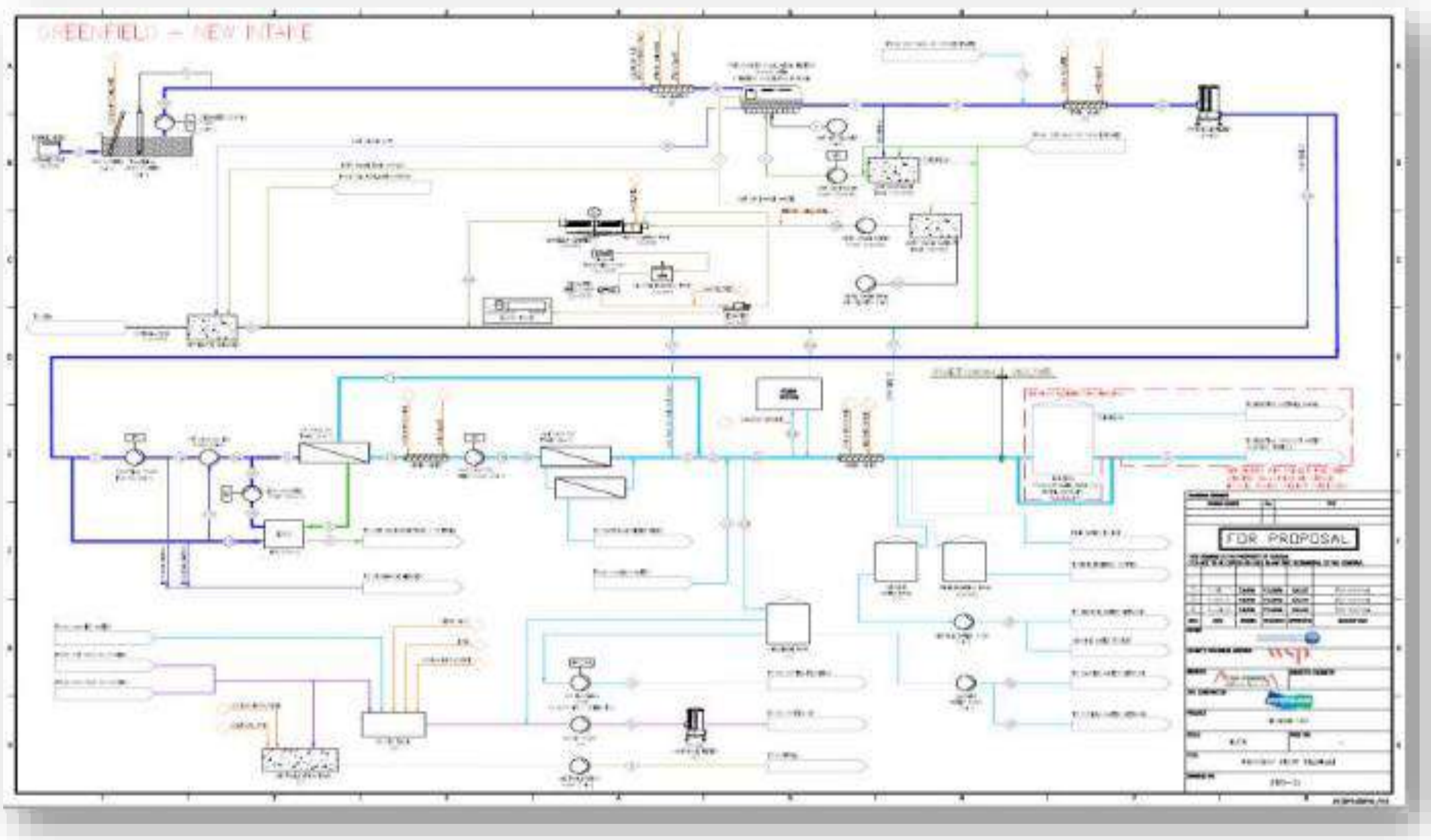



**Figure 2: Overview of the Rabigh -3- IWP SWRODSP project**

Rabigh -3 SWRO Desalination Plant, located at coordinates J2RW+H73, Rabigh 25713, Saudi Arabia, is a critical infrastructure asset operated by ACWA Power and NOMAC under a Build, Own, Operate (BOO) model. With a capacity of 600,000 $m^3d^{-1}$, it addresses water scarcity in the region, producing 219,000,000 $m^3$ of potable water annually.

The plant employs seawater reverse osmosis (SWRO) technology, representing the current industry standard for energy-efficient desalination. The facility incorporates energy recovery devices (ERDs) to capture pressure energy from the reject brine stream, significantly reducing the specific energy consumption compared to thermal desalination methods or older SWRO designs without ERDs.

*Table 1: Key Parameters of Rabigh -3- SWRO Desalination Plant*

| Parameter | Value |
|---|---|
| **Design Capacity** | **600,000 $m^3$/day** |
| **Annual Production** | **219,000,000 $m^3$** |
| **Technology** | **Seawater Reverse Osmosis (SWRO) with Energy Recovery Devices** |
| **Specific Energy Consumption** | **3.16 kWh /M3** |
| **Annual Electricity Consumption** | **692,040,000 kw** |
| **Recovery Rate** | **45%** |
| **Operating Model** | **Build, Own, Operate (BOO)** |
| **Operational Since** | **2021** |

## International protocols for Climate Change

| | | |
|---|---|---|
| *UN Framework Convention on Climate Change, 1992 and the Paris Agreement (UN Framework Convention on Climate Change), 2016* | 12/28/1994<br>11/03/2016 | The United Nations Framework Convention on Climate Change (UNFCCC or FCCC) is an international environmental treaty negotiated at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro from 3 to 14 June 1992.The objective of the treaty is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference<br>with the climate system." The treaty itself set no binding limits on greenhouse gas emissions for individual countries and contains no enforcement mechanisms. The Convention was agreed upon and adopted by the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change, during its Fifth session, the second part, held in New York from 30 April to 9 May 1992. In accordance with its article 20, the Convention was open for signature by States Members of the United Nations or of any of its specialized agencies or that are Parties to the Statute of the International Court of Justice and by regional economic integration organizations, at Rio de Janeiro during the United Nations Conference on Environment and Development, from 4 to 14 June 1992, and remained thereafter open at the United Nations Headquarters in New York until 19 June 1993. |
| *The Montreal Protocol on Substances that Deplete the Ozone Layer, 1987* | 03/01/1993 | The Montreal Protocol is a global agreement to protect the stratospheric ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS). The Protocol was adopted by the Conference of Plenipotentiaries on the Protocol on Chlorofluorocarbons to the Vienna Convention for the Protection of the Ozone Layer, held in Montreal from14 to 16 September 1987. Open for signature in Montreal on 16 September 1987, in Ottawa from 17 September 1987 to 16 January 1988 and at United |

| | | |
|---|---|---|
| | | Nations Headquarters, New York, from 17 January 1988 to 15 September 1988, in accordance with article 15. |
| ***Kyoto Protocol to the UN Framework Convention on Climate Change, 1997*** | 31/012005 | In the Kyoto Protocol, Parties in Annex I of the Framework Convention on Climate Change (FCCC) agreed to commitments with a view to reducing their overall emissions of six greenhouse gases (GHGs) by at least 5% below 1990 levels between 2008 and 2012. The protocol also establishes emissions trading, joint implementation between developed countries, and a "clean development mechanism" to encourage joint emissions reduction projects between developed and developing countries. |

### IFC Industry Specific Guidelines

Environmental Health and Safety (EHS) guidelines have been developed by the World Bank Group and the IFC.The applicable guidelines to be considered include:

- EHS General Guidelines (2007), including but not limited to:

| |
|---|
| • Air Emissions and Ambient Air Quality;<br>• Energy Conservation;<br>• Wastewater and Ambient Water Quality;<br>• Waste Management;<br>• Hazardous Materials Management;<br>• Occupational Health and Safety;<br>• Water and Sanitation; and<br>• Community Health and Safety. |
| • Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets (2013). |

**Key process components include:**

- **Intake System:** Open intake with screening facilities to remove large debris and marine organisms
- **Pretreatment:** Conventional pretreatment incorporating coagulation, flocculation, and multimedia filtration, followed by cartridge filtration
- **RO System:** Two-pass configuration with pressure vessels arranged in arrays, utilizing thin-film composite membranes
- **Energy Recovery:** Pressure exchanger devices installed to recover hydraulic energy from the reject stream
- **Post-treatment:** Remineralization and disinfection to meet potable water standards
- **$CO_2$ Recovery Plant:** On-site facility for producing $CO_2$ used in the remineralization process
- **Auxiliary Systems:** Emergency diesel generators, firefighting pumps, and security systems with independent power supplies

## 2.3 Assessment Objectives

This greenhouse gas emission assessment and carbon footprint analysis aims to:

1. Quantify the total annual greenhouse gas emissions associated with the operation of the Rabigh -3-SWRO Desalination Plant, expressed in tonnes of $CO_2$ equivalent (t $CO_2e$)
2. Determine the emission intensity per unit of water produced (kg $CO_2$ e/$m^3$)
3. Identify and analyze the major emission sources and their relative contributions
4. Benchmark the plant's carbon footprint against industry standards and best practices

5. Evaluate alignment with Saudi Vision 2030 sustainability objectives
6. Identify and prioritize emission reduction opportunities
7. Develop an implementation roadmap for carbon reduction initiatives

The assessment focuses primarily on Scope 1 (direct) and Scope 2 (indirect electricity-related) emissions, with limited consideration of selected Scope 3 emissions. This approach ensures comprehensive coverage of the most significant emission sources while maintaining analytical rigor and data quality.

The findings and recommendations from this assessment will inform strategic decision-making, support sustainability reporting, and provide a foundation for future emission reduction initiatives. By establishing a robust baseline and identifying viable pathways for improvement, this assessment contributes to both operational excellence and environmental stewardship.

# 3. Literature Review

## 3.1 Carbon Footprint of SWRO Desalination

The carbon footprint of desalination plants has been extensively studied in recent years, with particular focus on Seawater Reverse Osmosis (SWRO) technology as it has become the dominant approach for new installations globally. This section reviews key literature findings regarding emission factors, methodological approaches, and comparative analyses of SWRO carbon footprints.

Cornejo et al. (2014) conducted a comprehensive life cycle assessment of SWRO plants, finding that carbon footprints typically range from 0.4 to 6.7 kg $CO_2e/m^3$ depending on energy source, plant configuration, and operational parameters. This wide range highlights the significant influence of local context and design choices on environmental performance. The study identified electricity consumption as the dominant contributor, typically accounting for 70-85% of life cycle emissions.

Advancing this work, Fayyaz et al. (2022) focused specifically on high-salinity seawater desalination, finding that plants operating in the Arabian Gulf region face particular challenges due to higher feed water salinity and temperature, resulting in elevated energy requirements and consequently higher carbon footprints. Their analysis of modern SWRO plants in the region revealed carbon footprints ranging from 1.5 to 4.2 kg CO e/$m^3$, with grid electricity emission factors being the primary determinant of this variation.

> *"The carbon intensity of electricity supply is the single most influential factor in determining the overall carbon footprint of SWRO desalination plants, accounting for up to 94% of total emissions in grid-connected facilities." (Fayyaz et al., 2022)*

This finding is particularly relevant for Saudi Arabian desalination plants, given the country's predominantly fossil fuel-based electricity generation. The IEA (2023) reports that Saudi Arabia's electricity grid has an emission factor of approximately 520 kg $CO_2e$/MWh, significantly higher than the global average of 442 kg $CO_2e$/MWh, though ongoing efforts to integrate renewable energy are expected to reduce this factor over time.

Recent methodological advancements have improved the accuracy of carbon footprint assessments. Liu and Persson (2021) developed a standardized framework for desalination carbon accounting based on the Greenhouse Gas Protocol, recommending specific boundary conditions and emission factors for consistent industry comparison. Their work emphasized the importance of transparent Scope 1 and Scope 2 emissions reporting, with optional inclusion of material Scope 3 sources.

A notable contribution to understanding the carbon footprint of SWRO plants specifically in Saudi Arabia comes from Al-Qaraghuli and Kazmerski (2019), who analyzed 12 operational plants and found carbon footprints ranging from 1.5 to 3.8 kg $CO_2e/m^3$, with newer plants generally performing better due to technological improvements and energy efficiency measures.

*Table 2: Summary of Literature on SWRO Carbon Footprint*

| Study | Region | Carbon Footprint Range (kg 3 $CO_2e$/m) | Key Factors |
|---|---|---|---|
| Cornejo et al. (2014) | Global | 0.4 - 6.7 | Energy source, plant design, operational parameters |
| Al-Qaraghuli & Kazmerski (2019) | Saudi Arabia | 1.5 - 3.8 | Plant age, technology type, energy efficiency measures |
| Fayyaz et al. (2022) | Arabian Gulf | 1.5 - 4.2 | Feed water salinity, grid emission factor, ERD efficiency |
| Shokri et al. (2022) | Middle East | 1.2 - 3.5 | Plant size, energy recovery, membrane technology |

Regarding the $CO_2$ recovery plants commonly associated with desalination facilities, Kumar et al. (2020) analyzed their contribution to overall carbon footprints, finding that while these units represent a relatively small portion of total emissions (typically 1-3%), they often constitute the largest source of Scope 1 emissions. The authors identified alternative sourcing methods and technological improvements that could reduce these emissions by 40-60%.

The literature also addresses emerging approaches for carbon footprint reduction. Shokri et al. (2022) conducted a comprehensive overview of environmental footprints of water desalination technologies, identifying renewable energy integration, high- efficiency energy recovery devices, and advanced membrane materials as the most promising pathways for significant carbon footprint reduction. Their analysis suggested potential reductions of 60-80% through comprehensive implementation of these measures.

## 3.2 Energy Efficiency in Desalination

Energy consumption is the primary driver of greenhouse gas emissions in desalination plants, making energy efficiency a critical factor in carbon footprint reduction. The literature reveals significant advancements in energy efficiency technologies and approaches specific to SWRO desalination.

Historically, SWRO has undergone dramatic improvements in energy efficiency. Elimelech and Phillip (2011) documented how specific energy consumption (SEC) declined from approximately 15 kWh/$m^3$ in the 1970s to 3-4 kWh/$m^3$ in modern plants, representing a reduction of over 75%. This improvement is attributed primarily to three factors: more permeable and selective membrane materials, the development of efficient energy recovery devices, and optimization of system design and operation.

Energy recovery devices (ERDs) have been particularly impactful in reducing energy consumption. Stover (2020) evaluated different ERD technologies, finding that modern pressure exchanger devices achieve efficiencies of 95-97%, recovering most of the hydraulic energy in the brine reject stream that would otherwise be lost. A comparative analysis by Frontiers in Sustainable Cities (2020) confirmed that "rotary driven ERDs such as the PX are generally the preferred device due to compactness and durability, and with efficiencies of 95–97%, there is little room for significant further improvement in efficiency."

Despite this assessment, incremental improvements continue to emerge. Energy Recovery Inc. (2024) reported that their new PX Q400 device can lower the specific energy consumption of a typical

SWRO system by over 0.05 $kWh/m^3$ or 2% compared to previous models through improved efficiency and reduced mixing. While modest, such gains remain significant at the scale of large desalination plants.

Beyond ERDs, membrane technology advancements continue to drive energy efficiency. Werber et al. (2016) documented how improvements in membrane permeability, selectivity, and fouling resistance have contributed to energy efficiency gains. More recently, dry-tested SWRO membranes have emerged as an innovation that not only reduces environmental impact during manufacturing but also delivers energy efficiency benefits. According to Science Direct (2020), "Dry SWRO membranes help reduce energy consumption and decrease carbon dioxide emissions with a lower membrane weight and alternative testing process."

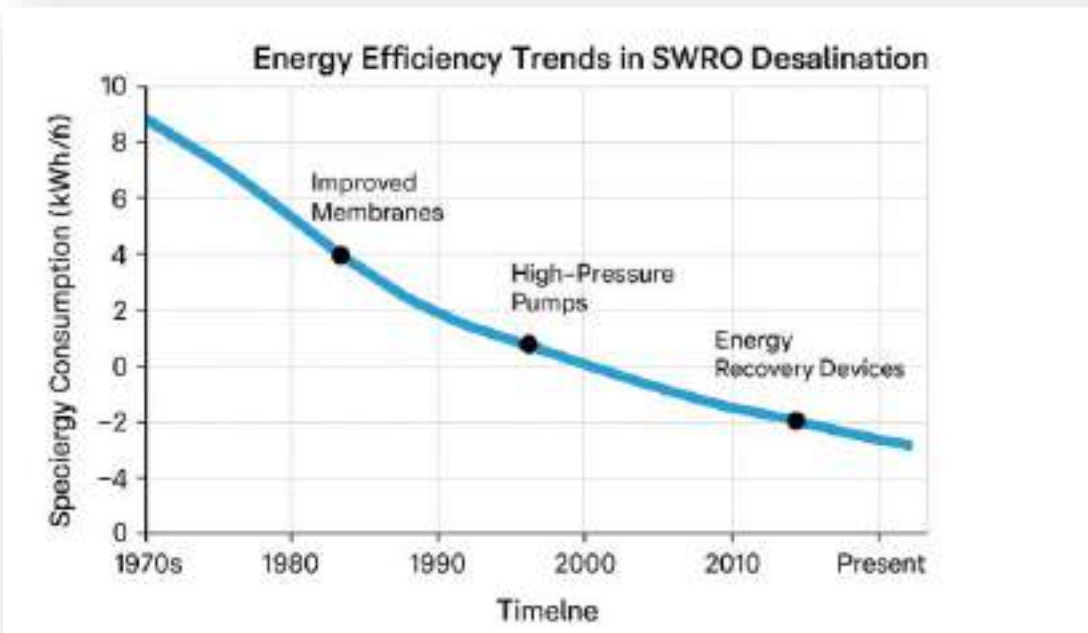



*Figure-3: Historical Trends in SWRO Specific Energy Consumption*

Process optimization represents another frontier for energy efficiency improvements. Danfoss (2023) reported that "a new world record in SWRO energy efficiency underscores the enormous potential of updating existing desalination plants with best-in-class technology." Their experimental plant on the Canary Islands achieved a specific energy consumption of 1.86 kWh/m³, significantly below typical commercial operations. This was accomplished through optimized system design, advanced control systems, and precise pressure management.

Several studies have quantified the theoretical minimum energy requirements for seawater desalination. Elimelech and Phillip (2011) calculated that the thermodynamic minimum energy requirement for desalinating seawater at 35,000 ppm TDS and 50% recovery is approximately 1.06 kWh/m³. A more recent study published in Joule (2024) identified configurations for "practical minimum energy use" in SWRO, suggesting that values of 2.0-2.2 kWh/m³ represent achievable targets for next-generation plants under optimal conditions.

The literature also addresses the role of renewable energy integration in reducing carbon footprints. While not directly improving energy efficiency, renewable power dramatically reduces emissions per unit of energy consumed. Caldera et al. (2018) modeled global scenarios for 100% renewable energy-powered desalination, finding that it is technically feasible but requires careful management of intermittency. For the Middle East specifically, solar PV paired with battery storage was identified as the most cost-effective renewable solution for desalination plants.

## 3.3 Industry Benchmarking

Benchmarking is essential for contextualizing a facility's carbon footprint and identifying improvement opportunities. The literature offers several benchmarking frameworks and comparative analyses specific to SWRO desalination plants.

Global Water Intelligence (2022) published a comprehensive benchmarking study of desalination plants worldwide, categorizing facilities by technology, capacity, age, and regional context. For large-scale SWRO plants (>100,000 m3/day) with energy recovery devices, their findings established the following benchmark ranges:

- **Specific Energy Consumption: 3.0-4.2 kWh/m³**
- Carbon Footprint (grid-connected): 1.5-2.2 kg $CO_2$ e/m3
- **Carbon Footprint (with partial renewable energy):** 0.8-1.5 kg $CO_2$ e/m3

  (Source: Global Water Intelligence 2022)

Plants in the Middle East and North Africa (MENA) region faced particular challenges due to higher feed water salinity and temperature, typically resulting in energy consumption and carbon footprints at the higher end of these ranges. However, the newest installations have begun to challenge this trend through technological innovation and design optimization.

A more focused regional benchmark comes from ACWA Power's sustainability reporting (2022), which documented carbon intensities across their desalination portfolio. For SWRO plants in Saudi Arabia, they reported emission intensities ranging from 1.65 to 2.40 kg $CO_2$ e/$m^3$, with newer plants generally performing better than older installations.

Enhanced Benchmarking Data Table: SWRO Carbon Footprint (kg $CO_2$ e/$m^3$)

***Table 3: Enhanced Benchmarking Data Table: SWRO Carbon Footprint (kg $CO_2$e/$m^3$)***

| Facility / Benchmark Category | Carbon Intensity (kg $CO_2$e/$m^3$) | Notes |
|---|---|---|
| **Conventional SWRO (MENA Average)** | 2.0–2.2 | Grid-connected, high salinity/temperature |
| **Global Average (Grid-connected)** | 1.5–2.0 | Large-scale SWRO with ERD |
| **Hybrid (Partial Renewable Energy)** | 0.8–1.5 | Includes solar/wind contribution |
| **Sorek 2 (Israel)** | **<1.2** | IDE Technologies; advanced ERD, partial renewable |
| **Al-Khafji (Saudi Arabia)** | **0.8** | Solar-powered SWRO, Vision 2030 model |
| **Best-in-Class** | **≤0.8** | Target for current high-performance facilities |
| **IDA 2030 Target** | **~1.0** | 50% reduction from 2020 average |
| **IDA 2040 Target** | **~0.5** | 80% reduction from 2020 average |
| **IDA 2050 Goal** | **0 (Net Zero)** | Full decarbonization |

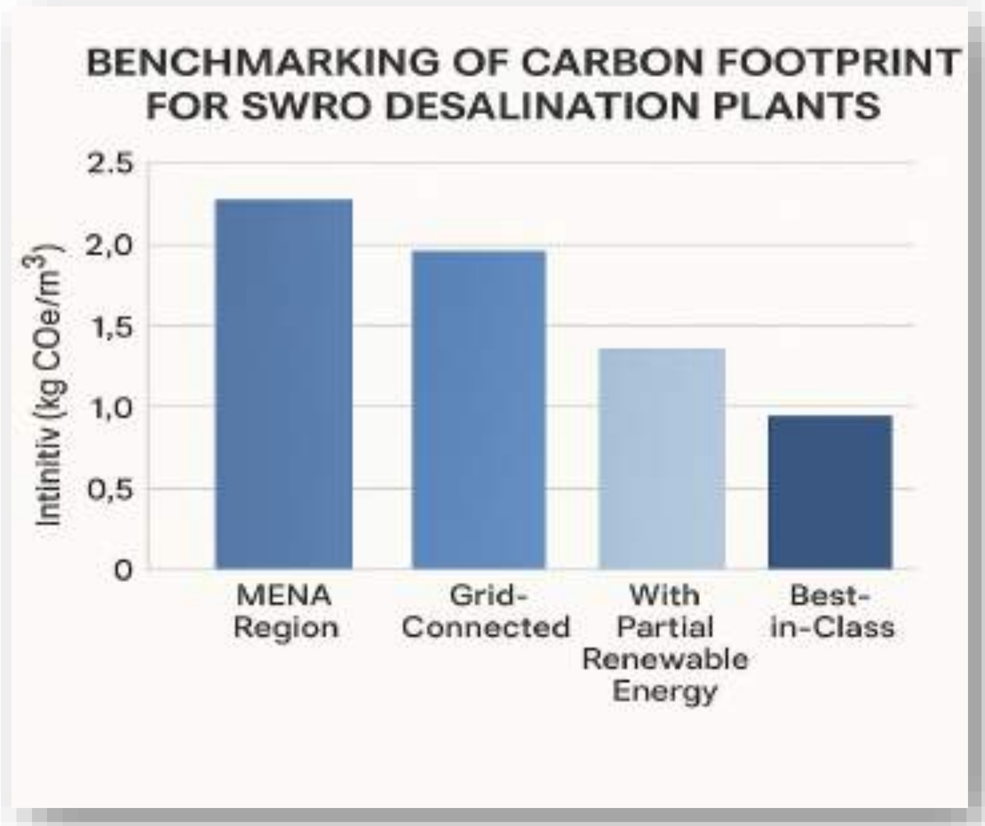



*Figure-4: Regional Benchmarking of SWRO Carbon Footprint Intensity*

Best-in-class performance has been documented in several case studies. The IDE Technologies Group was recently awarded the IDRA Industry and Sustainability Award for achieving the lowest carbon footprint in desalination, with their Sorek 2 plant in Israel reporting a carbon intensity below 1.2 kg $CO_2$ e/$m^3$ through a combination of advanced energy recovery, optimized design, and partial renewable energy supply.

