Multi-Stage ESG Analysis and Optimization Using Projection Pursuit Entropy and RAIGA for Coupling Coordination Degree Assessment

```
 ->To complete this task, the following procedures were implemented.
1) I will begin by loading and processing the data panel in the datasets
2) Build the DAPSIWRM framework of indicators.
3) Implement the Projection Pursuit Entropy model to reduce dimensions.
4) Apply the RAIGA algorithm to optimize the objective function.
5) Conduct Coupling Coordination Degree Analysis to analyze the interaction of the indicators and
subsystems.
```

Data Loading and Initial Inspection

In [1]:
```
#Importing the pandas library
import pandas as pd

# List of file paths
file_paths = [
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Chengtun Mining Group Co Lt
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Chifeng Jilong Gold Mining
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\China Nonferrous Metal Indu
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\CMOC Group Ltd洛阳钼业.xlsx
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Hunan Gold Corp Ltd湖南黄金
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Jinduicheng Molybdenum Co L
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\RISING NONFERROUS METAL SH
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\SHANDONG GOLD MINING CO LT
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Shengda Resources Co Ltd盛
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Western Mining Co Ltd西部矿
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Xizang Zhufeng Resources Co
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Yintai Gold Co Ltd银泰黄金.
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Youngy Co Ltd融捷健康.xlsx"
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Yunnan Chihong Zinc&Germani
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Zhongjin Gold Corp Ltd中金黄
    r"C:\Users\n\Downloads\Indicators (1)\Indicators\Indicators from ESG\Zijin Mining Group Co Ltd紫
]

# Load the data into a dictionary of DataFrames
data = {}
for file_path in file_paths:
    company_name = file_path.split('\\')[-1].split('.')[0]
    data[company_name] = pd.read_excel(file_path)

# Display the first few rows of each DataFrame to inspect the data
for company, df in data.items():
    print(f"\n{company} Data:\n", df.head())
print("Dataset loaded succesfully!")
```

```
Chengtun Mining Group Co Ltd盛屯矿业 Data:
   Chengtun Mining Group Co Ltd  2013  2014  2015  2016  2017  2018  2019  \
0     Nitrogen Oxide Emissions   NaN   NaN   NaN   NaN   NaN   0.0  0.01
1        Particulate Emissions   NaN   NaN   NaN   NaN   NaN   0.0  0.00
2    Sulphur Dioxide Emissions   NaN   NaN   NaN   NaN   NaN   0.0  0.04
3      Sulphur Oxide Emissions   NaN   NaN   NaN   NaN   NaN   NaN   NaN
4                  CO2 Scope 1   NaN   NaN   NaN   NaN   NaN   NaN   NaN

   2020  2021  2022     均值
0  0.01  0.05  0.03  0.020
1  0.00  0.00  0.00  0.000
2  0.01  0.06  0.03  0.028
3   NaN   NaN   NaN    NaN
4   NaN   NaN   NaN    NaN

Chifeng Jilong Gold Mining Co Ltd赤峰黄金 Data:
   Chifeng Jilong Gold Mining Co Ltd  2013  2014  2015  2016  2017  2018  2019  \
0         Nitrogen Oxide\nEmissions   NaN   NaN   NaN   NaN   NaN   NaN   NaN
```

In [2]:
```
#THE DATA PREPROCESSING STAGE
```

Data Preprocessing

In this step, handled missing values, normalize the data, and prepare it for clustering and projection pursuit analysis. Here is the code to handle missing values and normalize the indicators.

In [3]:
```
#imPORTing the necessary libraries for the Data preprocessing
import numpy as np
from sklearn.preprocessing import MinMaxScaler

# Function to preprocess the data
def preprocess_data(df):
    # Select only numeric columns for processing
    numeric_columns = df.select_dtypes(include=[np.number]).columns
    df_numeric = df[numeric_columns]

    # Handle missing values: Fill with the mean of the column
    df_numeric = df_numeric.fillna(df_numeric.mean())

    # Check for any remaining NaN values
    if df_numeric.isna().any().any():
        nan_columns = df_numeric.columns[df_numeric.isna().any()].tolist()
        nan_rows = df_numeric[df_numeric.isna().any(axis=1)]
        print(f"NaN values found in columns: {nan_columns}")
        print(f"NaN values found in rows:\n{nan_rows}")

    # Normalize the data
    scaler = MinMaxScaler()
    df_numeric[df_numeric.columns] = scaler.fit_transform(df_numeric)

    # Combine the numeric data with non-numeric data
    df[numeric_columns] = df_numeric
    return df

# Apply preprocessing to each company's data
for company in data:
    data[company] = preprocess_data(data[company])

# Display the first few rows of each preprocessed DataFrame
for company, df in data.items():
    print(f"\nPreprocessed {company} Data:\n", df.head())

print("Data preprocessing done!\n")
```

```
25     5.000000     6.0000     5.0000     4.5000
26     7.000000     7.0000     7.0000     7.2500
27    11.000000     8.0000     6.0000     9.1250
28   102.298824   100.0000   100.0000   100.0000
29     4.000000     4.0000     4.0000     4.0000
30     3.000000     3.0000     3.0000     3.0000
31     3.000000     3.0000     3.0000     3.0000
32    42.000000    43.0000    44.0000    39.5000
33    59.000000    60.0000    61.0000    67.5000
34     3.000000     3.0000     3.0000     3.0000
35     4.000000     4.0000     4.0000     4.0000
36     3.000000     3.0000     3.0000     3.0000
37    11.080000     0.9400     3.6000     2.3100
NaN values found in columns: [2013, 2014]
NaN values found in rows:
    2013  2014        2015     2016        2017        2018        2019  \
0    NaN   NaN   24.819375   40.825    0.000000    0.000000    0.000000
1    NaN   NaN   24.819375   40.825    0.000000    0.000000    0.000000
2    NaN   NaN   24.819375   40.825    0.000000    0.000000    0.000000
3    NaN   NaN   24.819375   40.825   32.105263   28.842105   39.107895
```

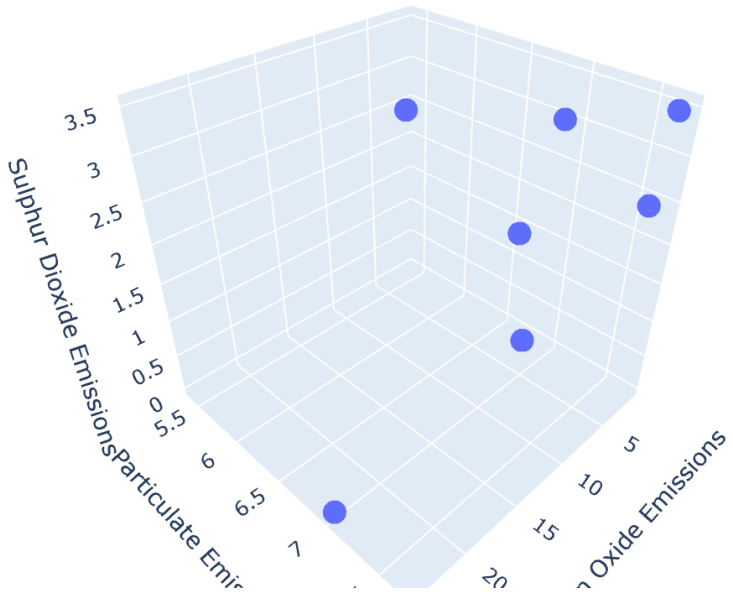
The preprocess_data function prints the columns and rows with NaN values after attempting to fill them with the mean.