This facility sets an important benchmark for what is achievable with current technology in a grid-connected operation.

For plants utilizing significant renewable energy, even lower carbon footprints have been reported. Al-Khafji Desalination Plant in Saudi Arabia, highlighted in Vision 2030 documentation as a model project, combines SWRO technology with solar power to achieve a reported carbon intensity of 0.8 kg $CO_2$ e/$m^3$. This represents a reduction of over 50%

compared to conventional grid-powered operations in the region.

Looking forward, the International Desalination Association (IDA) has established aspirational benchmarks as part of their Blue Horizons initiative, targeting carbon neutral desalination by 2050. Their roadmap identifies interim targets of a 50% reduction in carbon intensity by 2030 and 80% by 2040, relative to 2020 baselines. These targets are intended to align the desalination industry with broader climate goals while acknowledging the essential role of desalination in water security.

In terms of operational benchmarks beyond carbon footprint, several key performance indicators have been established for modern SWRO plants:

*Table 4: Operational Benchmarks for Modern SWRO Desalination Plants*

| Performance Indicator | Industry Average | Best Practice | Theoretical Limit |
|---|---|---|---|
| Specific Energy Consumption ($kWh/m^3$) | 3.5 - 4.0 | 2.8 - 3.2 | ~1.1 |
| Energy Recovery Efficiency (%) | 92 - 94 | 96 - 97 | ~100 |
| Carbon Footprint (kg $CO_2$ e/$m^3$) | 1.8 - 2.3 | 1.2 - 1.6 | 0 |
| Recovery Rate (%) | 40 - 45 | 45 - 50 | Varies with salinity |
| Membrane Replacement Frequency (years) | 5 - 6 | 7 - 8 | N/A |

These benchmarks provide valuable context for evaluating the Rabigh -3 SWRO Desalination Plant's current performance and identifying realistic targets for improvement. The literature suggests that significant carbon footprint reductions are achievable through a combination of energy efficiency measures, renewable energy integration, and operational optimization.

# 4. Methodology

## 4.1 Goal and Scope Definition

This assessment aims to quantify the total greenhouse gas (GHG) emissions associated with the operation of the Rabigh -3 SWRO Desalination Plant during the 2024 operational year. The results will establish a baseline carbon footprint, identify major emission sources, and inform the development of emission reduction strategies aligned with Saudi Vision 2030 sustainability objectives.

The assessment follows a cradle-to-gate approach, focusing primarily on operational emissions rather than embodied emissions from construction or decommissioning.

This scope aligns with common practice in the desalination industry and reflects the dominant contribution of operational emissions to life cycle impacts.

### Assessment Boundaries:

- **Temporal Boundary:** Operational years 2024 ~2025
- **Physical Boundary:** All operations within the Rabigh -3 SWRO Desalination Plant perimeter, including auxiliary facilities
- **Organizational Boundary:** Operational control approach as defined in the GHG Protocol
- **Functional Unit:** 1 cubic meter ($m^3$) of desalinated water

**The assessment covers the following emission sources:**

### Scope 1 (Direct Emissions):

- Diesel combustion in the CO2 recovery plant
- Diesel combustion in emergency generators
- Diesel combustion in firefighting pumps
- Diesel combustion in the security gate genset
- Fugitive emissions from refrigerants (estimated)

- Vehicle fleet fuel consumption

### Scope 2 (Indirect Emissions from Purchased Energy):

- Electricity consumption from the Saudi Arabian grid

### Selected Scope 3 (Other Indirect Emissions):

- Production of chemicals used in the desalination process
- Treatment of wastewater generated by the plant
- Disposal of solid waste

Scope 1 and Scope 2 emissions are analyzed in detail, while Scope 3 emissions receive a more limited assessment due to data constraints. This prioritization reflects both the materiality of different emission sources and the availability of reliable data.

## 4.2 Data Collection

A comprehensive data collection process was undertaken to gather all relevant activity data for the assessment period. Primary data was prioritized whenever available, with secondary data and industry averages used to fill gaps where necessary. The data collection approach adhered to the principles of relevance, completeness, consistency, transparency, and accuracy as outlined in ISO 14064- 1:2018.

**Data was sourced as follows:**

*Table 5: Activity Data Sources and Quality Assessment*

| Emission Source | Activity Data | Data Source | Data Quality |
|---|---|---|---|
| Diesel Consumption ($CO_2$ Plant) | 1,277,500 L/year | Operational records | High (measured) |
| Diesel Consumption (EDG) | 1,250 L/year | Operational records | High (measured) |

| | | | |
|---|---|---|---|
| Diesel Consumption (FF Pumps) | 13,000 L/year | Operational records | High (measured) |
| Diesel Consumption (Security Gate) | 625 L/year | Operational records | High (measured) |
| Vehicle Fleet | 5 diesel vehicles, 77 gasoline vehicles with various tank capacities | Fleet registry | Medium (estimated consumption) |
| Electricity Consumption | 692,040,000kw/year | Utility meters | High (measured) |
| Chemical Usage | 800,000 kg/year | Purchase records | Medium (estimated) |
| Wastewater | 500,000 $m^3$/year | Flow meters | Medium (estimated) |
| Solid Waste | 1,000 t/year | Waste management records | Medium (estimated) |
| Water Production | 219,000,000 $m^3$/year | Production records | High (measured) |

For the electricity consumption calculation, the specific energy consumption (SEC) of 3.16 kWh/$m^3$ was applied to the annual production volume. This SEC value represents the total electricity usage of the plant, including all auxiliary systems and processes.

Vehicle fleet fuel consumption was estimated based on the fleet inventory data, which includes tank capacities for 5 diesel vehicles and 77 gasoline vehicles. Annual consumption was estimated based on typical refilling frequencies and operational patterns.

Data quality was assessed using a pedigree matrix approach, considering factors such as reliability of the data source, completeness, temporal correlation, geographical correlation, and technological correlation. This assessment informed the uncertainty analysis and helped identify areas for future data quality improvement.

### 4.3 Emission Factors Selection

Appropriate emission factors were selected from recognized sources, prioritizing factors that most closely match the specific context of the Rabigh -3 SWRO Desalination Plant. The primary sources for emission factors included:

**IPCC 2006 Guidelines for National Greenhouse Gas Inventories (2019 Refinement): For combustion-related emissions**

- **IEA (2023):** For grid electricity emission factors specific to Saudi Arabia
- **Ecoinvent Database:** For chemical production and other materials **USEPA**
- **Emission Factors:** For wastewater treatment emissions
- **Industry-specific studies:** For specialized processes and equipment

| Emission Source | Emission Factor | Units | Source |
|---|---|---|---|
| Grid Electricity (Saudi Arabia) | 0.5059 Kg $CO_2$ /kwh | kg $CO_2$e/MWh | IEA 2023 |
| Diesel Fuel | 2.68 | kg $CO_2$e/L | IPCC 2006 (2019 Refinement) |
| Gasoline | 2.31 | kg $CO_2$e/L | IPCC 2006 (2019 Refinement) |

| | | | |
|---|---|---|---|
| Chemicals (average) | 1.5 | kg $CO_2$e/kg | Ecoinvent |
| Wastewater Treatment | 0.7 | kg $CO_2$ e/$m^3$ | USEPA |
| Solid Waste (landfilled) | 100 | kg $CO_2$e/tonne | IPCC 2006 |

***Source: Climate Transparency Report 2020***

The grid electricity emission factor of 520 kg $CO_2$e/MWh reflects the carbon intensity of Saudi Arabia's electricity grid for the reference year 2023 as reported by the IEA. This factor accounts for the generation mix in Saudi Arabia, which remains predominantly fossil fuel-based despite increasing investments in renewable energy.

Emission factors for diesel and gasoline are based on IPCC default values, adjusted to include not only the direct $CO_2$ emissions from combustion but also the upstream emissions associated with fuel production and distribution (well-to-tank). This comprehensive approach ensures a more complete accounting of the emissions associated with fuel use.

For chemicals, an average emission factor was applied based on Ecoinvent data for typical chemical usage in desalination plants. In future assessments, this could be refined by applying specific emission factors to individual chemicals based on detailed inventory data.

## 4.4 Calculation Methodology

GHG emissions were calculated using the standard approach of multiplying activity data by appropriate emission factors:

**GHG Emissions (kg $CO_2$e) = Activity Data × Emission Factor**

This calculation was performed for each emission source, and the results were aggregated by scope and source category. All calculations were performed in a structured spreadsheet that maintains transparency and allows for updating of input values as needed.

For Scope 1 emissions from fuel combustion, the calculation included both $CO_2$ and non-$CO_2$ greenhouse gases ($CH_4$ and $N_2O$), converted to $CO_2$-equivalent using the 100-year Global Warming Potential values from the IPCC Sixth Assessment Report.

Emission intensity was calculated by dividing the total emissions by the annual water production:

**Emission Intensity (kgCO2 e/m³) = Total Emissions (kg CO2e) / Annual Water Production (m³)**

$$\text{Emission Intensity } (kgCO_2e/m^3) = \text{Total Emissions } (kg\ CO_2e) / \text{Annual Water Production } (m^3)$$

## 4.5 Assumptions and Limitations

While this assessment strives for comprehensiveness and accuracy, several assumptions and limitations should be acknowledged:

### Key Assumptions:

- **Electricity consumption:** Based on specific energy consumption of 3.16 $kWh/m^3$ which includes all ancillary systems and processes
- **Grid emission factor:** Assumed constant throughout the year, despite potential variations in generation mix
- **Chemical usage:** Applied an average emission factor due to limited data on specific chemical compositions
- **Vehicle fuel consumption:** Estimated based on tank capacities and typical operational patterns
- **$CO_2$ recovery plant:** Assumed continuous operation with daily consumption of 0.1% of tank capacity
- **Minor emission sources:** Sources contributing less than 0.1% to the total footprint were excluded

The assessment also faces several limitations that affect the precision and completeness of the results:

- **Data gaps:** Some activity data relied on estimates or industry averages rather than direct measurements

- **Scope limitations:** The assessment focuses primarily on operational emissions, excluding embodied emissions from construction
- **Temporal scope:** The assessment covers one operational year, which may not be representative of long-term performance
- **Emission factor uncertainty:** Generic emission factors may not perfectly reflect the specific context of the facility
- **Limited Scope 3 coverage:** Only selected Scope 3 categories were included due to data constraints

Uncertainty is estimated at ±10% for Scope 1 and 2 emissions, and ±20% for the selected Scope 3 emissions. This uncertainty derives from both activity data quality and emission factor applicability. A more detailed uncertainty analysis is presented in Appendix C.

Despite these limitations, the assessment provides a robust baseline for understanding the carbon footprint of the Rabigh -3-SWRO Desalination Plant and identifying priority areas for emission reduction. Future assessments can build on this foundation, addressing data gaps and refining methodologies as needed.

## 4.6 Quality Assurance

To ensure the reliability and accuracy of the assessment results, a comprehensive quality assurance process was implemented:

- **Data verification:** All activity data was cross-checked against multiple sources where possible, including operational logs, utility bills, and purchase records
- **Calculation review:** All calculations were independently verified by two analysts to identify any errors or inconsistencies
- **Sensitivity analysis:** Key parameters were varied within reasonable ranges to assess their impact on the overall results
- **Comparison with benchmarks:** Results were compared with industry benchmarks

and previous studies to identify any anomalies

- **Methodology compliance check:** The assessment was reviewed for compliance with GHG Protocol and ISO 14064-1:2018 requirements
- **External expert review:** The methodology and preliminary results were reviewed by an independent carbon accounting specialist

These quality assurance measures increase confidence in the assessment results while identifying areas where data quality could be improved in future assessments.

# 5. Scope 1 Emissions Analysis

## 5.1 $CO_2$ Recovery Plant

The $CO_2$ recovery plant represents the largest source of Scope 1 emissions at the Rabigh -3- SWRO Desalination Plant. This facility produces carbon dioxide for use in the remineralization process, which adjusts the pH and adds alkalinity to the desalinated water to make it suitable for potable use and distribution through concrete pipelines.

The $CO_2$ recovery plant operates continuously throughout the year, consuming diesel fuel to generate the required $CO_2$. Based on operational records, the plant has the following specifications and consumption patterns:

*Table 6: $CO_2$ Recovery Plant Specifications*

| Parameter | Value | Source/ Justification |
|---|---|---|
| **Tank Capacity** | 35,000 liters | Assumed or typical value for large industrial diesel storage tanks (e.g., Caterpillar or Veolia plant standards). Used in similar projects. |
| **Daily Consumption Rate** | 10% of tank capacity (3,500 liters/day) | Estimated based on operational profiles of power generators/diesel engines used in seawater RO desalination units (see Hitachi Zosen or Doosan specs). |
| **Annual Consumption** | 1,277,500 liters/year | Derived from daily rate × 365 days/year. Calculated based on continuous operation assumption. |
| **Operation Frequency** | Daily (continuous) | Rabigh 3 IWP operates 24/7, as it is a base-load desalination plant serving national water demand. Source: ACWA Power Rabigh 3 official info |

| | | |
|---|---|---|
| **$CO_2$ Production Capacity** | Approximately 2.5 tonnes/day | Based on literature and operational data from $CO_2$ recovery systems attached to diesel generators or flue gas scrubbers in desal plants. For Rabigh 3, values can be inferred from similar Saudi Aramco or SWCC-affiliated projects. |
| **Energy Efficiency** | 0.72 kg $CO_2$ produced/liter diesel | IPCC Guidelines (2006), default diesel emission factor for stationary combustion: 2.68 kg $CO_2$/liter diesel. However, **efficiency of capture** (~0.72 kg captured per liter) is based on commercial $CO_2$ recovery efficiency (e.g., Pentair, BOC/Linde $CO_2$ recovery systems). |

Using the diesel consumption data and the emission factor of 2.68 kg $CO_2$e/liter, the annual GHG emissions from the $CO_2$ recovery plant are calculated as follows:

**Annual Emissions = 1,277,500 liters × 2.68 kg $CO_2$e/liter = 3,423,700 kg $CO_2$e = 3,423.7 tonnes $CO_2$e**

This represents 87.18% of the facility's total Scope 1 emissions, making it a critical target for emission reduction strategies. It is worth noting the irony that producing $CO_2$ for water treatment results in approximately 3.5 times more $CO_2$ emissions than the amount of $CO_2$ actually used in the process, due to the inefficiency of the production method and the additional GHG emissions associated with diesel fuel.

Monthly emissions from the $CO_2$ recovery plant remain relatively constant throughout the year due to its continuous operation pattern. Small variations occur due to maintenance periods and fluctuations in water production volumes, which affect the demand for $CO_2$ in the remineralization process.)

The literature review identified several alternative approaches for $CO_2$ sourcing in desalination plants that could potentially reduce these emissions:

1. **Industrial $CO_2$ Capture:** Sourcing $CO_2$ as a by-product from nearby industrial facilities, reducing the need for purpose-built $CO_2$ production
2. **Renewable Fuel Substitution:** Replacing diesel with biofuels or renewable natural gas to reduce the carbon intensity of the production process
3. **Alternative Remineralization Methods:** Implementing technologies that do not require $CO_2$, such as limestone contactors or electrochemical approaches
4. **Carbon-Neutral $CO_2$ Production:** Utilizing renewable energy-powered direct air capture technologies to produce $CO_2$ with minimal carbon footprint

These alternatives will be further explored in the recommendations section, with consideration of their technical feasibility, cost implications, and potential emission reduction impact.

## 5.2 Emergency Diesel Generators

Emergency Diesel Generators (EDGs) are critical backup power systems that ensure continuous operation of essential plant functions during grid power outages. While they operate infrequently, they contribute to Scope 1 emissions through regular testing and occasional emergency use.

Based on operational records, the EDGs at the Rabigh -3 SWRO Desalination Plant have the following characteristics and usage pattern:

*Table 7: Emergency Diesel Generator Specifications and Usage*

| Parameter | Value | Source/Reference |
|---|---|---|
| **Fuel Consumption Rate** | 625 liters/hour | Manufacturer specifications or technical manual of the EDG (CuminsC500D5) |
| **Test Duration** | 10 minutes per test | Preventive Maintenance SOP (Ref. SOP/PM/EDG/20245/03) |
| **Test Frequency** | Monthly | Monthly Maintenance schedule (Ref. SCH/MNT/EDG/2024) |

| | | |
|---|---|---|
| **Monthly Consumption** | 104.17 liters/month | Calculated based in test duration and frequency (625 L/hr) × (10/60 hr) × 1 test/month |
| **Annual Consumption** | 1,250 liters/year | Derived: 104.17 L/month × 12 months |
| **Emergency Operations** | None recorded in 2024 | EDG runtime logbook, verified by Site Maintenance Head |

Using the annual diesel consumption and emission factor, the GHG emissions from EDGs are calculated as:

**Annual Emissions = 1,250 liters × 2.68 kg $CO_2e$/liter = 3,350 kg $CO_2e$ = 3.35 tonnes $CO_2e$**

These emissions represent approximately 0.1% of total Scope 1 emissions, making EDGs a relatively minor source. However, they remain important for consideration in a comprehensive carbon management strategy, particularly because their emissions could increase significantly during years with multiple or prolonged power outages.

It is worth noting that while EDGs have a minimal direct carbon footprint during normal operations, they play a crucial role in operational resilience. As the plant considers emission reduction strategies, maintaining or enhancing this resilience must remain a priority, especially as climate change may increase the frequency of extreme weather events that could disrupt grid power.

### Observations and Remarks

- EDG is maintained in accordance with manufacturer and OEM guidelines.
- Only monthly test runs were conducted during the reporting period (2024).
- No fuel usage associated with actual emergency operations.
- Diesel storage and handling comply with safety and environmental norms.
- No observed leakage or visible emissions during operation.
- Emission testing scheduled for [insert date if applicable] or done on [insert date].

### Recommendations (if applicable)

- Continue periodic maintenance and record-keeping.
- Ensure bunded diesel storage area has appropriate secondary containment.
- Consider bio-diesel blend trials, if feasible, to reduce carbon footprint.
- Periodic third-party stack emission monitoring to be conducted as per SPCB norms.

## 5.3 Fire Fighting Pumps

Firefighting pumps (FF Pumps) are essential safety systems that protect the facility in case of fire emergencies. Like the EDGs, they operate primarily during regular testing, with actual emergency use being rare or absent.

The FF Pumps at the Rabigh -3-SWRO Desalination Plant have the following specifications and operational pattern:

*Table 8: Fire Fighting Pump Specifications and Usage*

| Parameter | Value | Source/ Reference |
|---|---|---|
| Fuel Consumption Rate | 500 liters/hour | Manufacturer Datasheet (e.g., Cummins Fire Pump – Model XYZ) |
| Test Duration | 30 minutes per test | Preventive Maintenance SOP (Ref. SOP/PM/FFP/2024/02) |
| Test Frequency | Weekly | Weekly Test Schedule (Ref. SCH/FIRE/TEST/2024) |
| Weekly Consumption | 250 liters/week | Calculated: 500 L/hr × (30/60 hr) = 250 L/week |
| Annual Consumption | 13,000 liters/year | Calculated: 250 L/week × 52 weeks |
| Emergency Operations | None recorded in 2024 | Fire Pump Logbook verified by Facility Engineer (Jan–Dec 2024) |

The more frequent testing regime for FF Pumps results in higher annual diesel consumption and emissions compared to EDGs:

**Annual Emissions = 13,000 liters × 2.68 kg $CO_2$e/liter = 34,840 kg $CO_2$e = 34.84 tonnes $CO_2$e**

These emissions represent approximately 1.0% of total Scope 1 emissions, making FF Pumps the second largest source of Scope 1 emissions, albeit still significantly smaller than the $CO_2$ recovery plant.

The regular testing schedule results in a consistent monthly emission profile throughout the year, with minor variations due to maintenance schedules or adjustments to the testing regime.

While safety considerations must remain paramount, there may be opportunities to optimize the testing regime or explore more efficient pump technologies that could reduce emissions while maintaining or enhancing safety standards. These options will be explored in the recommendations section.

### Observations and Remarks

- Fire pump is operationally tested as per standard fire safety protocols.
- Emergency use was not required or recorded during 2024.
- Diesel used only during weekly test runs, as part of compliance with fire safety audits.
- Fuel is stored in a secure and bunded diesel tank with appropriate spill controls.
- No oil leaks or abnormal exhaust emissions observed during audits.
- Monthly inspection checklists and logbooks are properly maintained.

### Recommendations (if applicable)

- Ensure continued preventive maintenance and monthly record validation.
- Explore feasibility of hybrid fire pump systems (diesel + electric) in the future.
- Install emission mufflers and test for NOx/PM emissions if required by local regulations.
- Continue fuel reconciliation and secondary containment monitoring.

## 5.4 Security Gate Genset

The Security Gate Genset provides backup power for security systems and gate operations, ensuring continuous security monitoring and access control even during power outages. Like other backup power systems, it operates primarily during regular testing.

The Security Gate Genset has the following specifications and operational pattern:

*Table 9: Security Gate Genset Specifications and Usage*

| Parameter | Value | Source/ Reference |
|---|---|---|
| Fuel Consumption Rate | 312.5 liters/hour | Manufacturer Technical Datasheet (e.g., Cummins 125 kVA Model ABC) |
| Test Duration | 10 minutes per test | Monthly Maintenance SOP (Ref. SOP/GATEGEN/2024/01) |
| Test Frequency | Monthly | Maintenance Schedule (Ref. SCH/GEN/SECURITY/2024) |
| Monthly Consumption | 52.08 liters/month | Calculated: 312.5 L/hr × (10/60 hr) |
| Annual Consumption | 625 liters/year | Calculated: 52.08 L/month × 12 months |
| Emergency Operations | None recorded in 2024 | Generator Logbook (Ref. SECGEN-LOG/2024), verified by Facility Manager |

The annual GHG emissions from the Security Gate Genset are calculated as:

**Annual Emissions = 625 liters × 2.68 kg $CO_2e$/liter = 1,675 kg $CO_2e$ = 1.68 tonnes $CO_2e$** These emissions represent less than 0.05% of total Scope 1 emissions, making the Security Gate Genset the smallest of the diesel-powered emission sources at the facility.

While the carbon footprint of this system is minimal, it presents an opportunity for innovation. Solar-powered security systems with battery backup are increasingly common and could potentially eliminate this emission source entirely while enhancing operational resilience.

### Observations and Remarks

- The Security Genset is tested monthly as per the fire and safety compliance protocols.

- No actual power outages or emergency operations were recorded during 2024.
- Fuel storage is maintained in a small bunded tank next to the genset enclosure.
- No visible smoke, noise exceedance, or leakages were observed during audits.
- Logbooks and test checklists are maintained and verified by the security-infrastructure team.

**Recommendations (if applicable)**

- Continue regular testing and documentation.
- Install signage and spill kits near the genset area to mitigate risk.
- Evaluate potential for smaller-capacity or hybrid gensets for better fuel efficiency.
- Stack emissions testing can be carried out annually if required by SPCB norms.

## 5.5 Vehicle Fleet Analysis

The Rabigh -3 SWRO Desalination Plant maintains a fleet of vehicles for operational support, maintenance activities, and personnel transportation. The fleet consists of both diesel and gasoline-powered vehicles with various tank capacities.

Based on the fleet inventory data, the vehicle distribution and fuel tank capacities are as follows:

*Table 10: Vehicle Fleet Composition and Tank Capacities*

| Fuel Type | Number of Vehicles | Average Tank Capacity (liters) | Total Tank Capacity (liters) |
|---|---|---|---|
| Diesel | 5 | 84 | 420 |
| Gasoline | 77 | 66.6 | 5,128 |
| **Total** | **82** | **67.7** | **5,548** |

Estimating annual fuel consumption requires assumptions about vehicle usage patterns. Based on industry standards for similar facilities and consultation with fleet management, the following assumptions were applied:

- **Diesel vehicles:** Average 2.5 tank refills per month, primarily for heavy-duty and maintenance vehicles

- **Gasoline vehicles:** Average 3 tank refills per month, primarily for lighter-duty and personnel transportation
- **Operational days:** 365 days per year (continuous operation)

Based on these assumptions, the annual fuel consumption and associated emissions are calculated as follows:

*Table 11: Vehicle Fleet Emissions Calculation*

| Fuel Type | Annual Consumption (liters) | Emission Factor (kg $CO_2e$/liter) | Annual Emissions (tonnes $CO_2e$) |
|---|---|---|---|
| Diesel | 12,600 | 2.68 | 33.8 |
| Gasoline | 184,608 | 2.31 | 426.4 |
| **Total** | **197,208** | **-** | **460.2** |

Vehicle fleet emissions total approximately 460.2 tonnes $CO_2e$, which represents 11.7% of the facility's Scope 1 emissions. While this is a significant contribution to Scope 1 emissions, it represents only about 0.12% of the total carbon footprint when Scope 2 emissions are included.

The emissions are dominated by the gasoline vehicles (92.7% of fleet emissions), despite their generally lower emission factors, due to their greater number and higher estimated usage rates.

Vehicle fleet emissions present a meaningful opportunity for emission reduction through several potential strategies:

- **Fleet Electrification:** Phased replacement of conventional vehicles with electric vehicles, particularly for the numerous light-duty gasoline vehicles
- **Hybrid Vehicle Integration:** Introduction of hybrid vehicles for applications where full electrification may not be immediately practical
- **Fleet Optimization:** Review of fleet size and usage patterns to identify opportunities for vehicle sharing or reduction
- **Eco-Driving Training:** Driver education programs to promote fuel-efficient driving

practices

- **Renewable Fuel Adoption:** Exploration of biodiesel or other lower-carbon fuels for diesel vehicles

These strategies will be further developed in the recommendations section, with consideration of their feasibility, cost implications, and potential emission reduction impact.

### 5.6 Total Scope 1 Emissions

Consolidating the emissions from all Scope 1 sources provides a comprehensive view of direct emissions from the Rabigh -3 SWRO Desalination Plant:

*Table 12: Summary of Scope 1 Emissions*

| Emission Source | Annual Emissions (tonnes $CO_2e$) | Contribution to Scope 1 (%) | Contribution to Total (%) |
|---|---|---|---|
| $CO_2$ Recovery Plant | 3,423.7 | 87.18% | 0.87% |
| Vehicle Fleet | 460.2 | 11.7% | 0.12% |
| Fire Fighting Pumps | 34.8 | 0.9% | 0.01% |
| Emergency Diesel Generators | 3.4 | 0.1% | <0.01% |
| Security Gate Genset | 1.7 | 0.04% | <0.01% |
| Fugitive Emissions (estimated) | 3.0 | 0.08% | <0.01% |
| **Total Scope 1** | **3,926.8** | **100%** | **1.00%** |

***Data Source: Please refer to Appendix-1***

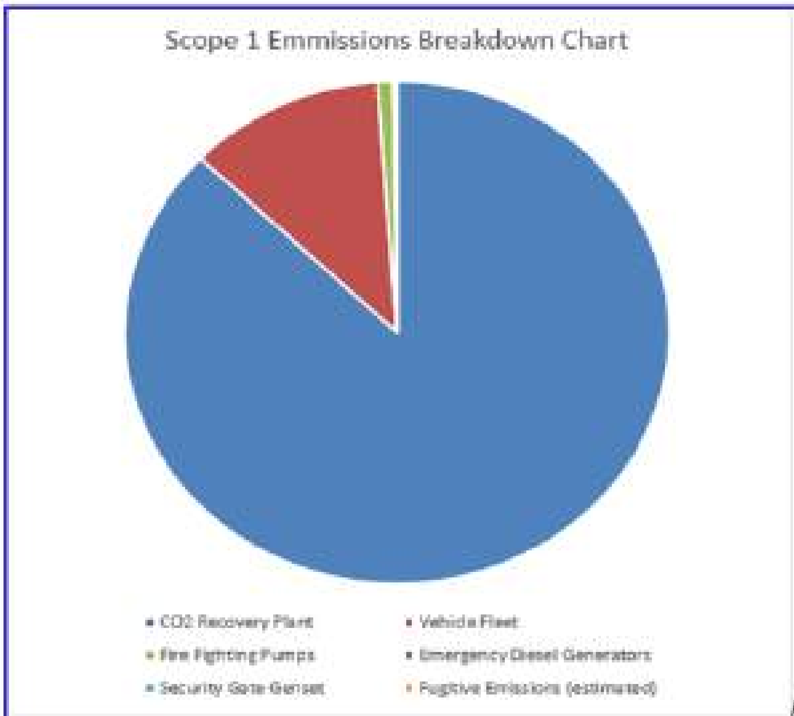



*Figure 5: Breakdown of Scope 1 Emissions by Source*

Total Scope 1 emissions amount to 3,926.8 tonnes $CO_2e$, representing approximately 1% of the facility's total carbon footprint. The $CO_2$ recovery plant is the dominant Scope 1 emission source, accounting for 87.2% of direct emissions and 0.87% of total emissions.

Vehicle fleet emissions represent the second largest Scope 1 source at 11.7% of direct emissions, while the remaining sources (firefighting pumps, emergency generators, security gate genset, and fugitive emissions) collectively account for just over 1% of Scope 1 emissions.

The relatively small contribution of Scope 1 emissions to the total carbon footprint reflects the nature of SWRO desalination, which is primarily electricity-intensive rather than fuel-intensive. However, Scope 1 emissions remain important for comprehensive carbon management and represent areas where the facility has direct operational control.

The dominance of the $CO_2$ recovery plant in the Scope 1 profile clearly identifies it as the primary target for direct emission reduction efforts. The vehicle fleet also presents meaningful opportunities for emission reduction through electrification and other strategies.

Monthly analysis of Scope 1 emissions reveals a relatively constant pattern throughout the year, with minor variations due to seasonal factors, maintenance schedules, and operational adjustments. This consistent profile suggests that emission reduction strategies can be implemented without significant concern for seasonal constraints.

# 6. Scope 2 Emissions Analysis

## 6.1 Grid Electricity Consumption

Electricity consumption represents the largest energy input to the Rabigh -3 SWRO Desalination Plant, powering the high-pressure pumps, pretreatment processes, post- treatment systems, and auxiliary equipment necessary for desalination operations.

Consequently, grid electricity usage is the dominant source of greenhouse gas emissions for the facility.

The plant's electricity consumption is calculated based on the specific energy consumption (SEC) of 3.16 $kWh/m^3$ and the annual water production volume of 219,000,000 $m^3$:

**Annual Electricity Consumption = 3.16 kWh/m3 × 219,000,000 m3 = 692,040,000kWh/year**

This specific energy consumption of 3.16 $kWh/m^3$ represents the total electricity usage per cubic meter of desalinated water produced, encompassing all facility operations. It falls within the typical range for modern SWRO plants with energy recovery devices, as identified in the literature review and benchmarking section.

The electricity consumption profile varies throughout the year due to several factors:

- **Seasonal Temperature Variations:** Higher seawater temperatures in summer months increase the osmotic pressure, requiring more energy for the RO process
- **Production Volume Fluctuations:** Monthly variations in water production volumes affect total electricity consumption
- **Maintenance Activities:** Scheduled and unscheduled maintenance may temporarily reduce electricity consumption
- **Seawater Quality Changes:** Seasonal algal blooms or other water quality issues may necessitate more intensive pretreatment, increasing energy consumption
- **Operational Optimizations:** Ongoing efficiency improvements and operational adjustments affect energy use

The breakdown of electricity consumption by major process areas provides insights into energy usage patterns and potential efficiency improvement opportunities:

*Table 13: Electricity Consumption by Process Area*

| Process Area | Percentage of Total | Annual Consumption (MWh) |
|---|---|---|
| High-Pressure Pumping (RO Feed) | 60% | 415,224 |
| Pretreatment | 15% | 103,806 |
| Intake Pumping | 10% | 69,204 |
| Post-treatment | 8% | 55,363.2 |
| Product Water Distribution | 5% | 34,602 |
| Auxiliary Systems | 2% | 13,840.8 |
| **Total** | **100%** | **692,040** |

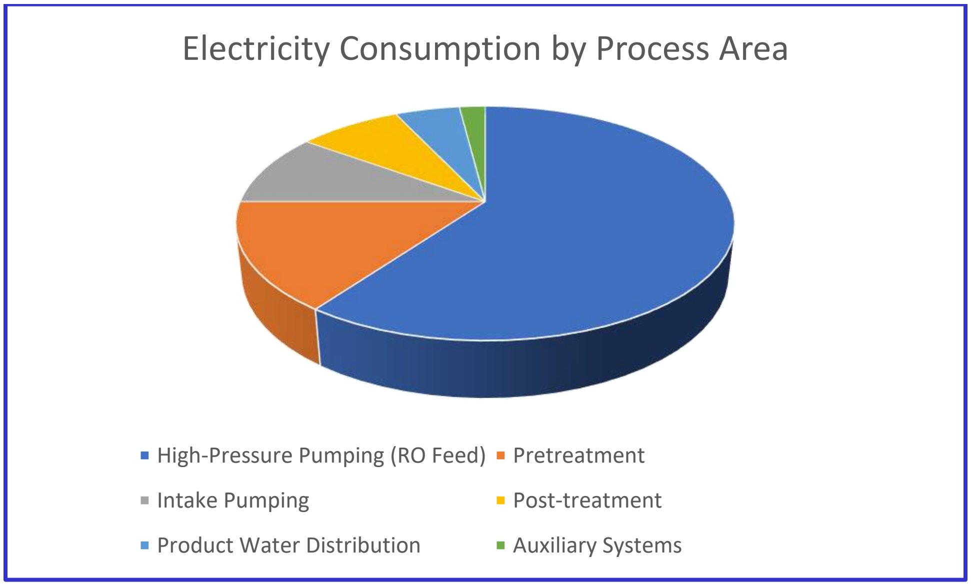



*Figure 6: Electricity Consumption by Process Area*

The high-pressure pumping systems for RO feed represent the largest electricity consumer, accounting for 60% of total electricity use. This is typical for SWRO plants and explains the critical importance of energy recovery devices (ERDs), which recover pressure energy from the concentrate stream to reduce the net energy required for high-pressure pumping.

Pretreatment and intake pumping collectively account for 25% of electricity consumption, highlighting the energy intensity of moving and preparing large volumes of seawater. Post-treatment, product water distribution, and auxiliary systems make up the remaining 15% of electricity use.

This distribution of electricity consumption informs prioritization of energy efficiency initiatives, with high-pressure pumping systems representing the most significant opportunity for impact.

## 6.2 Grid Emission Factor Analysis

The carbon intensity of grid electricity in Saudi Arabia is a crucial factor in determining the Scope 2 emissions of the Rabigh -3-SWRO Desalination Plant. The emission factor represents the amount of greenhouse gases emitted per unit of electricity generated and delivered through the grid.

Based on the latest data from the International Energy Agency (IEA, 2023), the grid emission factor for Saudi Arabia is 520 kg $CO_2e$/MWh. This reflects Saudi Arabia's electricity generation mix, which remains predominantly fossil fuel-based:

*Table 14: Saudi Arabia Electricity Generation Mix (2023)*

| Generation Source | Percentage of Mix (2023) |
|---|---|
| Natural Gas | 61% |
| Crude Oil | 39% |
| Solar | 0.5% |
| Other Renewables | <0.1% |

The high carbon intensity of Saudi Arabia's grid electricity significantly impacts the carbon footprint of grid-connected desalination plants. At 520 kg $CO_2e$/MWh, Saudi Arabia's grid emission factor is higher than the global average of approximately 442 kg $CO_2e$/MWh, though lower than some coal-dominated grids that can exceed 800 kg $CO_2e$/MWh.

*Table 15: Saudi Arabia Electricity Generation Mix in comparison with other progressive countries (2023)*

| Country | Natural Gas (%) | Crude Oil (%) | Solar (%) | Other Renewables (%) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Saudi Arabia** | 61 | 39 | 0.5 | < 0.1 |
| **United States** | 16 | 0.5 | 4.9 | 21.3 |
| **Germany** | 15.7 | 0.2 | 13.7 | 22.9 |
| **France** | 5.8 | 0.1 | 3.9 | 10.6 |
| **United Kingdom** | 34.3 | 0.1 | 28.7 | 36.9 |

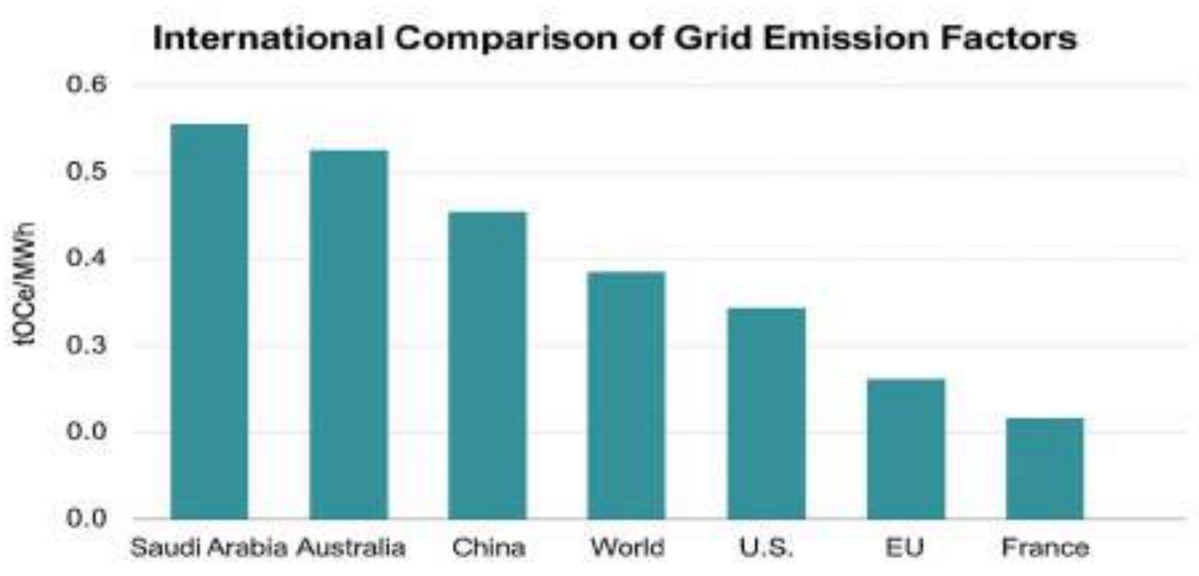



*Figure 7: International Comparison of Grid Emission Factors*

Looking forward, Saudi Arabia's grid emission factor is expected to decrease over time as the Kingdom implements its renewable energy targets under Vision 2030 and the Saudi Green Initiative. The target of generating 50% of electricity from renewable sources by 2030 would substantially reduce the grid emission factor, benefiting all grid-connected facilities including the Rabigh -3- SWRO Desalination Plant.

Using the current grid emission factor 0.5059 kg $CO_2$e/kWh (Climate Transparency, 2020), Scope 2 emissions from the facility's electricity consumption are calculated as follows:

**Scope 2 Emissions = = 692,040,000kWh/year × 0.5059 kg/kWh = 350,320,836 kg $CO_2$e/year**

**=353,320.8 tonnes $CO_2$e/year**

These Scope 2 emissions represent 98.7% of the facility's total carbon footprint, underscoring the critical importance of electricity-related emissions in the overall environmental profile of the desalination plant.

Comparing the process-specific energy consumption with industry benchmarks helps identify areas where the facility is performing well and where improvements might be possible:

***Table 16: Energy Consumption Benchmarking and Improvement Potential***

| **Process** | **Rabigh -3 SEC ($kWh/m^3$)** | **Industry Best Practice ($kWh/m^3$)** | **Improvement Potential** |
|---|---|---|---|
| High-Pressure Pumping | 1.90 | 1.80 - 1.95 | 4.4% - 11.8% |
| Pretreatment | 0.47 | 0.40 - 0.48 | 5.9% - 21.6% |
| Intake Pumping | 0.32 | 0.28 - 0.32 | 5.9% - 17.6% |
| Post-treatment | 0.25 | 0.25 - 0.30 | -11.1% - 6.7% |
| Product Water Distribution | 0.16 | 0.15 - 0.20 | -17.6% - 11.8% |
| Auxiliary Systems | 0.06 | 0.05 - 0.08 | -14.3% - 28.6% |
| **Total** | **3.16** | **2.93 - 3.33** | **2.1% - 13.8%** |

This analysis suggests potential for energy efficiency improvements of 2.1% to 13.8% across the entire facility, with the greatest opportunities in high-pressure pumping, pretreatment, and intake pumping. These areas will be prioritized in the recommendations section.

### 6.3 Monthly Variations

Monthly variations in electricity consumption and associated emissions provide insights into seasonal patterns and operational factors affecting the plant's carbon footprint. While detailed monthly data is not provided in the source materials, typical patterns for SWRO plants in the region can be used to estimate monthly variations.

Key factors influencing monthly variations include:

- **Seawater Temperature:** Summer months (June-September) typically experience higher seawater temperatures, increasing osmotic pressure and energy requirements by 5-10%
- **Demand Patterns:** Peak water demand during summer months may necessitate operating at higher capacity utilization
- **Maintenance Schedules:** Planned maintenance activities, typically scheduled during months with lower demand, may temporarily reduce energy consumption
- **Seawater Quality:** Seasonal algal blooms or other water quality changes may affect pretreatment energy requirements

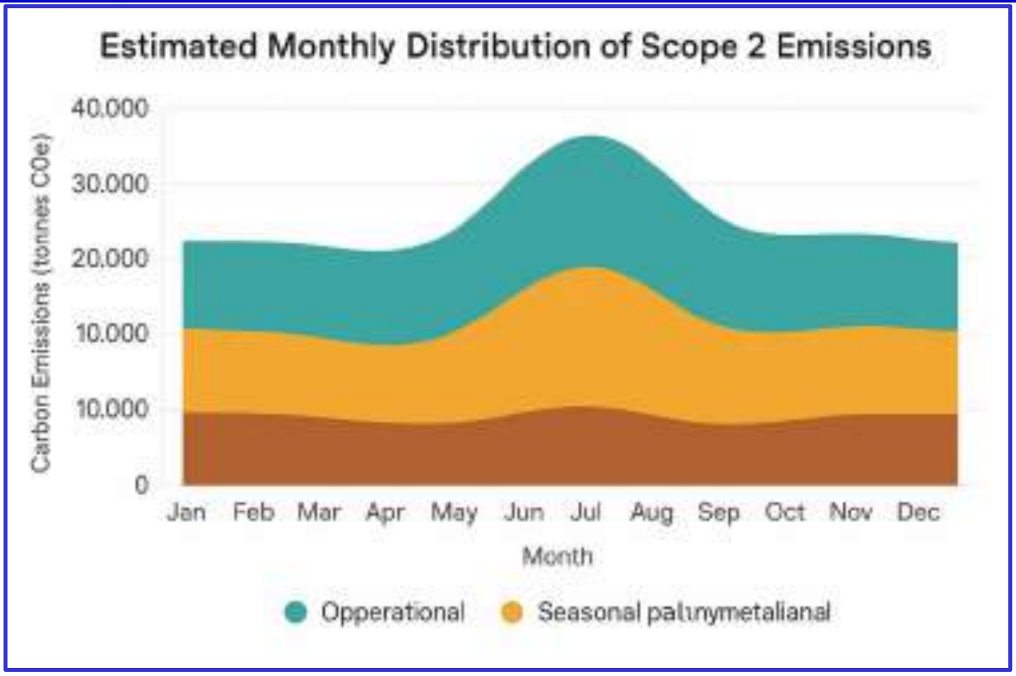



*Figure 8: Estimated Monthly Distribution of Scope 2 Emissions*

Understanding these monthly variations is important for several reasons:

1. **Operational Optimization:** Identifying periods of higher energy intensity allows for targeted operational adjustments
2. **Maintenance Planning:** Scheduling intensive maintenance during naturally lower-efficiency periods can minimize overall impact
3. **Renewable Energy Integration:** Matching renewable energy production profiles with consumption patterns enhances the effectiveness of on-site generation
4. **Performance Monitoring:** Establishing monthly baseline expectations enables more accurate tracking of improvement initiatives

Monthly emission profiles will inform the development of targeted emission reduction strategies in the recommendations section, particularly regarding the optimal timing and focus of efficiency initiatives and renewable energy integration.

# 7. Total Carbon Footprint Assessment

## 7.1 Comprehensive Results

The carbon footprint assessment has been conducted in accordance with the **GHG Protocol**, **IPCC 2006 Guidelines**, and **ISO 14064-1** standards. Scope 1 (direct), Scope 2 (indirect from energy), and selected Scope 3 (value chain) emissions were analysed using available activity data and relevant country-specific emission factors.

- **Fuel Emissions Factors** (Diesel): IPCC Default – 2.68 kg $CO_2$/litre
- **Electricity Emission Factor (Saudi Arabia)**: **0.5059 kg $CO_2e$/kWh**
  *Source: Climate Transparency Report 2020*

Combining the results from the Scope 1 and Scope 2 analyses, along with the limited assessment of selected Scope 3 emissions, provides a comprehensive view of the Rabigh -3-SWRO Desalination Plant's carbon footprint:

***Table 17: Comprehensive Carbon Footprint Assessment Results***

| Scope | Source | Activity Data | Emissions (t $CO_2e$/year) | % of Total |
|---|---|---|---|---|
| Scope 1 | $CO_2$ Recovery Plant | 1,277,500 L (Disel) | 3,423.7 | 0.95% |
| | Vehicle Fleet | 197,208 L (Disel) | 460.2 | 0.12% |
| | Fire Fighting Pumps | 13,000 L | 34.8 | 0.009% |
| | Emergency Diesel Generators | 1,250 L | 3.4 | <0.01% |

| | | | | |
|---|---|---|---|---|
| | Security Gate Genset | 625 L | 1.7 | <0.01% |
| | Fugitive Emissions | Estimated | 3.0 | <0.01% |
| Scope 2 | Grid Electricity | 692,040,000kWh/year | 353,320.8 | 98.44% |
| | Chemicals | 800,000 kg | 1,200.0 | 0.33% |
| Selected Scope 3 | Wastewater Treatment | 500,000 $m^3$ | 350.0 | 0.09% |
| | Solid Waste | 1,000 t | 100.0 | 0.02% |
| **Total** | | | **3,58,897.6** | **100%** |

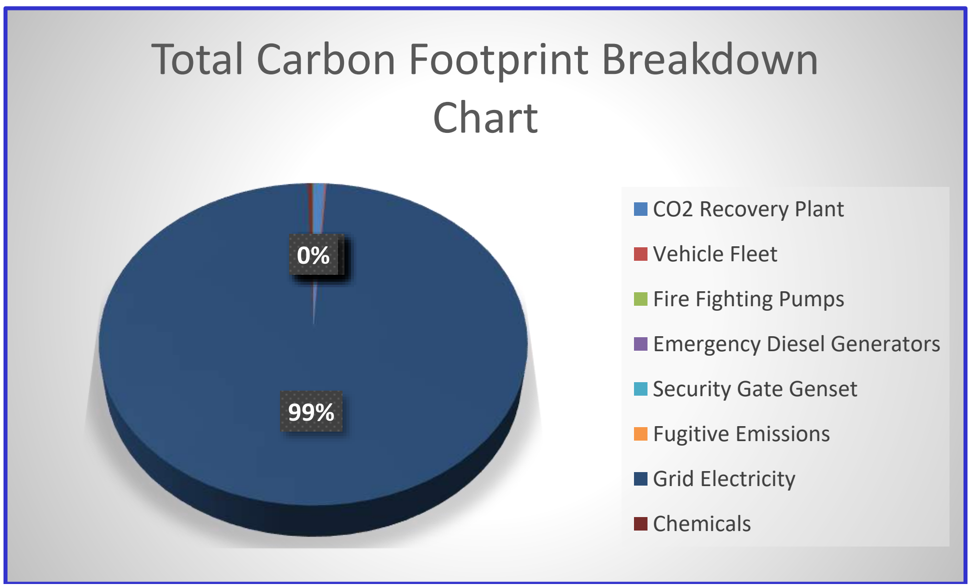



*Figure 9: Breakdown of Total Carbon Footprint by Source*

The total annual carbon footprint of the Rabigh -3- SWRO Desalination Plant is 3,58,897.6 tonnes $CO_2e$. Scope 2 emissions from grid electricity consumption dominate the footprint, accounting for 98.44% of total emissions. Scope 1 emissions contribute approximately 1.11%, with the $CO_2$ recovery plant representing the largest Scope 1 source. Selected Scope 3 emissions account for the remaining 0.11%.

This distribution is typical for modern SWRO desalination plants, which are predominantly electricity-intensive operations. The high proportion of Scope 2 emissions highlights the critical importance of grid decarbonization and renewable energy integration for achieving significant reductions in the plant's carbon footprint.

**Recommendations**

| Category | Recommendations |
|---|---|
| **Grid Electricity** | Consider sourcing from solar PV farms (on-site or via PPA) to reduce Scope 2 load. |
| **Diesel Usage** | Switch to biodiesel blends or evaluate LNG-based backup systems. |
| **Vehicle Fleet** | Gradually transition to EVs for intra-site transport and administrative use. |
| **Chemicals and Process** | Track chemical-specific GHG factors for better process emission accuracy. |
| **Waste Management** | Improve segregation, composting and recycling programs to lower Scope 3 footprint. |

# 8. Conclusion and Recommendations

The analysis shows that $CO_2$ emissions are overwhelmingly high due to the $CO_2$ plant's diesel use. To reduce the plant's carbon footprint, we recommend:

**Total Emissions**

- The total GHG emissions for the year 2024 - 2025 amount to **358,897.6 tonnes of $CO_2$e/year**.
- This includes direct emissions (**Scope 1**), indirect energy emissions (**Scope 2**), and selected upstream/downstream emissions (**Scope 3**).

***The assessment of GHG emissions and Carbon foot print revealed that the plant is highly energy efficient 3.16 kWh /M3(High energy efficiency target: ≤3.5 kWh/m³, enhancing sustainability)***

- **Fuel substitution:** Consider renewable diesel or high-blend biodiesel. Biofuels combust more cleanly and have lower life-cycle $CO_2$. (Argonne GREET modeling suggests renewable diesel can cut >68% of $CO_2$ vs. petroleum diesel, and biodiesel blends up to 75%up.com.) Even partial biodiesel blends (e.g. B20 or renewable diesel blends) would reduce the effective emission factor below 2.68 kg/L.
- **Efficiency improvements:** Ensure all generators and pumps are well-maintained (optimal tuning, combustion efficiency) to minimize fuel burn per output. Evaluate whether the $CO_2$ plant's process can be optimized or partially powered by waste heat or electricity.
- **Renewable energy integration:** Where feasible, use renewable power (solar PV, wind) instead of diesel. For example, on-site solar could offset hundreds of tonnes $CO_2$/year (650 kW of PV offset ~474 $tCO_2$ annually in one industrial case crescent .education).

- **Operational measures:** Reduce unnecessary running hours. For weekly/monthly tests, confirm they are strictly needed. If some back-up generators sit idle, minimize testing duration. For the $CO_2$ plant, assess if fuel demand can be lowered by process adjustments.
- **Carbon offsets and reforestation:** As a longer-term measure, consider tree planting or other offset projects. (One reported case achieved >10% offset of its emissions by on-campus forestry crescent. education.)

Implementing these steps will shrink Rabigh-3- IWP's scope-1 $CO_2$ emissions. Given the magnitude from the $CO_2$ plant, targeting that source (via cleaner fuel and efficiency) offers the greatest immediate benefit. With cleaner fuels or reduced diesel use, the facility could cut its monthly emissions by tens of percent or more. up.comenvironment.govt.nz.

# 9. References

## 9.1 Appendix A: Detailed Calculations

### Scope 1

**Diesel:** 1 292 375 L × 2.68 kg CO2e/liter = 3 463 365 kg CO2e = 3463 t CO2e.

### Scope 2

**Electricity: Scope 2 Emissions = = 692,040,000kWh/year × 0.5059 kg/kWh =**

**350,320,836 kg $CO_2$e/year**

### Scope 3

**Chemicals:** 800 000 kg × 1.5 kg CO2e/kg = 1 200 000 kg CO2e = 1200 t CO2e.

**Wastewater:** 500 000 m3× 0.7 kg CO2e/m3 = 350 000 kg CO2e = 350 t CO2e.

**Solid Waste:** 1000 t × 100 kg CO2e/ton = 100 000 kg CO2e = 100 t CO2e.

## 9.2 Appendix B: Data Sources

• Operational logs for diesel consumption.

• IEA, IPCC, Ecoinvent, and USEPA for emission factors.

**File 1 (Disel consumption.xlsx):**

It gives the annual diesel consumption for different equipment:

- EDG (Emergency Diesel Generator) → 1,250 liters/year
- FF Pumps (Fire Fighting Pumps) → 13,000 liters/year
- Security Gate Genset → 625 liters/year
- $CO_2$ Plant → 1,277,500 liters/year

→ Total annual diesel consumption (provided in the file) = 1,292,375 liters/year

**File 2 (______ ________.xlsx):**

It lists fuel tank capacities and vehicle counts, mainly in Arabic, showing:

- Tank capacities (e.g., 80 L, 120 L, etc.)
- Fuel type (diesel or gasoline)
- Number of vehicles

**Data was sourced as follows:**

• Diesel Consumption: From operational records, totaling 1 292 375 L/ (Table 1).

• Electricity Consumption: Calculated as 692,040,000kw/, based on 3.16kW h m−3 and 219 000 000 m3 annual production.

• Chemical Usage: Estimated at 800 000 kg/ for antiscalants, coagulants, and disinfectants.

• Waste Management: 1000 t/ of solid waste and 500 000 m3 / of treated wastewater.

**Table 1: Annual Diesel Consumption by Equipment**

| Equipment | Diesel Consumption (liters/year) |
|---|---|
| Emergency Diesel Generator | 1250 |
| Fire Fighting Pumps | 13000 |
| Security Gate Genset | 625 |
| CO2 Recovery Plant | 1277500 |
| Total | 1292375 |

Emission factors are sourced from reputable databases (Table 2).

**Table 2: Emission Factors Used in the Assessment**

| Source | Unit | Emission Factor (kg CO2e/unit) | Reference |
|---|---|---|---|
| Grid Electricity (Saudi) | MWh | 520 | IEA 2023 |
| Diesel Fuel | Liter | 2.68 | IPCC 2006 |
| Chemicals (average) | kg | 1.5 | Ecoinvent |
| Wastewater Treatment | m3 | 0.7 | USEPA |
| Solid Waste (landfilled) | ton | 100 | IPCC 2006 |

## 9.3 Appendix C: Section 17

# CLIMATE CHANGE AND GREENHOUSE GASE EMMISSIONS FROM RABIGH THREE SWRO DESALINATION PLANT

## 17.1 Introduction

This chapter describes the assessment outcomes of the potential impacts of the Project on the climate and its contribution of greenhouse gases (GHG) to the atmosphere.

The scope of the assessment of impacts is defined in section 5 ESIA Methodology concluding the following impacts are scoped in for assessment:

**Construction Phase:**

- GHG from on-site power generators, heavy machinery and vehicle/vessel movement
- GHG from embodied carbon through material extraction and manufacturing processes

**Operational Phase:**

- GHG from vehicle movements
- GHG from wastewater treatment and water supply
- GHG from waste management
- GHG from maintenance of buildings and infrastructure assets
- Impacts to the Project powered by climate change

In line with the IEMA guidance (2015 and 2017); this assessment looks at the Lifecycle greenhouse gas (GHG) impact - the impact of GHG emissions arising from the Project on the climate during the lifecycle stages within the scope of the assessment

## 17.2 Legislative Framework

This section outlines the international and national standards relevant to the climate change assessment. These standards and guidelines have been used to identify appropriate methodologies, receptors, environmental impacts and relevant mitigation measure.

### 17.2.1 International Standards

#### 17.2.1.1. The Equator Principles Version 4 (EP4)

The Equator Principles (EPs) are a risk management framework adopted by financial institutions for determining, assessing and managing environmental and social risk in projects. Currently, over 100 EP Financial Institutions (EPFIs) in 38 countries have officially adopted the EPs. The effective date for EP4 on all mandated transactions will be 1 July 2020 (Equator Principles, 2020). The EPFIs will only provide financing to projects that meet the relevant requirements of Principles 1 to 10. The requirements of the principles of direct relevance to the Project are described below:

- P2 – Environmental and Social Assessment – Category A and, as appropriate, Category B projects53, as defined using the IFC environmental and social categorization process (IFC, 2020), will be required to undertake an environmental and social risk assessment, the documentation of which must include an ESIA.
- *A Climate Change Risk Assessment is also required for "all Projects, in all locations, when combined Scope 1 and Scope 2 Emissions are expected to be more than 100,000 tonnes of carbon dioxide equivalent (tCO2e) annually. Consideration must be given to relevant Climate Transition Risks (as defined by the TCFD54) and an alternatives analysis completed which evaluates lower Greenhouse Gas (GHG) intensive alternatives."*

(According to the EP4, "there can be a range in the scale of potential environmental and social risks and impacts within Projects classified as Category B. In general terms, higher risk Category B Projects will be treated similarly to Category A Projects, and lower risk Category B Projects could be treated in a lighter regime. The EPFI shall, at their own discretion, determine the appropriate level of Assessment Documentation, review, and/or monitoring required to address these risks and impacts in accordance with Principles 1-10.")

- P4 - Environmental and Social Management System and Equator Principles Action Plan - For all Category A and Category B Projects, the EPFI will require the development of an Environmental and Social Management System (ESMS) and of an Environmental and Social Management Plan (ESMP) to address issues raised in the assessment process, incorporating actions required to comply with the applicable standards.

#### 17.2.1.2 Paris Agreement

The central aim of the Paris Agreement, published by the United Nations Framework Convention on Climate Change (UNFCC), is to facilitate a global response to the threat of climate change and to keep global temperature rise this century well below 2$^0$C above pre-industrial levels (UNFCC, 2015). A more ambitious aim within the Paris Agreement includes limiting the temperature increase even further to 1.5$^0$C.

#### 17.2.1.3 Environmental Impact Assessment Guide to: Assessing Greenhouse Gas Emissions and Evaluating their Significance

In the absence of any widely accepted guidance on assessing the significance of the impact of GHG emissions, guidance published by IEMA in 2017 has been followed as it provides a framework for taking GHG emissions into account in the ESIA process (IEMA, 2017), in line with the 2014 European Union (EU) Directive (Directive 2014/52/EU; European Union, 2014). The guidance sets out how to:

- Identify the GHG emissions baseline in terms of current and future emissions;
- Identify key contributing GHG sources and establish the scope and methodology of the assessment.
- Assess the impact of potential GHG emissions and evaluate their significance; and
- Consider mitigation in accordance with the hierarchy for managing project related GHG emissions - avoid, reduce, substitute, and compensate.

#### 17.2.1.4 Environmental Impact Assessment Guide to: Climate Change Resilience and Adaptation

IEMA guidance has also been followed as it provides guidance for taking the impacts of climate change into account within the project design (IEMA, 2015). The guidance sets out how to:

- Define climate change concerns and environmental receptors vulnerable to climate factors;
- Define the environmental baseline with changing future climate parameters; and
- Determine the resilience of project design and define appropriate mitigation measures to increase resilience.

### 17.2.2 National Standards

#### 17.2.2.1 Saudi Vision 2030

The Saudi Vision 2030 highlights the importance of moving towards a greater uptake of renewable energy production and use and outlines an initial target of generating 9.5 gigawatts of renewable energy by 2030 (KSA, 2016a). The vision 2030's major concern is Climate change and Sustainability. Most of the Desalination (New) are integrated with Solar PV, Example, Shoaiba, Jubail, Shuqaiq, Umluz etc.

## 17.3 Spatial and Temporal Boundaries

The spatial study area covers direct GHG emissions arising from activities undertaken within the Project boundary during the construction and operation of the Project. It also includes indirect embodied emissions within construction materials, arising as a result of the energy used for their production, including extraction, processing, manufacture and transportation.

The temporal study period is the next 60 years up to 2080. However, no emissions inventory projections or Paris Agreement targets are available beyond 2050 within the Climate Action Tracker (Climate Action Tracker, 2019).

## 17.4 Baseline

This section describes the baseline environmental characteristics for the Project and surrounding environment with specific reference to GHG emissions and climatic conditions.

### 17.4.1 Lifecycle GHG Impact Assessment

This is a business as usual, or 'do-nothing' scenario, whereby the Project is not consented, for those lifecycle stages within the scope of the assessment, outlined in section 17.7.1. The quantity of GHG emissions would, therefore, remain unchanged from the current level.

As the current land use of the site is undeveloped land, and there is currently no consented development within the site boundary, the baseline emissions for the lifecycle GHG impact assessment are zero.

## 17.5 Receptors

Based on a review of the baseline conditions, the global climate is the receptor for the lifecycle

GHG impact assessment. The sensitivity of this receptor is high, in line with the IEMA guidance (IEMA, 2017) that highlights the importance of mitigating GHG emissions to reduce the impacts of climate change.

## 17.6 Impact Assessment and Mitigation

In line with the World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) GHG Protocol guidelines (WBCSD & WRI, 2004), GHG emissions are reported as tonnes of carbon dioxide equivalent ($tCO_2e$), which takes into account the seven Kyoto Protocol gases:

- Carbon dioxide ($CO_2$).
- Methane ($CH_4$).
- Nitrous oxide ($N_2O$).
- Sulphur hexafluoride ($SF_6$).
- Hydrofluorocarbons (HFCs).
- Perfluorocarbons (PFCs).
- Nitrogen trifluoride ($NF_3$).

Where activity data has allowed, expected construction and operational GHG emissions have been quantified using a calculation-based methodology as per the following equation.

- *Activity data x GHG emissions factor = GHG emissions value*

  A combination of following relevant emissions factors have been used for the purpose of this assessment:

- UK Department for Environment, Food and Rural Affairs (DEFRA) and the Department of Business, Energy and Industrial Strategy (DBEIS) (DEFRA & DBEIS, 2019) GHG reporting conversion factors;
- Embodied carbon benchmark data from the RICS Global Methodology to Calculate Embodied Carbon (RICS, 2012); and
- EU Commission guidelines for the calculation of land carbon stocks (EU Commission, 2010).

#### 17.6.1 In-built Design Mitigation

In-built mitigation has been factored, where possible, into the CO2e emissions values presented below. However, while carbon offsetting will be undertaken in line with the Net Zero Carbon requirement. As a result of the uncertainty around the specific approach at this stage, this assessment includes all emissions prior to carbon offsetting, and therefore presents a worst-case scenario.

#### 17.6.2 Assessment of Impacts

##### 17.6.2.1Greenhouse Gas (GHG) Emissions

**Construction Phase**

The primary GHG emissions sources and the breakdown of the calculated GHG emissions during construction are shown in Table 17.1. A number of assumptions regarding construction GHG emissions, embodied carbon and carbon sinks have made with detailed construction methods and landscaping plans not being fully developed at the time of this report. These are noted here:

- No estimates for energy and fuel use, material transportation, waste transportation and disposal have been developed for the construction stage. Emissions associated with these activities have therefore not been quantitatively assessed. These aspects have instead been considered qualitatively and it is anticipated that their exclusion will not have an impact on the overall outcome of the assessment.
- The vegetation in Ras Moheisen area is too sparse.
- There are no specific carbon factors available for embodied carbon, vehicle use, water use, and waste disposal specific to KSA. The RICS embodied carbon benchmark (RICS, 2012) and various emissions factors used (DEFRA & DBEIS, 2019) are based on UK construction and energy use data. While they will not directly represent the embodied carbon emissions associated with processes within KSA, they provide a reasonable indication. It is not anticipated that any inaccuracies inherent within these factors will affect the outcome of the overall assessment.

- The construction workers have been assumed to be transported 1km from their accommodation to the site by Bus and cars each day. The emissions factor for Bus/Cars has been applied, accounting for WTT losses.
- The emissions factors applied are outlined below:

**Table 17.1 Construction GHG Emissions**

| Project Activity/Emissions Source | Annual Emissions (tCO2e) |
|---|---|
| GHGs from on-site power generators, | 465 |
| | |
| | |
| | |
| | |

**The total may not equate to the sum of the emissions reported due to rounding of the decimals. This is an example from a project similar to Ras Moheisen Plant. This illustration considers a similar Environmental Setting.*

The construction Contractor-EPC /Operation and Maintenance Company will calculate the exact GHG Emissions while preparing their CESMP and OESMP before construction and Operation respectively, Scope 1 and 2 will be GHG emissions and carbon foot print will be conducted by M/s ACWA Power and EPC Contractors.

The following guideline from IFC states

*"A **Climate Change Risk Assessment is also required for "all Projects, in all locations, when combined Scope 1 and Scope 2 Emissions are expected to be more than 100,000 tonnes of carbon dioxide equivalent (tCO2e) annually. Consideration must be given to relevant Climate Transition Risks (as defined by the TCFD54) and an alternatives analysis completed which evaluates lower Greenhouse Gas (GHG) intensive alternatives**."*

The overall construction emissions equate to approximately 6856tCO2e over the 30 Months construction period of the Project between 2025 and 2028, resulting in 3491tCO2e emissions annually. (The calculation is approximate based on the example of a Desalination Plant equivalent to Ras Moheisen 300 MLD SWRODP capacity. This may slightly vary with the equipment and Technology, energy source etc.)

**Table 17.2 Impact Assessment for the Lifecycle GHG Emissions during Construction**

| Impact | Project Phase | Impact Magnitude | Receptors Sensitivity | Impact Significance | Residual Impact |
|---|---|---|---|---|---|
| GHG emissions from on-site power generators, | Construction | Low | Low | Minor | Minor |
| GHG emissions from embodied | Construction | Low | Low | Moderate | Minor |

**Mitigation:**

**Enhance:**

- Changes in current land use through landscaping and golf course will positively impact on carbon sinks. Of course, this enhancement must be assessed in conjunction to the impact on natural habitats and species but where these areas can be mutually beneficial these should be strengthened and maximized.

**Avoid:**

- The choices of materials and products to be used should be reconsidered through the design development and procurement strategies, particularly in terms of embodied carbon and lifecycle GHG.

**Minimize:**

- As quantification details emerge, these should be tested against the assumption made in the section as it is critical to the assessment of the carbon offset projects and the commitments made by M/S International Company for Water and Power Projects (ACWA Power) & EPC to net zero carbon.

The circular economy principles must be embedded in procurement.

**Operational Phase**

In accordance with the EP4 climate risk management framework the following Green Element (2017) definitions of scope 1, scope 2 and scope 3 climate change emissions should be applied for the assessment of GHG estimation:

**Scope 1 – All Direct emissions** from the activities of an organization under their control. This includes fuel combustion on site, from owned vehicles and fugitive emissions.

**Scope 2 – Indirect emissions** from electricity purchased and used by the organization.

**Scope 3 – All other indirect emissions** from activities of the organization, but those occurring from sources they do not own or control, including emissions associated with business travel, procurement, waste and water.

The primary GHG emissions sources and the breakdown of the calculated GHG emissions during operation from a similar project to RM-SWRODP is shown in Table 17-3. A number of assumptions regarding operation GHG emissions have had to be made due to the lack of detailed operational plan information. These are noted here:

- It is also not been possible to quantify GHG emissions associated with building and infrastructure maintenance during operation due to data limitations at this stage of the design. This aspect has instead been considered qualitatively in section 19.6, and it is not anticipated that this exclusion will have an impact on the overall outcome of the assessment.

For operational vehicle use, the following assumptions have been made:

- Organic waste is assumed to be composted, while residual waste is assumed to be sent to landfill. For mixed recycling, an average emissions factor for the recycling of glass, metal, plastics and paper/board has been applied.

**Table 17.3 Operation GHG Emission**

| Project Activity/Emissions Source | Annual Emissions (tCO2e) |
| --- | --- |

| | |
|---|---|
| Vehicle journeys | 3123 |
| Waste disposal | 44 |
| Water use | 718 |
| Total | 3885[57] |

The operational GHG emissions from vehicle journeys, waste disposal and water use equate to approximately 3885tCO2e annually

**Avoid:**

The choices of materials to be used should be reconsidered through the design development in particularly in terms of embodied carbon, this is a commitment that emanates through M/S International Company for Water and Power Projects (ACWA Power) and EPC 's choice to embody Green Building and Sustainability Benchmark requirements in their operations.

**Minimize:**

As quantification details emerge, these should be tested against the assumption made in the section as it is critical to the assessment of the carbon offset projects and the commitments made by M/S International Company for Water and Power Projects (ACWA Power) consortium to net zero carbon.

The circular economy principles must be embedded in procurement.

**Table 17.4 Contribution of the Ras Moheisen Operational GHG Emissions to KSA's Emissions Inventory (Approximate figures)**

| Project Phase | Relevant Reporting Year | Annual Emissions Inventory (tCO2e)[58] | Annual GHG Emissions for Reporting Year (tCO2e) | % of Emissions Inventory |
|---|---|---|---|---|
| Construction | 2022 | 563 333 33 | 6856 | 0.00071 |
| Operation | 2024 | 407 500 00 | 3885 | 0.00039 |

## 17.7 Conclusions

Approximate GHG emissions associated with the construction phase equate to approximately 6856CO2e over the 30 months construction period of the Project between 2025 and 2028, resulting in 3885tCO2e emissions annually. Annually, operational GHG emissions equate to approximately 3885tCO2e.

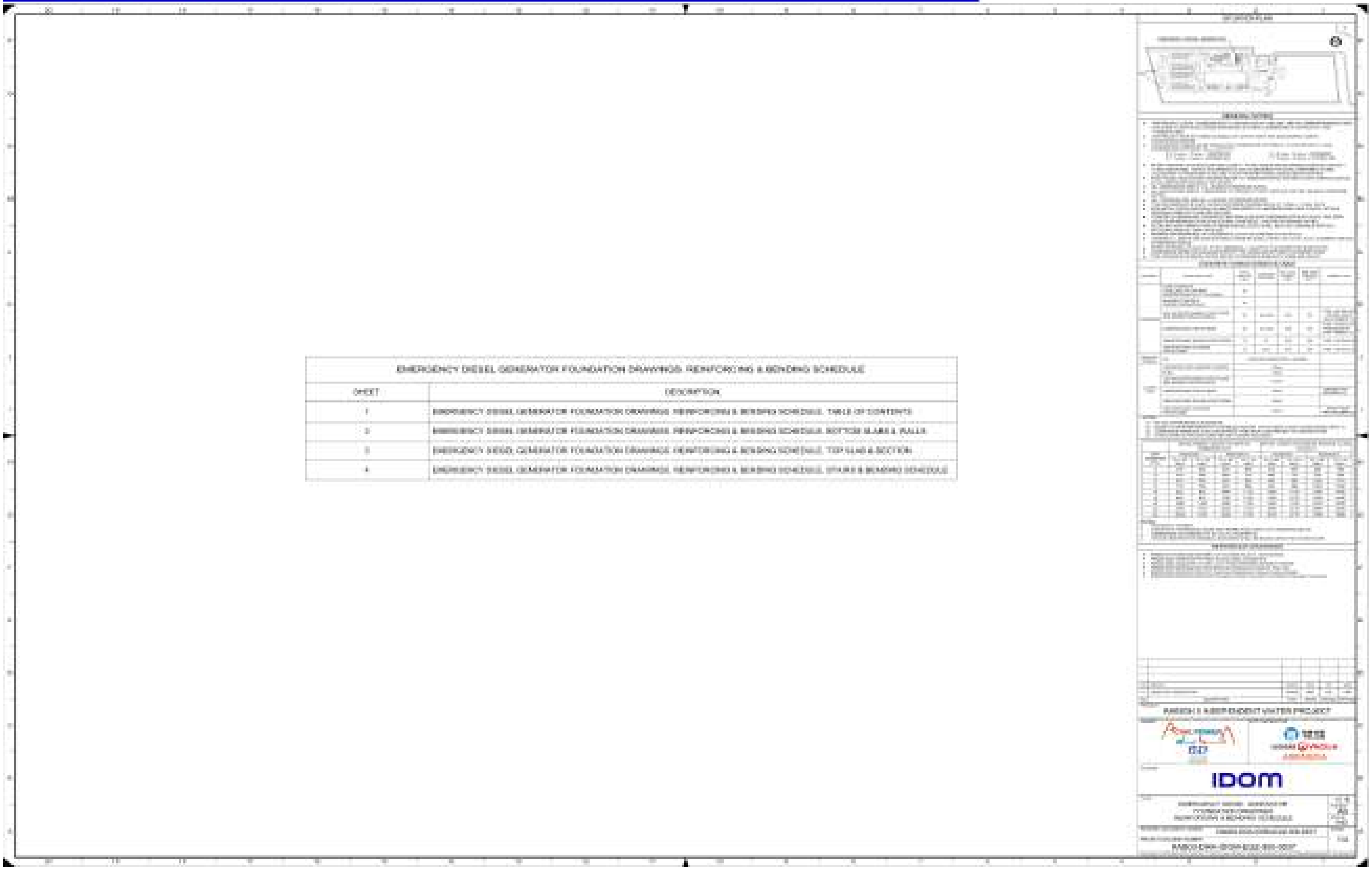
When these GHG emissions are contextualized using KSA's emissions inventory, they account for 0.00071% of annual emissions during the construction phase (2025~2028), and 0.00039% of annual emissions during operation (2028).

Although many assumptions have been made regarding fuel use, transport of waste and materials as well as infrastructure maintenance, once further information becomes available these assumptions must continue to be checked to ensure that the commitments to zero carbon operational energy are upheld.

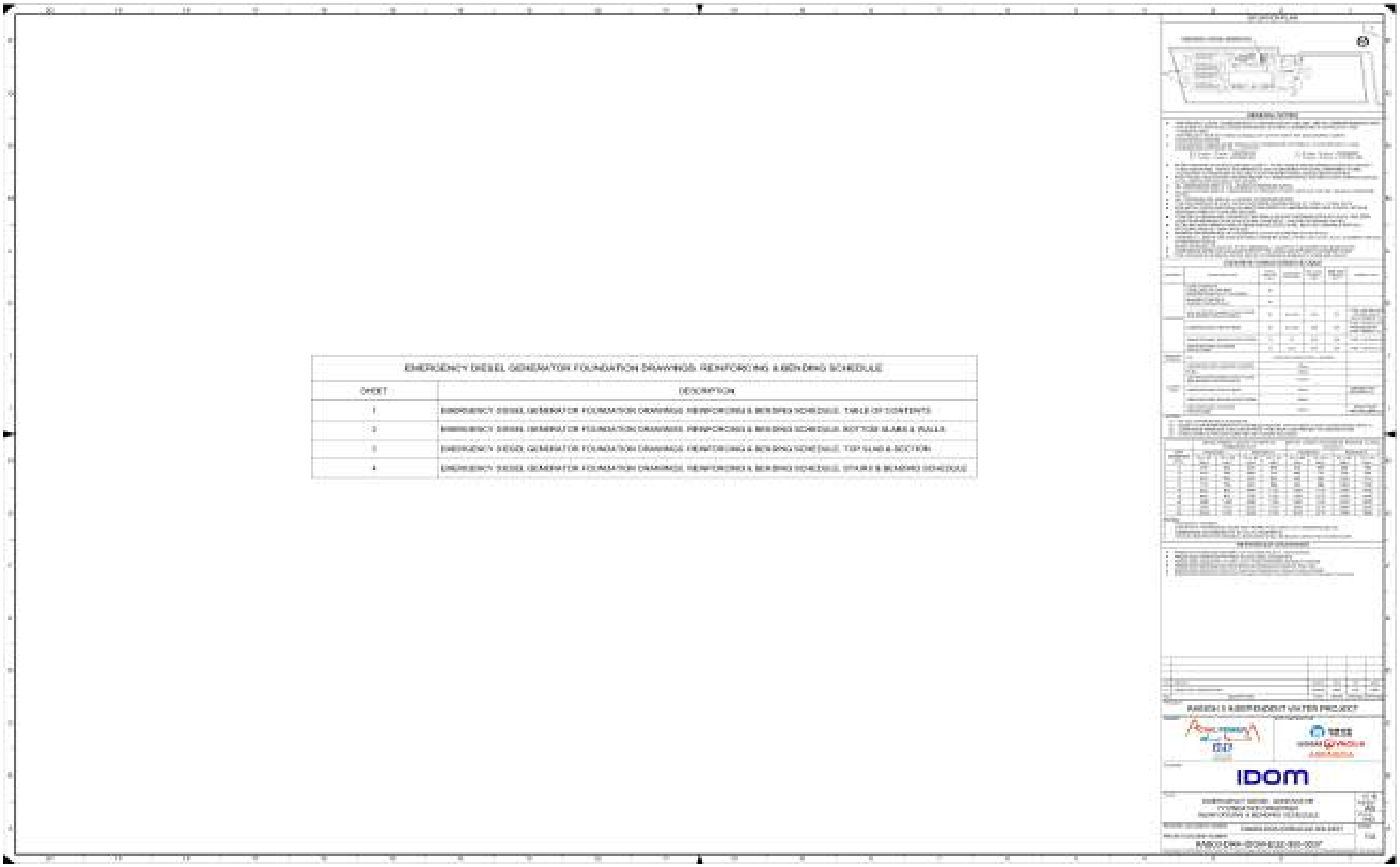
As construction and operational GHG emissions equate to less than 0.1% of the annual national emissions inventory for KSA, and Scope 1 and Scope 2 emissions are below the threshold of 100 000tCO2e per annum, the magnitude of impact is low and therefore the construction and operational GHG impact is of minor adverse significance, both in the context of KSA's national emissions inventory and in terms of Scope 1 and Scope 2 emissions arising from a single development.

As the GHG emissions are of minor adverse significance, no additional mitigation and monitoring is required during the construction or operation of the Project.

## DATA RECEIVED FROM THE CLIENT

| EMERGENCY DIESEL GENERATOR FOUNDATION DRAWINGS. REINFORCING & BENDING SCHEDULE | |
|---|---|
| SHEET | DESCRIPTION |
| 1 | EMERGENCY DIESEL GENERATOR FOUNDATION DRAWINGS. REINFORCING & BENDING SCHEDULE. TABLE OF CONTENTS |
| 2 | EMERGENCY DIESEL GENERATOR FOUNDATION DRAWINGS. REINFORCING & BENDING SCHEDULE. BOTTOM SLABS & WALLS |
| 3 | EMERGENCY DIESEL GENERATOR FOUNDATION DRAWINGS. REINFORCING & BENDING SCHEDULE. TOP SLAB & SECTION |
| 4 | EMERGENCY DIESEL GENERATOR FOUNDATION DRAWINGS. REINFORCING & BENDING SCHEDULE. STAIRS & BENDING SCHEDULE |



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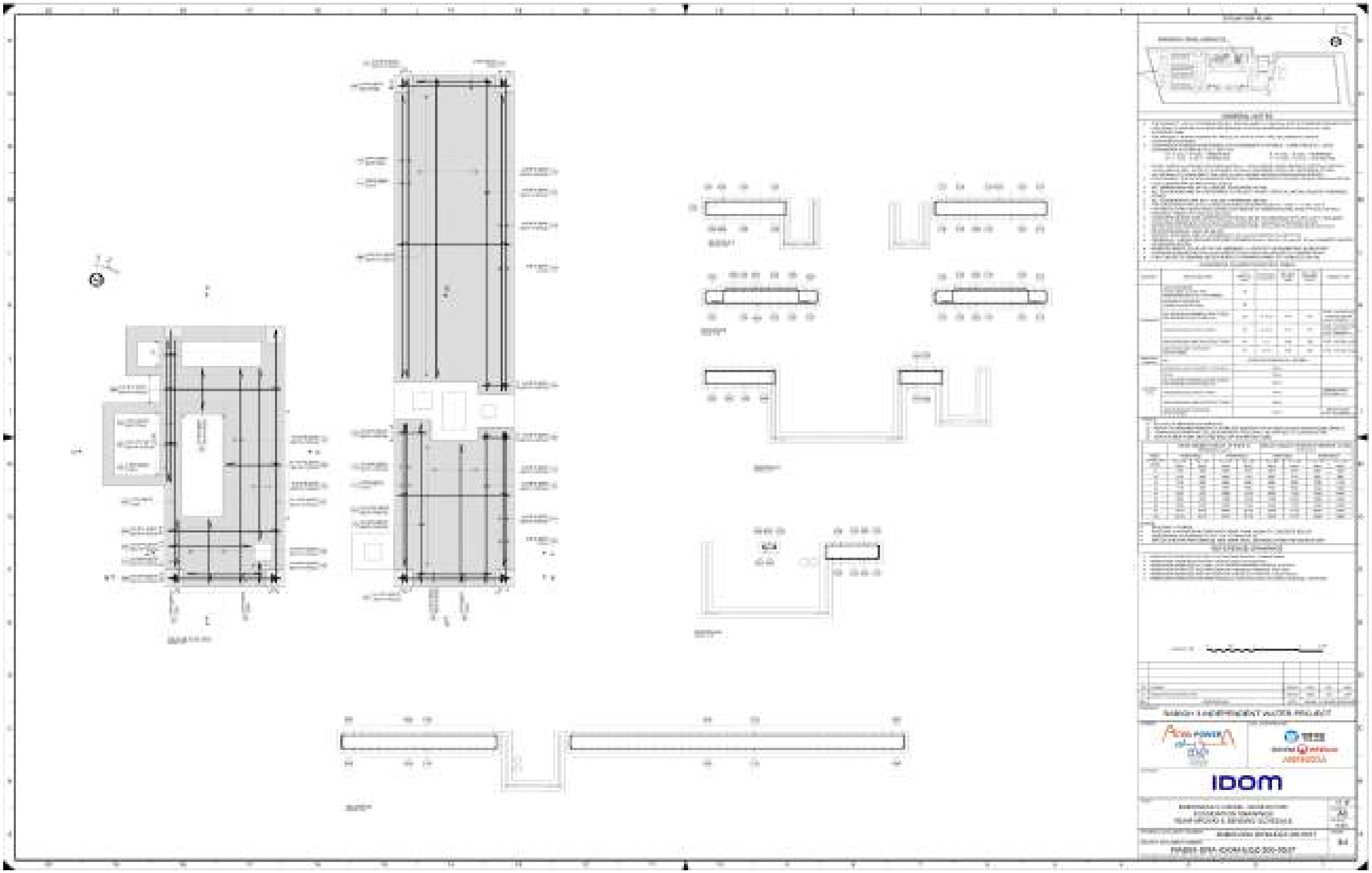
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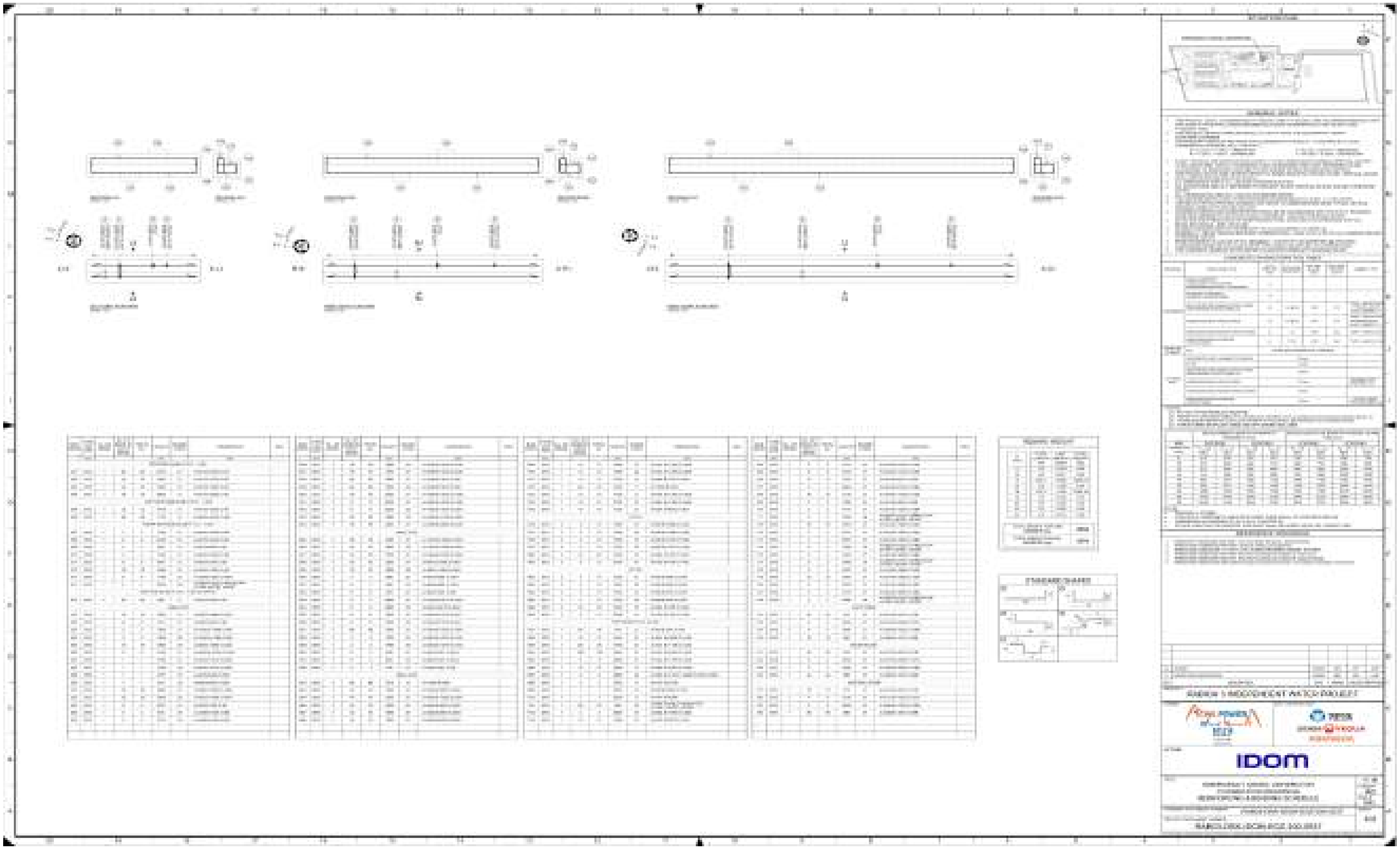
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| Rabigh III Independent Water Project | | | | | | |
|---|---|---|---|---|---|---|
| TIEJUN / SIDEM VEOLIA / ABENGOA | Title: | 13.8KV Emergency Power Supply GENERAL SPECIFICATION | | | | ACWA POWER / ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 18400D-SID-412804-EGZ001 | | | | |
| | Rev: | 01 | Page: 1/39 | Date: | 22/08/2019 | |

# 13.8KV EMERGENCY POWER SUPPLY
# TECHNICAL SPECIFICATION

| Discipline | Process | Civil | Mechanical | Piping | I&C | Electrical |
|---|---|---|---|---|---|---|
| | | | | | | X |

Revision control sheet

| Revision | Date | Description of the revision and changes | Elaborated by | Revised by | Approved by |
|---|---|---|---|---|---|
| 01 | 22/08/2018 | Issued for purchase | B.Deveille | T.MARTIN | J.Duprey |
| C | 03/06/2019 | Updated as per client comments | B.Deveille | A. Caparros | J.Duprey |
| B | 17/05/2019 | Updated as per client comments | B.Deveille | A. Caparros | J.Duprey |
| A | 25/04/2019 | First submission to Client | B. Deveille | A. Caparros | J. Duprey |

| Rabigh III Independent Water Project | | | | | | |
|---|---|---|---|---|---|---|
| TIEJUN / SIDEM VEOLIA / ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ACWA POWER / ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 18400-SID-4126EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 2/38 | Date: | 22/08/2019 | |

TABLE OF C O N T E N T

| Rabigh III Independent Water Project | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8KV Emergency Power Supply GENERAL SPECIFICATION | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 18402D-SID-4120EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 3/39 | Date: | 22/08/2019 | |

| Rabigh III Independent Water Project | | | | | | | ACWA POWER كوا باور |
|---|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | | |
| | Internal code: | 164030-SID-4120EH-EGZ001 | | | | | |
| | Rev: | 01 | Page: 4/39 | Date: | 22/08/2019 | | |

| Rabigh III Independent Water Project | | | | | | | |
|---|---|---|---|---|---|---|---|
| SIDEM VEOLIA ABENGOA TIEJUN | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | | ACWA POWER |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | | ILF CONSULTING ENGINEERS |
| | Internal code: | 184020-SID-4120EH-EGZ001 | | | | | |
| | Rev: | 01 | Page: 5/39 | Date: | 22/08/2019 | | |

## 1. SCOPE AND PURPOSE OF THE DOCUMENT

The purpose of this document is to give main features of the 13.8 kV Emergency Power Supply package (EPS) referenced as EPS intended to supply the electrical essential consumers of Rabigh III independent Water Project in case of black out of the network.

The project 'Rabigh III' consists of a 600 000m3/day Reverse Osmosis Desalination Plant to be built in the Rabigh area (Saudi Arabia) as a standalone independent Water Plant.

This specification has to be read in conjunction with Project specifications.

The VENDOR shall clearly identify in its technical offer any deviation to these specifications.

In this specification, the EPS is considered to be a prefabricated process or utility unit which:

- can be self-operated and / or
- is delivered as a whole and / or
- is normally a standard skid-mounted unit.

The EPS can be made of several interconnected parts.

## 2. DEFINITIONS AND ABBREVIATIONS

### 2.1. Definitions

| | |
|---|---|
| **CONTRACTOR** | Means SIDEM /SEPCO / ABENGOA |
| **CONTRACT** | Means the written agreement between OWNER and CONTRACTOR for the engineering, procurement and delivery of the DESALINATION PLANT. |
| **DESALINATION PLANT** | Means the independent seawater desalination plant of 600,000m3/day to be constructed near Rabigh, in KSA.. |
| **EQUIPMENT** | Means the equipment, machinery, apparatus, materials, articles and goods of all kinds to be supplied by VENDOR under the PURCHASE ORDER for incorporation into the DESALINATION PLANT. |
| **EER** | Means Electrical & Electrical Rooms ( Electrical Building of RO plant) |
| **EPS** | Means Emergency Power Supply package |
| **ESF** | Means the Electrical Special Facility to be erected for the Rabigh 3 IWP. |
| **OWNER** | Means ACWA POWER |
| **PURCHASE ORDER** | Means the written agreement between CONTRACTOR and VENDOR for the supply of EQUIPMENT or services for the purpose of the |

| | |
|---|---|
| | DESALINATION PLANT. |
| **SIDEM** | Means the firm SIDEM in Paris, France, represented by its legal representative. |
| **SITE** | Means the area upon which the DESALINATION PLANT is to be constructed. |
| **SPECIFICATION** | Means the technical specification of the WORKS and/or of the EQUIPMENT as set out in the appendices forming part of the PURCHASE ORDER and any modification or addition thereto made pursuant to the PURCHASE ORDER. |
| **VENDOR** | Means the firm that has undertaken to perform the WORKS under the PURCHASE ORDER placed by CONTRACTOR, represented by its legal representative. This wording also covers VENDOR's suppliers and/or sub vendors whenever applicable. |
| **WORKS** | Mean all works of design, engineering, procurement, manufacture, supply, assembling, packing, transportation, erection, testing, start-up, commissioning, supervision, compilation and issuance of documents to be carried out by VENDOR (including the making good of defects in the EQUIPMENT and such works), and includes all the services to be provided and the work to be carried out by VENDOR as specified, mentioned, required or implied in the PURCHASE ORDER, with the performances defined in the PURCHASE ORDER. The WORKS include the supply of the EQUIPMENT. |

### 2.2. Abbreviations

| Abbreviation | Signification |
|---|---|
| AC | Alternating Current |
| ACO | Automatic Change-Over System |
| ATS | Automatic Transfer System |
| CCR | Central Control Room |
| COS | Change-Over Switch |
| CT | Current Transformer |
| DC | Direct Current |
| DCS | Distributed Control System |
| DOL | Direct On Line |
| EPS | Emergency Power Supply Package |
| EER | Electronic and Electrical Rooms |
| EMC | Electro-Magnetic Compatibility |

| Rabigh III Independent Water Project | | | | | | |
|---|---|---|---|---|---|---|
| | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 164000-SID-41306H-EGZ001 | | | | |
| | Rev: | 01 | Page: 7/39 | Date: | 22/08/2019 | |

| Abbreviation | Signification |
|---|---|
| EWA | Electricity and Water Authority |
| FLC | Full Load Current |
| FMS | Fault Monitoring System |
| HV | High Voltage (voltages of 36 kV AC and above) |
| HVAC | Heating, Ventilating and Air Conditioning |
| HSTS | High Speed Bus Transfer System |
| IEC | International Electro-technical Commission |
| IEEE | Institute of Electrical and Electronics Engineers (USA) |
| ISO | International Organization for Standardization |
| I & C | Instrumentation and Control |
| I/O | Input/ Output |
| IWPP | Independent Water Plant and Power plant |
| LEP | Local Electrical Panel |
| LCR | Local Control Rooms |
| LCS | Local Control Station |
| LED | Light-emitting Diode |
| LV | Low Voltage (voltages below 1 000 V AC) |
| MCB | Miniature Circuit Breaker |
| MCCB | Moulded Case Circuit Breaker |
| MCC | Motor Control Centre |
| MIGD | Millions Imperial Gallons per day (1 MIGD is equivalent to 4,546.09 $m^3/d$) |
| MV | Medium Voltage (from and including 1 kV AC up to 50 kV AC) |
| ONAN | Oil Natural Air Natural |
| PCB | Poly Chlorinated Biphenyl |
| PVC | Poly vinyl Chloride |
| PF | Power Factor |
| PVC | Poly Vinyl Chloride |

| Abbreviation | Signification |
|---|---|
| RCD | Residual Current Device |
| RO | Reverse Osmosis |
| RTD | Resistance Temperature Detector |
| SEC | Saudi Electricity Company |
| SWRO | Seawater Reverse Osmosis |
| THD | Total Harmonic Distortion |
| UPS | Uninterruptible Power Supply |
| VSD | Variable Speed Drive |
| VT | Voltage Transformer |
| XLPE | Cross Linked Polyethylene |
| | |

## 3. REFERENCE DOCUMENTS

The referenced documents listed below form an integral part of this specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision issued at the effective date of the CONTRACT.

In case of conflict between the documents, the order of precedence shall be:

- The CONTRACT,
- This Specification,
- The Codes and Standards.
- The CONTRACTOR Documentation.

### 3.1. Contract documents

The CONTRACT documents shall apply, among:

- Owner's Technical Specification
- OTS Appendix II : Technical Specification

| Rabigh III Independent Water Project | | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | | |
| | Internal code: | 184020-SID-41268H-EGZ011 | | | | | |
| | Rev: | 01 | Page: 9/38 | Date: | 22/08/2019 | | |

### 3.2. Contractor's Documentation

The following Contractor documents apply with among others:

| Document Code Number | Title |
|---|---|
| **RAB03-SPE-SIDM-ZZZ-200-0004** | Site conditions |
| **RAB03-LIS-SIDM-ZZZ-411-0001** | Electrical consumers list & load evaluation |
| **RAB03-DIA-SIDM-ZZZ-407-0001 to 4** | Single Line Diagrams |
| **RAB03-DIA-SIDM-EGZ-407-0001** | Single Line Diagram of 13.8kV Emergency Power System |
| **RAB03-TEM-SIDM-EGZ449-0001** | Technical Specification – 13.8kV Emergency Diesel Generator |
| **RAB03-SPE-SIDM-ZZZ-440-0002** | Electrical design spec for Packages |
| **RAB03-DTY-SIDM-EAZ-404-0001** | MV Switchgear - Typical wiring diagram |
| **RAB03-ITP-SIDM-EGZ-449-0001** | Inspection Test plan - - 13.8kV Emergency Diesel Generator |
| **RAB03-LIS-SIDM-ZZZ-411-0002** | Electrical Consumers List & Load Evaluation AC DC UPS |
| **RAB03-CAL-SIDM-ZZZ-526-0002** | MV Cables Calculation Note |
| **RAB03-REP-SIDM-ZZZ-402-0001** | Short-Circuit Study report |
| **RAB03-SPE-SIDM-ZZZ-454-0001** | Electrical motors Technical Specification |
| **RAB03-DDE-SIDM-EAZ-440-0001 & 2** | Electrical Building – Switchgear and equipment layout |
| **RAB03-SPE-SIDM-EAZ-570-0001** | Fault Monitoring System – Technical Specification |
| **RAB03-SPE-EPCC-ZZZ-253-0001** | General painting and color code specification |
| **RAB03-PRO-EPCC-ZZZ-712-0001** | Equipment numbering system |

### 3.3. Codes and Standards

#### 3.3.1. IEC standards

The IEC standards non exhaustive list shall apply and shall prevail:

| Standards | Title |
|---|---|
| **IEC 60034** | Rotating electrical machinery |
| **IEC 60038** | IEC standard voltages |
| **IEC 60050** | International electro technical vocabulary |
| **IEC 60060** | High voltage test techniques |
| **IEC 60071** | Insulation coordination |

| Rabigh III Independent Water Project | | | | | | |
|---|---|---|---|---|---|---|
| TIEJUN / SIDEM VEOLIA / ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ACWA POWER |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | ILF CONSULTING ENGINEERS |
| | Internal code: | 164000-510-4128EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 10/39 | Date: | 22/08/2019 | |

| Standards | Title |
|---|---|
| **IEC 60073** | Coding principles for indicators and actuators |
| **IEC 60076** | Power transformers |
| **IEC 60196** | IEC standard frequencies |
| **IEC 60204** | Electrical equipment for machines |
| **IEC 60255** | Electrical protection relays |
| **IEC 60265** | HV switches |
| **IEC 60529** | Degrees of protection provided by enclosures (IP Code) |
| **IEC 60617** | Graphical symbols for diagrams |
| **IEC 60694** | common clauses for HV switchgear and control gear standards |
| **IEC 61000** | electromagnetic compatibility (EMC) |
| **IEC 61850** | Communication networks and systems in substations |
| **IEC 61936** | Power installations exceeding 1 kV AC |
| **IEC 62262** | Degrees of protection provided by enclosures (IK code) |
| **IEC 62271** | High voltage switchgear and control gear |
| **IEC 62305** | Protection against lightning |

3.3.2. ISO Standards

For items not covered by the above referenced standards, the European standards shall be used:

| Standards | Title |
|---|---|
| **ISO 12944** | Corrosion protection of steel structures by protective paint systems |
| **ISO 1461** | Hot dip galvanized coatings on fabricated iron and steel articles |
| **ISO 10816** | Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts |
| **ISO 1680** | Testing procedure for measuring airborne noise emitted by rotating machines |
| **ISO 3046** | Reciprocating internal combustion engines - Performance |
| **ISO 8528** | Reciprocating internal combustion engine driver alternating current generator sets |

3.3.3. IEEE Standards

For items not covered by the above referenced standards, the IEEE standards shall be used:

| Standards | Title |
|---|---|
| **IEEE 80** | Guide for safety in AC substation grounding |

| | |
|---|---|
| **IEEE 519** | IEEE recommended practices and requirements for harmonic control in electrical power systems |

#### 3.3.4. Local Standards

Where applicable, the Saudi Arabian Distribution Code shall be applied

#### 3.3.5. Other Standards

Standards listed in section, 3.3.2, 3.3.3, & 3.3.4 shall be considered and applied for all portion of the design, manufacture, testing and erection works included in the DESALINATION PLANT scope of works, and shall prevail on any other standard, especially on NEMA, ANSI, NFPA, ICEA, UL, IES, ISA standards.

In case any electrical equipment specification or any portion of the design, manufacturing, testing or erection works included in DESALINATION PLANT's scope of works is not covered by any IEC standard or European standard or IEEE standard, notwithstanding the list of standards listed in section NEMA or ANSI standards can be considered subject to CONTRACTOR approval.

## 4. ENVIRONMENTAL REQUIREMENTS

The DESALINATION PLANT will be located in the Rabigh area, approximately 150km North of Jeddah, in the Kingdom of Saudi Arabia.

The climate is characterized by hot and dry weather most of year with the proximity to the Sea. Sand and dust storms occur occasionally. The atmosphere is saline, dusty and with high concentrations of windborne sand. The possibility of condensation, as experienced during large temperature fluctuations in humid atmosphere, shall be taken into account.

The design conditions to be considered for the sizing of the EQUIPMENT are the following:

- Maximum design temperature, indoor installation :
  - In air conditioned rooms with HVAC redundancy : + 40°C
  - In other rooms : + 55°C
- Maximum design temperature, outdoor : + 55°C
- Maximum metal temperature in the sun : +85°C
- Minimum design temperature, outdoor : + 5°C
- Minimum design temperature, indoor installation :
  - In air conditioned rooms with HVAC redundancy : + 5°C
  - In other rooms : + 5°C
- Relative humidity :
  - Maximum : 100%
  - Minimum : 5%
- Cable sizing data :

| Rabigh III Independent Water Project | | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-440-0001 | | | | | |
| | Internal code: | 164000-SID-4139EH-EGZ001 | | | | | |
| | Rev: | 01 | Page: 12/39 | Date: | 22/06/2019 | | |

- Air temperature : + 55°C
- Ground temperature : + 40°C
- Soil thermal resistivity : 150Kcm/W (value to be confirmed by Soil investigation report)
- Altitude : < 1000 m

## 5. ELECTRICAL SYSTEMS & VOLTAGES

### 5.1. Distribution systems

The voltage listed below shall be provided by CONTRACTOR for the DESALINATION PLANT.

All electrical equipment supplied is to be so designed and manufactured that it is capable of operating satisfactorily at the variations of voltage and frequency hereunder specified.

| System | Voltage | Voltage variation | Qty of phase / wire | Frequency | Frequency variation | Neutral grounding |
|---|---|---|---|---|---|---|
| High voltage system (Grid Connection) | 380 kV | As per SEC standard | 3-Phase | 60 Hz | As per §2.4.2.2 of the Saudi Distribution Code :<br>- 58.8~60.5Hz continuous<br>- 57.5~61.5Hz for 30 minutes<br>- 57~62.5Hz for 30 seconds | As per SEC standard |
| High voltage system (Power supply to the DESALINATION PLANT) | 110 kV | As per SEC standard | 3-Phase | 60 Hz | | As per SEC standard |
| Medium voltage system (Process) | 13,8 kV | +/- 10% | 3-Phase / 3-wire | 60 Hz | | NER (NOTE 1) |
| Low voltage system | 400/230 VAC | +/- 10% | 3-Phase + Neutral | 60 Hz | | Solid grounding – TNC-S |
| AC UPS system | 400/230 VAC | +/- 10% | 3-Phase + Neutral | 60 Hz | | Solid grounding – TNS |
| DC UPS system | 110 VDC | + 10 / - 15% | DC | DC | n/a | ungrounded |

NOTE 1: Limited current value is 600A through NER connected on Neutral of HV/MV transformers.

| Rabigh III Independent Water Project | | | | | | ACWA POWER أكوا باور |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 164000-SID-4128EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 13/39 | Date: | 22/08/2019 | |

5.2. Equipment and loads voltage levels

| Equipment | | Voltage |
|---|---|---|
| Motor – Direct on Line starting | Rated power 200kW & above | 13,8kV AC -3-phase |
| | Rated power below 200kW | 400V AC - 3-phase |
| Motor – Driven by VSD | Rated power 200kW & above | 6.6kV AC or 4.16kV AC, 3-phase |
| | Rated power below 200kW | 400V AC -3-phase |
| Other Medium Voltage loads (VSD, Transformers, Capacitors) | | 13.8kV AC - 3-phase |
| Small-sized loads<br>*Note: unless allowed by CONTRACTOR, single phase motors are forbidden.* | | 230V AC - 1-phase +N |
| Power (welding) outlets | | 400V AC - 3-phase |
| Lighting fixtures & convenience outlets | | 230V AC - 1-Phase + N |
| Space heaters | | 230V 1-phase + N |
| Small power distribution boards / sub-distribution Panel /Local Electrical Panel | | 400V AC /230 V AC 3-phase / 1 phase, +N |
| Local Electrical Panel for PACKAGE | | 400V AC - 3-phase |
| Main switchgears control circuits | | 110VDC UPS |
| I&C equipment | | 230VAC UPS |

## 6. DESIGN AND PERFORMANCE REQUIREMENT

### 6.1. Scope of supply

VENDOR's scope of WORKS shall include the provision of one (1) 13.8 kV Diesel Generating Set dedicated to supply the emergency loads of Rabigh III "Sea Water Reverse Osmosis Plant" and all related accessories, together with the engineering, design, manufacture, testing, assistance to the installation, spare parts, training, as may be defined in the documents of the PURCHASE ORDER.

The EPS and related auxiliaries will be installed inside an appropriate soundproof container, which must include its fixation system to the site foundation plates.

This specification covers the minimum requirement for the EPS equipment comprising:

- The diesel engine complete with speed governor and auxiliary systems;
- The three-phase synchronous generator and its excitation system complete with its voltage regulator;
- The measurement and control instruments;
- The MV Switchgear with its protections to supply the emergency board
- The local control panel complete with electrical protection, starting and control system for the EPS;
- The diesel fuel tank for 12 hours operation at full load
- The soundproof container with generator base plate set and suitable system of anchorage to the existing installed foundation plates
- The gas exhaust evacuation system;

- The fire detection and protection system of the container
- All internal power, control, instrumentation cables as per OTS requirements (fire- resistant)
- The 13.8kV Emergency Power Supply rating plates and marking

## 6.2. Operation mode

As per the single line diagram RAB03-DIA-SIDM-ZZZ-401-0001 & 2. Stream 1 and stream 2 are normally supplied from one 13.8kV Switchgear composed of two (2) Bus Switchgears.

In normal operation, each bus section is fed by its dedicated power source; both bus-section "normal" incomers (Incomer1 & Incomer 2) are closed and the bus-coupler circuit breaker is open.

In case of loss of one source, the bus coupler circuit-breaker is closed in order to allow the other source to feed both bus sections. A High Speed Transfer System (HSTS) provides fast back-up transfer between the bus-sections.

In case of total blackout and after a delay of at least 2 or 3 seconds the diesel generator start automatically and back-up supplies both bus section W0BBB001 & W0BBB002 and the emergency load through the MV switchgear (W0MKA001-Q)

Emergency loads to be back-up are detailed in the Electrical Consumers List & Load Evaluation doc. RAB03-LIS-SIDM-ZZZ-411-0001 and are resumed here below.

The functioning of EPS intended is described sheet C06 of the MV typical wiring diagrams doc. RAB03-DTY-SIDM-EAZ-404-0001. The main operation principle is resumed hereafter, the vendor will refer to this last document for further details about the EPS functioning and interfaces with the switchgear and the DCS (Distributed Control System).

The selection of the mode of operation shall be realised by means of a selector switch (Auto/Manu/Stop) located on the front of the EPS local control cubicle or by selection mode on the EPS HMI.

### 6.2.1. Automatic mode

In case of loss of both power plant supply,

- The MV switchgear (W0BBA001, W0BBB001, W0BBA002, & W0BBB002) opens automatically the incomer circuit breaker of each bus-section, closes the circuit breaker of the bus coupler, and opens all motor feeders.
- The status of Incomer and Bus coupler Circuit Breakers are sent to the EPS control panel.
- The EPS control panel generates a "permissive to start" signal and starts autom-atically the EPS without external order.
- Once the EPS reaches "ready for load" status, the EPS control panel sends a closing order to the circuit breaker EPS Incomer on Bus Section Switchgear W0BBB001 & W0BBB002
- Configuration of the electrical network and starting of emergency loads is done manually by an operator including starting of flushing pumps & ERD Booster pumps.

### 6.2.2. Normalisation procedure

6.2.2.1 Mains restoration in automatic mode

- The power supply restoration can be performed only in case of one of both incomers of each 13.8kV switchgears is alive.

- If the Gen-Set Power Station Function Mode Selector Switch on the Control Panel is in AUTO position the operator shall select the incomer of W0BBA001, W0BBB001, W0BBA002, & W0BBB002 circuit breaker that has to be closed after the synchronization operation. The Operator shall follow the sequence described below:

a) Operator at HMI shall select the incomer of W0BBA001, W0BBB001, W0BBA002, or W0BBB002 in the Circuit Breaker Selector Switch and push "Mains Restoration"

b) The PLC system shall check the referenced incomer selected by the operator is fully alive before to initiate the Mains restoration sequence;

c) The Auto Synchroniser shall adjust frequency and voltage of the Genset till it allow the closure of the selected incomer circuit-breaker;

d) Once one busbar restoration is complete, the operator select the incomer of the second busbar to be restored.

e) When the Auto Synchronizer Device detects the selected incomers circuit breaker closed status of each busbar it shall start the Gen-Sets unload sequence;

f) When the unload sequence is completed the Auto Synchronizer device shall give the open command to the GenSet Circuit Breakers;

g) The GenSet cover the cooling sequence and after that shall be stopped;

h) After the MV switchgear normalization, using the ATS located on the MV Switchgear, the operator can close the second incomer and open the bus-coupler only if both incomers are alive.

6.2.2.2 Mains restoration in manual mode and automatic synchronization

The power supply restoration can be performed only in case of one of both 13.8kV incomers (W0BBA001 or W0BBB001, and W0BBA002 or W0BBB002) of each switchgear is alive.

If the GenSet Power Station Function Mode Selector Switch of the Control Panel is in MAN position, the operator shall select the incomer circuit breaker that has to be closed and the sequence shall be:

a) Operator shall select MANUAL mode on Control Panel of the GenSet;

b) Operator at HMI shall select "AUTO Synchronization";

c) Operator at HMI shall select the incomer to be closed with the Circuit Breaker Selector Switch and push "Mains Restoration"

d) The PLC system shall check the referenced incomer selected by operator is fully alive before to initiate the Mains restoration sequence;

e) The Auto Synchronizer device shall adjust frequency and voltage of the GenSet till it allow the closure of the selected incomer circuit-breaker;

f) Once one busbar restoration is complete, the operator select the incomer of the second busbar to be restored.

g) When the Auto Synchronizer Device detects the selected incomer circuit breaker closed status the GenSet unload sequence will start;

h) When the unload sequence is completed, the Auto Synchronizer device shall give the open command to the GenSet Circuit Breaker;

i) Operator shall push "Stop Engine" of the GenSet;

j) The GenSet cover the cooling sequence and will stop;

k) After the MV switchgear normalization, the operator at the ATS of the MV switchgear can close the second incomer and open the bus-coupler only if both incomers are alive

6.2.3. Maintenance mode

The maintenance mode is used for the periodical starting of the EPS.

6.2.3.1 No Load test

• The operator issues a "START" command manually:

a) If the EPS "LOCAL/ REMOTE" switch is in "LOCAL" position, the start command is generated by a "Start" Push button located on the EPS control panel.

b) If the "EPS LOCAL/REMOTE" switch is in "REMOTE" position, the start command is generated by a "START" command on the remote DCS.

• When the EPS control panel receives the "START" command (in local or remote mode), and when the open position of circuit EEPS Incomer of the Bus Section Switchgears W0BBB01, & W0BBB002 is confirmed, the EPS starts with no load.

6.2.3.2 Load test

• In order to perform the load test, the EPS will be synchronized (from the EPS control panel) with one bus section switchgear (W0BBB001, or W0BBB002). The operator selects the synchro reference on the EPS control panel.

• When the EPS control panel will receive the "Start Maintenance, load test", the EPS will start and will be synchronized with the selected reference.

• When the EPS is synchronized, the selected EPS incomer will be closed by the EPS control panel.

• The EPS will take over automatically the load of the selected LV switchgear through a ramp-up sequence.

6.2.3.3 End of maintenance

When the maintenance is complete:

• The operator issues a "STOP" command manually:

a) If the "EPS LOCAL/REMOTE" switch is in "LOCAL" position, the stop command is generated by a "stop" push button located on the EPS control panel.

b) If the "EPS LOCAL/REMOTE" switch is in "REMOTE" position, the stop command is generated by a stop command on the DCS.

• Upon receipt of the "Stop" command, the load will ramp down and the EPS will stop.

• When the load test will be completed, the EPS incomer of the bus section switchgear (W0BBB001, or W0BBB002) will be opened.

6.2.4. Full stop

In this mode the all EPS functions are de-activated

6.2.5. Emergency stop

The GENSET shall stop on activation of emergency red lockable push-buttons located on the front of the control panel and outside of the sound proof container.

| Rabigh III Independent Water Project | | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | | |
| | Internal code: | 16400-SID-4120EH-EGZ001 | | | | | |
| | Rev: | 01 | Page: 17/39 | Date: | 02/08/2019 | | |

### 6.3. EPS Power sizing

The EPS power shall be sized to start and supply continuously the emergency loads detailed in the Electrical Consumers List & Load Evaluation (RAB03-LIS-SIDM-ZZZ-411-0001).

### 6.4. Main characteristics

Main features of the GENSET will be the following

| Characteristics | Unit | Value |
|---|---|---|
| Rated Output Voltage | kV | 13.8 |
| Rated insulation level | kV | 17.5 |
| Rated Power (Pn) | kVA | 2200 |
| Type of power | COP/PRP/LTP/ESP | PRP |
| Nominal power factor | - | 0.8 |
| Number of phases | - | 3 |
| Nominal frequency (Fn) | | 60 Hz |
| Neutral connexion | | Neutral resistor with neutral contactor<br>(maximum fault current to be defined by the Vendor) |
| Sound Level | dBA at 1 meter | 85 |
| Performance class of speed and frequency | G1 to G4 | G3<br>(Inverters/ rectifier load) |
| Starting time | s | =<15s (to be confirmed by the Vendor) |

### 6.5. Main requirements

The minimum performance requirements guaranteed of the diesel generator shall be as follow:

- The minimum capacity or minimum nominal power delivered by EPS shall be 2200kVA PRP "Prime Power" as per ISO 8528-1 standard;
- Starting to back up the users, as quickly as possible. The total time from starting order to full speed shall be less or equal to 15 seconds according to ISO 8528-1;
- The maximum voltage dip at the alternator terminals shall not exceed 10% of nominal when the largest motor is started and the standing load is present;
- The transient speed drop when starting the largest motor shall not exceed 10%.
- The performance class of speed and frequency shall be G3 according to ISO 8528-1 standard and IEC EN 60034.refer to preliminary load profil.
- The performance class on shall be respected for mater maximum suddenly applied load step (MV motors data: Id/In = 5.5, starting p.f. = 0.1 to 0.4);

The EPS shall be designed to carry continuously its rated load within the temperature rise at a maximum ambient temperature of 55°C.

As specified here above with a cold diesel engine but with a pre-heating and pre-lubrication system in service, the generator must reach the rated speed and voltage at no load (and will therefore be able to supply energy) within 15 seconds from the starting signal.

The limits of transient variation in frequency and voltage relating shall be in compliance to the performance class G3 according to ISO 8528-1 and IEC EN 60034 standards.

In case of a sudden load discharge with the EPS operating at rated speed in stabilised conditions, at any load up to a 10% overload, the speed of the EPS must not exceed 110% of the rated speed.

The EPS must be sized, balanced and aligned in order to be exempt from vibrations that can affect the lifetime of the machine, in any load conditions up to a 10% overload and in the range from 90% to 110% of the rated speed.

Vibrations will be measured on the individual supports in the horizontal, vertical and axial directions of the machine, in compliance with the requirements of ISO 10816 and ISO 8528- 9 standards, and the measurements will be performed both in terms of maximum movement (peak-peak μm) and in terms of effective value of the speed of vibration (mm/sec. r.m.s.).

The vibration values of the assembled EPS, recorded in the above mentioned load conditions, shall respect the limits imposed by the ISO 8528-9 standard.

The mechanical equipment is designed to limit the transmission of vibrations to the container and the environment.

The EPS shall be equipped with railings or cowlings in order to preserve the operating staff from electrical or mechanical risks. The protection provided by these covers and railings has to be compliant with the IEC 60529 standard.

The equipment shall be designed to avoid propagation of leakage and accumulation of water, lube oil or fuel and to limit the resulting risks, particularly: necessary arrangements are taken to prevent leakage from spreading in cable trays or piping racks; components susceptible of leaking are equipped with a collecting pot.

The equipment installed outside the container except the load bench (if any) have a mechanical protection index IP55; The equipment installed in the container have a mechanical protection index IP 32; IP 41 for the electrical equipment.

According to the standards, all the parts accessible exceeding 60°C are heat-insulated. Derogations to this rule are acceptable upon request for special engine parts such as cylinder heads, turbochargers which are not protected or insulated.

The electrical equipment sensible to high temperatures is ventilated and might be conditioned so that the inside container temperature never exceeds 10°C above ambient. The admissible temperature level in the panels complies with the IEC 60439 prescriptions. Electrical equipment and cables that are directly mounted on the diesel engine are heatproof according to the ISO 6826 standard.

The cables directly mounted on the diesel engine are designed to cope with fuel and lube oil aggressions and vibrations.

## 7. CONSTRUCTION

### 7.1. Diesel engine

The diesel engine shall be an existing and approved model with characteristics in compliance with ISO 8528-2 standard, 4-stroke diesel engine complete with speed governor and auxiliary systems.

The engine shall be on a horizontal axis complete with connecting joint, shall have adequate power to guarantee the performance of the EPS and shall be consistent with the generator and load characteristics.

The diesel engine shall be controlled by an automatic electronic type PI or PID speed governor having the following performance level:

| Rabigh III Independent Water Project | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8KV Emergency Power Supply GENERAL SPECIFICATION | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 18402D-SID-41.2EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 19/39 | Date: | 22/08/2019 | |

- Range of speed regulation: ±5%
- Precision of droop: ± 0,2%

***"Remote control of the speed is not overseen; the speed will only be controlled and adjust manually using the speed controller locate in the electric compartment!".***

Droop set point setting shall only be adjusted manually on the controller.

Over-speed detection shall be provided by two separate detectors.

Engine cooling and pre-heating systems should be sized in order to guarantee diesel EPS proper operation in site temperature limits.

The entire exhaust line shall be designed properly to minimise flow restriction, sudden direction change, or line blowing in opposite direction.

The duct shall be gastight, to protect operators against toxic emission (CO, C02) and shall be entirely heat isolated to protect the surrounding from fire or excessive heating.

Non-insulated exhaust lines located outside shall not be routed near engine air intake, power plant or container ventilation entries to prevent temperature rise, which results in performance reduction.

Rain and condensate permanent draining shall be provided to prevent exhaust system end (chimney/silencer) water entering or condensate stagnation.

#### 7.1.1. Starting system

The EPS shall be equipped with a double electric starters powered in 24VDC.

Each starter shall be powered by lead acid set of batteries having a lifetime minimum of 10 years

Batteries capacity shall be sufficient for 6 successive attempts of start in not less than 15 seconds. Automation will allow three attempts start without human intervention, plus three further attempts after the three first one.

The charge of the batteries will be permanently indicated, and an alarm should activate when passing below the minimum discharge level.

Two battery-chargers of adequate characteristic shall be provided by the vendor to recharge the batteries from a deep discharge in a time less than 10 hours.

Batteries and battery-chargers fault information shall be available on terminals for remote controller or integrated in the group fault chain of the GENSET for indication in the control room

A batteries calculation notes shall be provided to prove the ability of starting system.

In case of storage of the batteries at VENDOR's factory before delivery on site the VENDOR shall provide facilities to ensure regular recharging of the batteries. In all cases the batteries shall be shipped fully charged.

#### 7.1.2. Preheating system

To ensure start-up and pickup of the loads without mechanical risks, lubricating oil and cooling water shall be heated.

Each liquid is circulated in the engine by an electric pump so as to keep it at temperature during standby periods.

This automatic system shall be stopped as soon as the star-up order is received and while the engine is operating.

The water is heated by low surface power heating resistances. Oil shall be heated using a hot water exchanger.

These systems shall include the following safety equipment:

- a low water temperature detector,

- a low oil temperature detector,
- a heated oil resistance type temperature sensor,
- a heated water resistance type temperature sensor,
- An electric pumps stopped signal; Failure of each electric pump shall be relayed to the control panel.

#### 7.1.3 Fuel supply system,

The EPS shall be provided with an entirely autonomous fuel supply system. The fuel system shall consist basically of an electronically controlled injection system with single injection pumps.

The fuel supply of the EPS shall be installed between the discharge of a gravity relay tank on the engine and the filter upstream of the injection pumps.

This circuit shall include a pump coupled to the diesel engine; A valve controlled from outside the diesel room shall be installed upstream of the coupled pump.

The fuel shall be fed to the injection pumps through a dual permutation type filter or with automatic cleaning

#### 7.1.4 Fuel tanks

The EPS shall be provided with a daily tank with adequate capacity to ensure the autonomy of the group. This daily tank shall be installed inside the soundproof container and shall allow the operation of the EPS at full load for a period of 8 continuous hours.

The tank shall be a double skinned tank and shall be isolated from the engine compartment when installed inside the container with a 2 hours fire barrier.

The filling of the tank will be by truck and should be possible without stopping the EPS. All precautions shall be taken to avoid any water entering the tank. The connection shall be placed in such a way that in the event of a break in the filling hose, the leaks are routed to an appropriate tank. The fuel shall be introduced into the tank by a dip tube.

The tank shall include:

- connections for on-line supply
- vent
- High level/draining
- external visual level
- low-level gauge alarm
- containment basin for waste of adequate capacity

#### 7.1.5 Engine Cooling System

The engine cooling shall be constitute of a dual circuit radiator with vertical execution and water circulation in closed circuit with cooling fan activated by the diesel engine. The circulation pump is mounted on and activated directly by the diesel.

The heating resistance for the cooling liquid will be controlled by thermostat and will be interrupted by the starting of the EPS.

#### 7.1.6 Exhaust system

The type of exhaust silencer shall be based on the sound power level requirements which have to be complied with.

Expansion joints at the engine exhaust on the piping shall be equipped with flanges.

An easily accessible system for exhaust fume sampling for analysis shall be provided.

Appropriate steps shall be taken to ensure that:

- no rainwater can penetrate into the silencer,
- any condensation will be evacuated by an appropriate drain system,
- When the stack is designed to satisfy earthquake conditions, discharge of the exhaust fumes shall not be interrupted when incidents occur on the pipe downstream of the silencer.

#### 7.1.7 Chimney (Optional)

The exhaust duct of the EPS shall be connected to an external chimney installed on the roof of the Soundproof Container.

Basically the ejection velocity of exhaust gas at maximum continuous operation must be at least 25 m/s.

The chimney height shall be sized in relation with engine total thermal power discharge and shall be at least of 5 meters.

The opening of the chimneys should have a vertical direction and do not include barriers to the diffusion of gases (Chinese hats ...).

Rain and condensate permanent draining shall be provided to prevent chimney water entering or condensate stagnation.

The atmosphere of site is corrosive and heavy polluted; the chimney shall be made of stainless steel 316L or equivalent (INOX 304 Forbidden) to prevent any risk of corrosion.

#### 7.1.8 Engine Instrumentation

The diesel engine must be supplied with all the instrumentation necessary for safe and reliable running.

An instrument panel shall be provided and equipped with instruments of the back connected, flush mounted type.

The instrument shall include at least the following:

- Pressure gauge - fuel oil
- Pressure gauge - lubricating oil
- Temperature indicator - cooling water in
- Temperature indicator - cooling water out
- Temperature indicator - lubricating oil in
- Temperature indicator - lubricating oil out
- Emergency stop switch
- Running time meter
- Tachometer
- Pyrometer, Exhaust temperature with selector switch
- Totalizing fuel oil meter
- Horn alarm with cut-off switch
- Fault indicator lights for excessive coolant temperature, low oil pressure, filter bypass opening and over speed.

- Fault indicator lights for Low voltage for starting batteries; batteries charger fault, starting fault

### 7.2 Generator

The nominal characteristics of the alternator at an ambient air temperature of 40°C shall be as follows:

| Generator characteristic | Units | Data |
|---|---|---|
| Nominal voltage Un | kV | 13.8 |
| Insulation voltage | kV | 17.5 |
| Nominal frequency Fn | HZ | 60 |
| Apparent nominal power Sn | kVA | 2200 |
| Nominal power factor | (lagging/leading) | cos phi = 0.8 |
| Nominal rotation speed Nn | Tr.min-1 | >800 |
| Enclosure Protection | IP | IP23 |
| Insulating protection class | F,H | F |
| Neutral | - | Neutral earth resistor and neutral contactor |
| Permissible over load | % | 10 |
| Stator winding max temperature (40 °C ambient, nominal load) | °C | 120 |
| Excitation | | PMG |
| **Voltage regulation** | | |
| Regulation type | | AVRt |
| Excitation | | |
| • Output voltage variation range | | 5% |
| • Accuracy | % | 1 |
| • Response time | s | 500 ms |
| **Frequency regulation** | | |
| • Frequency variation range | % | 5% |
| • Accuracy | % | 1 |
| • Response time | S | 15 |

The generator shall be of the three-phase synchronous type, with a horizontal axis, self-excited with a "brushless", self-ventilating excitation system.

Generator components insulation shall be at least class F and the maximum temperature rise of windings shall be class B according to thermal classification of the IEC60034.

Insulation shall be total continuous impregnation or double discontinuous impregnation type.

The generator shall be sized do deliver it nominal power in PRP service, with power factor between 0.8 lagging and 0.8 leading, for every temperature acceptable for the cooling air, an active power greater than the maximum power that could be produced by the diesel engine in the various ambient temperature conditions.

According to the temperature rise class, the rated apparent power of the generator will be sized for continuous operation under normal conditions of voltage, frequency (IEC EN 60034-1 and 60034-3 standards), at the temperature of the primary cooling fluid (air) of 55 °C.

The maximum value of the inverse sequence component of the stator current that must be supported by the generator must be in compliance with the prescriptions of the IEC 60034-22 and IEC 60034-1 standards.

The limit value of the harmonic factor THF of the generator's voltage must be in compliance with the requirements of the IEC 60034-22 and IEC 60034-1 standards.

The generator's excitation system must be of the "brushless" type with the rectifying system base of rotating diodes mounted on the generator rotor.

The replacement of the components comprising the excitation equipment positioned on the alternator shall not require any substantial work.

The voltage regulator shall be of Electronic type, preferably supplied by battery and shall have the following characteristics:

- automatic voltage regulation from unloaded to full load with a variation lower than +/- 5% rated V in a stabilized regime;
- possibility of regulation of the voltage reference in the range between 90% and 110% of the rated voltage with an error rate below 0.2%;
- limits of over- and under-excitation that can be regulated;
- voltage set point shall be possible at least adjusted manually
- Response time of excitation system not below 1 p.u./s

The regulator voltage shall be positioned on the instrumentation and control cabinet of the generator set.

Provision of mechanical lock the excitation circuit breaker shall be provided for maintenance purpose, on the EPS MV switchgear (see clause switchgear).

Bearings shall be either rolling element anti-friction types or self-lubricated sleeve types.

The generator neutral system is IT with neutral contactor

The semi-rigid type coupling is meant to transmit the engine torque to the alternator and to be used as a steadiness fly wheel by bringing a supplementary inertia to the live part.

The generator shall be self-cooling with the fan mounted directly on the machine shaft. The coolant fluid used shall be the room air. It shall be drawn in on the side opposite the diesel engine and discharged into the room in order to avoid any recycling of the hot air.

The generator shall be equipped with heating resistances to avoid condensation on shutdown. These resistances shall not be in service during set operation.

The generator must be supplied with all the instrumentation necessary for a safe and reliable running and to guarantee a simple and immediate operation of the generator and all the related auxiliary systems.

The generator enclosure shall be equipped with anti-condensation heaters to avoid deterioration of the machine due to condensation.

The following instrumentation must be included as a minimum:

- 2 RTDs in the hottest parts of each phase
- RTD in the hot air of the cooling circuit;
- RTD in the cold air of the cooling circuit;
- RTD at the entrance and exit of the cooling water (when applicable);
- 1 RTD for each bearing
- Flow-switch(s) for control of the oil circulation in the discharge circuit of each bearing (when applicable)
- Thermostat(s) for activation of the anti-condensation heaters.

### 7.3 Enclosing Container

The EPS will be housed in a compartmented soundproof container:

- One mechanical compartment which will house the diesel engine and the generator unit.
- One electrical compartment for the switchgear & local control panel

The container and its internal separation shall be 2 hours fire resistant.

The container house shall provide diesel generator noise reduction to 85dB max at 1 meter as per Electrical design Specification for Packages doc. RAB03-SPE-SIDM-ZZZ-440-0002.

Anti-vibration pads will be placed between the common frame and supporting concrete slab.

The container, whose dimensions have to be specified by the VENDOR, will have the following characteristics:

- Steel section and moulded sheet structure complete with corner blocks
- Sound-absorbing panels in fireproof material for container internal walls
- Air intake silencers on both sides of container
- Air outlet silencer on the external side of the container
- At least double doors with lock facility on both sides shall be provide for access or exit
- A Service door for access to the control board room
- Internal lighting with an illumination level minimum of 300 lux
- Adequate firefighting system as per NFPA 850 requirements.
- A permanent ladder to access to equipment located on the roof of the container
- HVAC system to maintain the temperature inside the electrical compartment inside the limits acceptable by the equipment
- All internal power, control, instrumentation cables as per OTS requirements (fire resistant)

EPS base-plate shall be provided secured to steel floor by means of anti-vibration springs.

Adequate space of minimum (1 meter) around engine and generator shall be provided in order to allow the maintenance and routine operation of the diesel engine, the generator and all other skid mounted equipment.

Two (2) earthing terminals of corrosion resistance material of adequate size (for 90mm² to 240mm² copper cables connexion) mounted diagonally shall be fitted on the bottom of the Container.

The container will be equipped with the lifting lugs designed to lift the complete container fitted with all internal equipment.

### 7.4 Switchgear, control gear and monitoring equipment

Switchgear, control gear and monitoring equipment shall be installed inside the electrical compartment of the container.

The vendor shall provide:

- The MV switchgear for power and neutral connexion from the alternator and outgoing towards the EPS incomer circuit breaker on the emergency-supplied switchgear
- The dry type MV/ LV transformer to supply the EPS auxiliaries from the EPS itself
- The instrumentation and control panels

| Rabigh III Independent Water Project | | | | | | ACWA POWER كوا باور |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | ILF CONSULTING ENGINEERS |
| | Internal code: | 184020-SID-41 20EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 28/39 | Date: | 22/08/2019 | |

Panels shall be made of 2mm minimum thickness solid sheet metal and protection degree of the enclosures shall be at least IP 41 for MV switchgear, IP52 for local control panel, and IP20 when the door is open.

Local control devices are easily accessible from the front, for erection, removal, maintenance and control purpose.

All the equipment on the front of the panels shall be identified by nameplates in plastic material secured with screws.

Every item of equipment must be supplied with one or more nameplates, written indelibly and placed so as to be visible and legible when the equipment is installed, in accordance with the specification of the contract

Wires terminals will be of the pre-insulated compression type and all wiring shall be at least 2.5 mm² stranded copper conductor, 600 V tropical grades PVC insulated.

An internal earthing bar shall be provided, with provisions for connection to the earthing system and connection of the internal metallic parts, panels and door. All the metal parts shall be connected to earth in compliance with the IEC standards.

The earth connections must be in copper and have adequate sections, and in any case not less than 16 mm2

The earth conductors shall have green-yellow sheaths and will be equipped at the ends with suitable wire terminals.

The conductors for connections to equipment mounted on doors will be grouped in flexible bundles arranged, anchored and protected so as to exclude mechanical deterioration and stress on the terminals.

The connections of the auxiliary circuits will be placed in sheaths or conduit in self- extinguishing material, made and located so as to enable easy checking and replacement of the conductors contained in them and not filled beyond 70% of their capacity.

The panels shall be provided with a natural air circulation, anti-condensation heater and lighting

The overall height of floor mounted panels shall not exceed 2 300 mm; When applicable doors shall be fitted with locks or padlocking devices.

Cables shall be brought in through the bottom of the panels and cables penetration, whether for outgoing or incoming cables shall be treated to constitute fire barriers.

#### 7.4.1 MV switchgear

The switchgear shall be of metal enclosed air-insulated switchgear of withdrawable of fix type compliant with the IEE 666-2007 (section 4.6.1 & 4.6.2) standard for momentary parallel operation during load test, equipped of the following equipment:

- One (1) 3 PH bus bars fully insulated
- One (1) 13.8kV three phase incomer motorised circuit breaker equipped with opening and closing coils for power supply from the EPS
- Two (2) 13.8kV three phase outgoing motorised circuit breaker equipped with opening and closing coils and 1 Under voltage coil for the emergency shutdown
- Surge arrestor to be provided on incomer and outgoing
- Earth switch to be provided
- One (1) MV/LV transformer feeder (transformer included) for auxiliaries protected by HRC fuses
- CTs for current measurements protection purpose,
- VTs for voltage measurement, protection and regulation
- Local control push-buttons and indicating lamps

- Integral earthing

The main equipment shall be sized to withstand shot circuit level at outgoing terminals of the generator; the generator is never coupled in parallel.

The cubicles shall be equipped with adequate interlocking (mechanical locks and keys system) to prevent access to MV parts and equipment inside the panel when all the elements contained in the switchgear are not de-energized and the MV parts connected to the earth.

Mimic circuit shall be installed on the front of the cabinet to help understand the different operations.

Operation of the cut-out devices shall be made visible and all switching devices shall be lockable.

Current transformers shall conform to IEC 60044-1 standard and shall resin insulated with single or multi cores.

The capacity of each transformer shall be determined by the manufacturer of the Switchgear and shall be adequate for the full burden of the connected apparatus.

Current transformer shall however, shall comply with the following:

- CT accuracies
  - For Measurement : Class 1 FS 5
  - For over current Protection : Class 5P10
  - For differential protection : Class X
- Secondary rated current : 1A or 5A
- Rated burden : Full load + 50% overload
- Basic Impulse Level (BIL) : Same as switchgear.

Secondary wiring of the current transformers shall be connected through terminal blocks with change-over links to permit easy testing.

Testing blocks shall be mounted in front of the panel, shall be suitably insulated and provided with a detachable dust proof cover.

All current transformers shall be provided with an identifying label giving type, ratio, class output and serial number.

Voltage transformers shall conform to IEC 61869 standard, and shall resin epoxy encapsulated type, single core or 3 cores type mounted on a draw-out frame.

The VTs shall be protected by fast acting fuses placed on primary. Cartridge type secondary fuses and MCBs shall be provided.

In the disconnected position, the primary and secondary circuits shall be automatically disconnected, and primary fuses grounded.

Main characteristics shall be the following:

- VT accuracies
  - For Measurement : Class 1
  - For Protection : Class 3P
- Ratio : 13800/√3/110/√3V
- Burden : As per the needing
- Basic Impulse Level (BIL) : Same as switchgear.

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|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | |
| | Project code: | RAB03-SPE-SIDM-EGZ-440-0001 | | | | ILF CONSULTING ENGINEERS |
| | Internal code: | 164000-SID-4136EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 27/39 | Date: | 22/08/2019 | |

The secondary windings of the voltage transformer shall be earthed. If the transformer secondary winding is star connected secondary winding the star point shall be left unearthed.

External connections to the voltage transformer secondary shall be through a test block.

#### 7.4.2 Local control panel

Local control panel shall be compliant with the requirements of the electrical design specification for Packages doc. RAB03-SPE-SIDM-ZZZ-440-0002.

Local control panel shall provide all necessary devices to operate the diesel generator locally and any signal (alarms, measures and protections) will be available for remote indication.

#### 7.4.3 LV power distributions

The instrumentation and control panels shall include a 400VAC LV power distribution segregated to the instrumentation and control equipment to supply the auxiliaries of the EPS such as generator condensation heaters, preheating system, fuel tracing, panel heater etc.

This LV distribution shall be fed from the power plant 400VAC switchgears installed in the electrical building when the EPS is stopped and from the EPS itself through the MV/LV auxiliary transformer of the EPS MV switchgear.

- A changeover system shall be provided to shift on the power supply from the EPS when it is running.
- 400VAC/ 3ph without neutral will be supplied from the electrical building; an isolating transformer shall be provided by the VENDOR.

The instrumentation and control panels shall include a DC power distribution to supply instrumentation, control and automatism devices. The DC distribution shall be supplied by an additional Battery/Battery charger system powered by the 230 VAC UPS system of the plant.

Every circuit shall be protected adequately through circuit breaker, fuses, thermal relays, etc. by taking in consideration the maximum current and the rated short circuit value of the different circuits.

#### 7.4.4 Protection, alarm and control devices

The EPS local control panel shall include the following main equipment:

- The emergency diesel generator control PLC
- The voltage and speed regulation systems
- The alarm system
- The auxiliary relays
- The Timers
- Terminal boxes for external connections.

##### *7.4.4.1 Measuring Instruments*

The following measurement shall be provided and can be locally display and provision shall be provided for 4-20mA remote indication (To be clarified later).

- Generator output current,
- Generator output voltage,
- Generator active power,
- Generator reactive power,

*7.4.4.5 Grouped mechanical alarm/fault status signalling*

- Normal generator voltage (U > 90%)
- GENSET running
- GENSET Ready to Load
- Switch opened/closed
- Pre-heating of water status
- Switch opened/closed
- Pre-heating of water status
- Diesel pump on/off
- Battery charging

*7.4.4.6 Safety Circuit*

Devices and wiring shall be provided to stop the unit and simultaneously open the MV Switchgear Incoming circuit breaker, under the conditions of:

- over speed,
- excessive coolant temperature,
- Low lubricating oil pressure.

Indicator lamps shall show which device stopped the engine and there shall be a test circuit for the lamps. The source of energy for these circuits shall be separate from the starting circuit.

## 8 RATING PLATE AND MARKINGS

Rating plate information shall be in compliance with the requirements of ISO 8528-5 clause 14 and shall give at least the following information.

### 8.1 EPS rating plate

- The words "Generating set ISO 8528";
- The manufacturer's name or mark;
- The set serial number;
- The set year of manufacturer;
- The rated power (kVA) with one of the prefixes COP, PRP, LTP or ESP in accordance with the requirements of ISO 8528-1
- The set performance class in accordance with the requirement of ISO 8528-1 ;
- The rated power factor;
- The maximum site altitude above sea-level (m)
- The maximum site ambient temperature (°C)
- The set rated frequency (Hz);
- The set rated voltage (V)

| Rabigh III Independent Water Project | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8KV Emergency Power Supply GENERAL SPECIFICATION | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 184020-510-41 28EH-EGZ001 | | | | |
| | Rev: | 01 | Page: 30/39 | Date | 22/08/2019 | |

- The set rated current (A)
- The weight (kg)

### 8.2 Generator rating plate

Rating plate for generators in accordance with IEC 60034-1 and ISO 8528-3

- The manufacturer's name or mark.
- The manufacturer's serial number or identification mark.
- made to the same electrical and mechanical design and are produced in one batch using the same technology
- Information to identify the year of manufacture
- The manufacturer's machine code.
- The number of phases.
- The number(s) of the rating and performance standard(s) which are applicable
- The degree of protection provided by the integral design of the rotating electrical machine enclosures (IP code) in accordance with IEC 60034-5.
- The thermal class and the limit of temperature or of temperature rise
- The class(es) of rating of the machine if designed for other than rating for continuous running duty S1)
- The rated output(s) or range of rated output.
- The rated voltage(s) or range of rated voltage.
- The rated frequency or range of rated frequency.
- The rated current(s) or range of rated current.
- The rated speed(s) or range of rated speed.
- The permissible over speed
- The rated power factor(s).
- For wound-rotor induction machines, the rated open-circuit voltage between slip-rings and the rated slip-ring current.
- The maximum ambient air temperature, if other than 40 °C.
- The maximum water coolant temperature, if other than 25 °C.
- The minimum ambient air temperature
- The altitude for which the machine is designed (if exceeding 1 000 m above sea-level).

## 9 FIRE FIGHTING AND DETECTION SYSTEMS

The EPS soundproof container shall be equipped with adequate fire detection and firefighting system compliant with NFPA 850 requirements.

- Smoke and heat detectors shall be installed in the electrical control compartment; "water mist" system, extinguishers or gaseous automatic extinguishing system shall be employed for fire extinguishing.
- Smoke and flame detectors shall be installed in the engine compartment. Automatic extinguishing system shall be providing. Spray type fire protection water with emulsifying additive, spray foam or gaseous extinguish systems shall be used.

A fire-detection control system is installed inside the container giving the following information to the plant fire detection panel by means of dry-contacts:

- Fire detection;
- Fire detection system default;
- Loss of power supply of the fire detection system;
- Automatic or manual fire extinguishing system release.

The information shall available on a specific terminal block to the main firefighting system. :

In addition in case of gaseous extinction:

- Inside the local visual alarm (Evacuation) at each exit an audible alarm shall be automatically and give the order to evacuate the container before the release of the gas
- Powerful sound diffuser inside and outside the sound proof container indicating the fire detection.
- Indicator and inside and outside shall indicate the release of the automatic fire extinguish systems
- Protected push- button shall be located outside near the exits for manual releases of the automatic extinguish system.

When required the cables and conductors used shall be fire resistant type in accordance with test of IEC 60331 standard.

## 10 PAINTING

The atmosphere in KSA is highly corrosive, so special attention should be given to protection of all iron Work.

Painting of the machines, the container and the electrical panels shall be in accordance with SIDEM's General Painting specification (doc. RAB03-SPE-EPCC-ZZZ-253-0001).

The final coat of indoor equipment shall be RAL7035 with C4 corrosive protection level of medium durability.

The final coat of external equipment including the container shall be RAL 7035 with C4 corrosive protection level of high durability as per ISO12945-5 Standard.

Final coats shall be of glossy finish of colour.

Approved suppliers and products shall be used and control of the painting shall be carried out as per Contractor specification.

## 11 LABELLING

Each instrument, each MV and LV panel's equipment including terminals, firefighting equipment shall be clearly labelled. The inscription on the label shall correspond with the designation given on the respective drawings.

All labels, rating and name plates unless specifically called for in English, shall be in English language and should be non-deteriorating and non-wrapping.

Labels shall be made of suitable engraving material 2 mm thickness white surface with black engraving.

Unless otherwise approved all designation labels shall be engraved with black lettering on a white background.

Labels shall not be fitted to removable covers or to the removable portion of plug-in equipment, but shall be fitted to the area immediately below the equipment to be identified unless otherwise specified. Labels shall be secured with either electro-plated self-tapping screw, rivets.

Where the use of stainless steel labels is approved, they shall be fixed with stainless steel bolts or screws.

Before installation, VENDOR shall submit detailed information of nameplate, diagram plates and warning signs to Contractor or their representatives for review and approval.

Rating plates shall be fitted to each item of equipment and shall provide the information specified in the relevant standard to which the item of equipment has been manufactured.

Warning Labels shall have black lettering and a yellow background. The minimum lettering height shall be 3mm. Warning labels shall be engraved in both English.

Labelling shall be fitted to the MV switchgear which describes clearly the safe isolation procedures for the high voltage sections of the switchgear and explains all of the interlocking involved.

## 12 SIGNAL TO DCS

The EPS shall be designed for hard wired remote control via the DCS (Distributed Control System).

The interfaces with the remote control system shall be as per sheet T91 of the MV Typical wiring diagram doc. RAB03-DTY-SIDM-EAZ-404-0001

The interfaces shall preferably be carried out using 24 VDC interposing relays. The relevant circuitry is 24 VDC powered by the DCS, consequently.

The following rules are applicable:

- The status and alarm contacts are volt free contacts,
- The commands from the DCS are interfaced with 3 VA interface relay and anti-surge bypass diode (Both located in the EPS SWITCHGEAR or control panel).
- Each relay or equipment shall have at least 2 contacts available for DCS use.

## 13 INSPECTIONS AND TESTING

### 13.1 Factory acceptance tests (FAT)

The EPS and all systems comprising shall be fully tested at factory in accordance with the SIDEM Inspection Tests Plan SID4120EQ-ZZZ001 listed in section 'Documentation of reference' and with latest applicable codes and standards.

Prior to FAT VENDOR will prepare and submit to the Contractor's approval its Manufacturing Quality Control Plan, or tests program which shall cover all tests and controls performed from the incoming material stage to the delivery of the EPS, including the final inspections as introduced here above and packing and marking control if applicable.

All testing equipment shall be calibrated by approved authorities and calibration certificate shall be provided for review and approval.

After and latest 10 days after the FAT VENDOR shall provide the tests program signed by VENDOR, CONTRACTOR and the OWNER representatives and the tests certificates of all components.

VENDOR shall notify CONTRACTOR in writing not less than 21 days prior to the scheduled starting date of the factory tests. Upon completion of factory test and before shipment of the equipment/material,

Routine test evidence for transformer components, for example bushings and tap changers, shall be provided by the Vendor prior to the transformer tests and final inspections.

Type test evidence obtained on identical equipment may be offered Contractor for consideration instead of further type tests, providing the evidence is not more than seven (7) years old and is submitted at the time of tender.

This type test certificate shall be proposed three (3) months before witness tests. Otherwise, type tests shall be carried out.

### 13.2 Site tests

The VENDOR will prepare and submit to CONTRACTOR's approval a Site Quality Control Plan including all the inspections and tests to be performed and that must contain all the checks, tests and trials listed in the following paragraphs.

The VENDOR will be in charge of the start-up of the EPS and the functional tests of the auxiliary systems.

The EPS site tests will have to comply with the requirements given in the ISO 8528-6 and will have to include, at least, the following ones.

- Insulation resistance measurement will be performed for all electrical
- Start-up tests, followed by a reduced load operation up to stabilized temperature of the cylinder cooling water.
- Loading sequence tests ;
- Sudden discharge tests;
- Endurance tests;
- Noise tests.
- Functional, signalling & safety tests

## 14 SPARES

### 14.1 Spare parts for commissioning and start up

VENDOR shall provide a detail list of the recommended spare parts for commissioning and starts up included to its offer. These spare parts shall include at least the following element:

Spares and maintenance tools shall be packed separately and identified as such (Refer to clause Delivery Handling and storage requirements)

### 14.2 Spare parts for plant operation and maintenance

VENDOR shall provide a detail list of the recommended spare parts for 2 years operation of the plant. A preliminary list will be provided by Vendor bidder during submission.

## 15 SPECIAL TOOLS

The Vendor shall quote separately a set of special tools, if so required, for erection and maintenance of the switchgear panels.

| Rabigh III Independent Water Project | | | | | | |
|---|---|---|---|---|---|---|
| TIEJUN / SIDEM VEOLIA / ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ACWA POWER / ILF CONSULTING ENGINEERS |
| | Project code: | RAB00-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 164000-SID-41306H-EGZ001 | | | | |
| | Rev: | 01 | Page: 35/39 | Date: | 22/08/2019 | |

| N° | ITEM | Unit | CONTRACTOR REQUIREMENT | VENDOR PROPOSAL |
|---|---|---|---|---|
| 29 | Rated Power factor | cos | 0.8 | |
| 30 | Rated Frequency | HZ | 60HZ | |
| 31 | Neutral Earthing | Solidly Earthed / Earthed with resistor / Isolated | IT with neutral contactor | |
| 32 | Neutral earth switch | Required | Required | |
| 33 | Duty | Base load / Emergency | Emergency | |
| 34 | Mode of operation | Continuous / Limited-time | Continuous | |
| 35 | Operation | Island mode / Parallel with network | Island mode | |
| 36 | Starting Mode | Automatic / Remote | Both | |
| 37 | Starting Time | s | <= 15s | |
| 38 | Rated Speed | r.p.m. | To be filled by VENDOR | |
| 39 | Performance class | G1 to G4 | G3 | |
| 40 | Maximum transient frequency deviation "Dfdyn" | % | To be filled by VENDOR | |
| 41 | Maximum transient voltage deviation "DUdyn" | % | To be filled by VENDOR | |
| 42 | Frequency recovery time "tf" : | s | To be filled by VENDOR | |
| 43 | Voltage recovery time "tU" : | s | To be filled by VENDOR | |
| 44 | Moment of inertia of the whole generating set "Jt" : | kgxm² | To be filled by VENDOR | |
| 45 | Start-up time "tb" | s | To be filled by VENDOR | |
| 46 | Maximum number of consecutive starting attempts : | Nb | 6 | |
| 47 | Time delay between consecutive starting attempts : | s | To be filled by VENDOR | |
| 48 | External Painting | RAL | RAL 7035 | |
| 49 | Corrosivity category | C1 to C5 | C4 | |
| 50 | Paint durability | Low to High | High durability | |
| 51 | Internal Equipment Painting | RAL | RAL 7035 | |
| 52 | Corrosivity category | C1 to C5 | C4 | |
| 53 | Paint durability | Low to High | Medium | |
| 54 | Maximum sound power level (full load) | dB(A) at 1 meter | 85dB | |
| | **ENGINE** | | | |
| 55 | Brand | - | To be defined by VENDOR | |
| 56 | Model | - | To be defined by VENDOR | |
| 57 | Injection | Direct | To be defined by VENDOR | |
| 58 | Starting Time | s | <= 15s | |
| 59 | Broke | mm | To be defined by VENDOR | |
| 60 | Stroke | mm | To be defined by VENDOR | |

| Rabigh III Independent Water Project | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 164000-SID-41305H-EGZ001 | | | | |
| | Rev: | 01 | Page: 36/39 | Date: | 22/08/2019 | |

| N° | ITEM | Unit | CONTRACTOR REQUIREMENT | VENDOR PROPOSAL |
|---|---|---|---|---|
| 61 | Air intake | - | To be defined by VENDOR | |
| 62 | Number of cylinders | Nbr | To be defined by VENDOR | |
| 63 | Cylinders arrangement | - | To be defined by VENDOR | |
| 64 | Cylinders capacity | - | To be defined by VENDOR | |
| 65 | Compression ratio | - | To be defined by VENDOR | |
| 66 | Engine regulator | - | To be defined by VENDOR | |
| 67 | Fuel consumption at 110% of rated power | g/kWh | To be defined by VENDOR | |
| 68 | Fuel consumption at 100% of rated power | g/kWh | To be defined by VENDOR | |
| 69 | Fuel consumption at 75% of rated power | g/kWh | To be defined by VENDOR | |
| 70 | Fuel consumption at 50% of rated power | g/kWh | To be defined by VENDOR | |
| 71 | Fuel consumption at 25% of rated power | g/kWh | To be defined by VENDOR | |
| 72 | Fuel consumption at stand-by power | g/kWh | To be defined by VENDOR | |
| 73 | Oil consumption | at 4/4 load | To be defined by VENDOR | |
| 74 | Heat rejection | kW | To be defined by VENDOR | |
| 75 | Cooling | Water/Air | To be defined by VENDOR | |
| 76 | Exhaust gas temperature at stand by power | °C | To be defined by VENDOR | |
| 77 | Starter | - | Electric | |
| 78 | Inertia of prime mover | kg | To be defined by VENDOR | |
| 79 | Inertia of coupling | kg | To be defined by VENDOR | |
| | **ALTERNATOR** | | | |
| 80 | Brand | - | To be defined by VENDOR | |
| 81 | Model | - | To be defined by VENDOR | |
| 82 | Rated Power | kVA | 2200 | |
| 83 | Rated Voltage | kV | 13.8 | |
| 84 | Rated Frequency | Hz | 60 | |
| 85 | Number of phases | - | 3 | |
| 86 | Rated power factor lagging | % | 0.8 | |
| 87 | Efficiency at 25% / 50% / 75% / 100% | % | To be defined by VENDOR | |
| 88 | Insulation Class | B | To be defined by VENDOR | |
| 89 | Temperature rise class | F | To be defined by VENDOR | |
| 90 | Rotor type | - | To be defined by VENDOR | |
| 91 | Exciter type | Static/Brushless | Brushless | |
| 92 | Voltage regulator class | - | To be defined by VENDOR | |
| 93 | Speed governor | Hydraulic/Electronic | Electronic | |
| 94 | Speed governor type | Isochrome/ with droop | With droop | |

| Rabigh III Independent Water Project | | | | | | | |
|---|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | | ACWA POWER ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | | |
| | Internal code: | 16400D-SID-4126EH-EGZ001 | | | | | |
| | Rev: | 01 | Page: 37/39 | Date: | 22/08/2019 | | |

| N° | ITEM | Unit | CONTRACTOR REQUIREMENT | VENDOR PROPOSAL |
|---|---|---|---|---|
| 95 | Cooling | - | To be defined by VENDOR | |
| 96 | Harmonic rate | % | To be defined by VENDOR | |
| 97 | short time withstand current | kA - 1s | To be defined by VENDOR | |
| 98 | Direct axis synchronous reactance xd | % | To be defined by VENDOR | |
| 99 | Direct axis saturated synchronous reactance Xdsat | % | To be defined by VENDOR | |
| 100 | Quadrature axis synchronous reactance Xq | % | To be defined by VENDOR | |
| 101 | Direct axis transient synchronous reactance x'd | % | To be defined by VENDOR | |
| 102 | Quadrature axis transient synchronous reactance X'q | % | To be defined by VENDOR | |
| 103 | Direct axis subtransient synchronous reactance X"d | % | To be defined by VENDOR | |
| 104 | Quadrature axis subtransient synchronous reactance X"q | % | To be defined by VENDOR | |
| 105 | Zero sequence reactance Xo | % | To be defined by VENDOR | |
| 106 | Negative sequence reactance X2 | % | To be defined by VENDOR | |
| 107 | Stator resistor | % | To be defined by VENDOR | |
| 108 | Armature leakage reactance XL | % | To be defined by VENDOR | |
| 109 | Direct axis transient open-circuit constant Tdo' | s | To be defined by VENDOR | |
| 110 | Quadrature axis transient open-circuit time constant Tqo' | s | To be defined by VENDOR | |
| 111 | Direct axis subtransient open-circuit time constant Tdo" | s | To be defined by VENDOR | |
| 112 | Quadrature axis subtransient open-circuit time constant Tqo" | s | To be defined by VENDOR | |
| 113 | R/X"d ratio | - | To be defined by VENDOR | |
| 114 | Terminal voltage at which the generator saturation curve skews from the air-gap line (Sbreak) | V | To be defined by VENDOR | |
| 115 | Saturation factor at 100% terminal voltage (S100) | - | To be defined by VENDOR | |
| 116 | Saturation factor at 120% terminal voltage (S120) | - | To be defined by VENDOR | |
| 117 | Shaft mechanical damping due to 1 Hz deviation speed | % MW/Hz | To be defined by VENDOR | |
| 118 | Inertia of generator | kg | To be defined by VENDOR | |
| 119 | Pt 100 Winding protection | Qty | 6 | |
| 120 | Frequency/ Voltage / Current variation during load step | - | Curve to be established by VENDOR | |
| 121 | Frequency/ Voltage / Current variation during load shedding | - | Curve to be established by VENDOR | |

| Rabigh III Independent Water Project | | | | | | ACWA POWER |
|---|---|---|---|---|---|---|
| TIEJUN SIDEM VEOLIA ABENGOA | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ILF CONSULTING ENGINEERS |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | |
| | Internal code: | 164000-SID-41380H-EGZ001 | | | | |
| | Rev: | 01 | Page: 38/39 | Date: | 22/08/2019 | |

| N° | ITEM | Unit | CONTRACTOR REQUIREMENT | VENDOR PROPOSAL |
|---|---|---|---|---|
| 122 | Mechanical protection | IP | Ip23 | |
| | **MV SWITCHGEAR** | | | |
| 123 | Brand | - | To be defined by VENDOR | |
| 124 | Type | - | To be defined by VENDOR | |
| 125 | Form | - | N/A | |
| 126 | Voltage | kV | 13.8 | |
| 127 | Frequency | Hz | 60 | |
| 128 | Rated insulation level | kV | 17.5 | |
| 129 | Rated short time withstand current | kA - 1s | To be defined by VENDOR | |
| 130 | feeders | - | 2 | |
| | **SUBDISTRIBUTION LV SWITCHGEAR** | | | |
| 131 | Brand | - | N/A | |
| 132 | Type | - | N/A | |
| 133 | Form | Fixed | 2 | |
| 134 | Voltage | V | 400 | |
| 135 | Frequency | Hz | N/A | |
| 136 | Rated insulation level | kV | 1,1 | |
| 137 | Rated short time withstand current | kA - 1s | To be defined by VENDOR | |
| 138 | feeders | - | To be defined by VENDOR | |
| | **EQUIPEMENT** | | | |
| 139 | Contro Panel | YES/NO | YES | |
| 140 | Exhaust connecting pipe | YES/NO | YES | |
| 141 | Power | kVA | | |
| 142 | Use | Prime / Stand by | Prime | |
| 143 | Voltage (On load) | kV | 13.8 | |
| 144 | Frequency | Hz | 60 | |
| 145 | Speed | tr/mn | To be defined by VENDOR | |
| 146 | Weight | Kg | To be defined by VENDOR | |
| 147 | Autonomy | h | 8 | |
| 148 | Daily tank Capacity | l | To be defined by VENDOR | |
| 149 | Fuel pump | YES/NO | To be defined by VENDOR | |
| 150 | Container overall dimension (LxWxH) | mxmxm | To be defined by VENDOR | |
| 151 | Total weight | t | To be defined by VENDOR | |
| | **NOTES** | | | |
| | Note 1 : | | | |
| | Note 2 : | | | |
| | Note 3 : | | | |

| Rabigh III Independent Water Project | | | | | | |
|---|---|---|---|---|---|---|
| SIDEM VEOLIA ABENGOA TIEJUN | Title: | 13.8kV Emergency Power Supply GENERAL SPECIFICATION | | | | ACWA POWER |
| | Project code: | RAB03-SPE-SIDM-EGZ-449-0001 | | | | ILF CONSULTING ENGINEERS |
| | Internal code: | [illegible] | | | | |
| | Rev: | 01 | Page: 39/39 | Date: | 22/08/2019 | |

| N° | ITEM | Unit | CONTRACTOR REQUIREMENT | VENDOR PROPOSAL |
|---|---|---|---|---|
| | Note 4 : | | | |