Exploratory Data Analysis

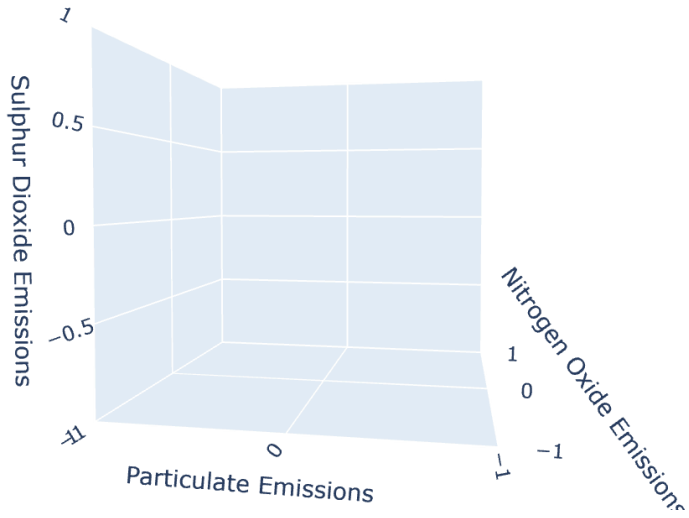
In [17]:
```
# !pip install plotly
```

In [18]:
```
import pandas as pd
import plotly.express as px
import plotly.graph_objects as go

# Define a function to generate 3D scatter plots
def plot_3d_scatter(df, x_col, y_col, z_col, title):
    fig = px.scatter_3d(df, x=x_col, y=y_col, z=z_col)
    fig.update_layout(title=title)
    fig.show()

# Define a function to generate 3D surface plots as an alternative to 3D histograms
def plot_3d_surface(df, x_col, y_col, z_col, title):
    fig = go.Figure(data=[go.Surface(z=df[z_col].values, x=df[x_col].values, y=df[y_col].values)])
    fig.update_layout(title=title, scene=dict(xaxis_title=x_col, yaxis_title=y_col, zaxis_title=z_c
    fig.show()

# Define a function to generate 3D pie charts
def plot_3d_pie_chart(df, values, names, title):
    fig = px.pie(df, values=values, names=names, title=title)
    fig.update_traces(marker=dict(line=dict(color='#000000', width=2)))
    fig.show()

# CMOC Group Ltd Data
cmoc_data = {
    "Year": [2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Nitrogen Oxide Emissions": [1.2, 1.9, 1.5, 1.8, 2.3, 24, 5.45],
    "Particulate Emissions": [7.6, 7.7, 6.9, 5.4, 6.8, 7, 6.9],
    "Sulphur Dioxide Emissions": [2.4, 3.5, 3, 2.4, 0, 0, 1.883333333],
    "GHG Scope 1": [370, 470, 480, 530, 360, 670, 480],
}

cmoc_df = pd.DataFrame(cmoc_data)

# Plot 3D scatter plot for CMOC Group Ltd
plot_3d_scatter(cmoc_df, 'Nitrogen Oxide Emissions', 'Particulate Emissions', 'Sulphur Dioxide Emis

# Zijin Mining Group Co Ltd Data
zijin_data = {
    "Year": [2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Nitrogen Oxide Emissions": [1.08, 0.98, 0.88, 0.96, 0.77, 0.89, 0.8],
    "Particulate Emissions": [0.64, 0.65, 0.75, 0.62, 0.64, 0.65, 0.62],
    "Sulphur Dioxide Emissions": [2.1, 1.93, 1.33, 1.38, 1.34, 1.48, 1.25],
    "CO2 Scope 1": [350.16, 418.42, 449.77, 692.29, 1628.49, 2206.14, 1940.54],
    "CO2 Scope 2": [1348.32, 1491.01, 1674.69, 1725.25, 2401.67, 3002.28, 1940.54],
    "Hazardous Waste": [285.95, 259.51, 309.82, 414.01, 79.29, 357.21, 320.81],
    "Total Waste": [156045, 239326, 191792, 538624, 652259, 756425, 868611],
}

zijin_df = pd.DataFrame(zijin_data)

# Plot 3D surface plot for Zijin Mining Group Co Ltd
plot_3d_surface(zijin_df, 'Nitrogen Oxide Emissions', 'Particulate Emissions', 'Sulphur Dioxide Emi

# Create pie chart data for Zijin Mining Group Co Ltd
pie_chart_data = {
    "Indicators": ["Nitrogen Oxide Emissions", "Particulate Emissions", "Sulphur Dioxide Emissions",
    "Values": [0.908571429, 0.665, 1.544285714, 957.545, 1940.536667],
}

pie_df = pd.DataFrame(pie_chart_data)
```

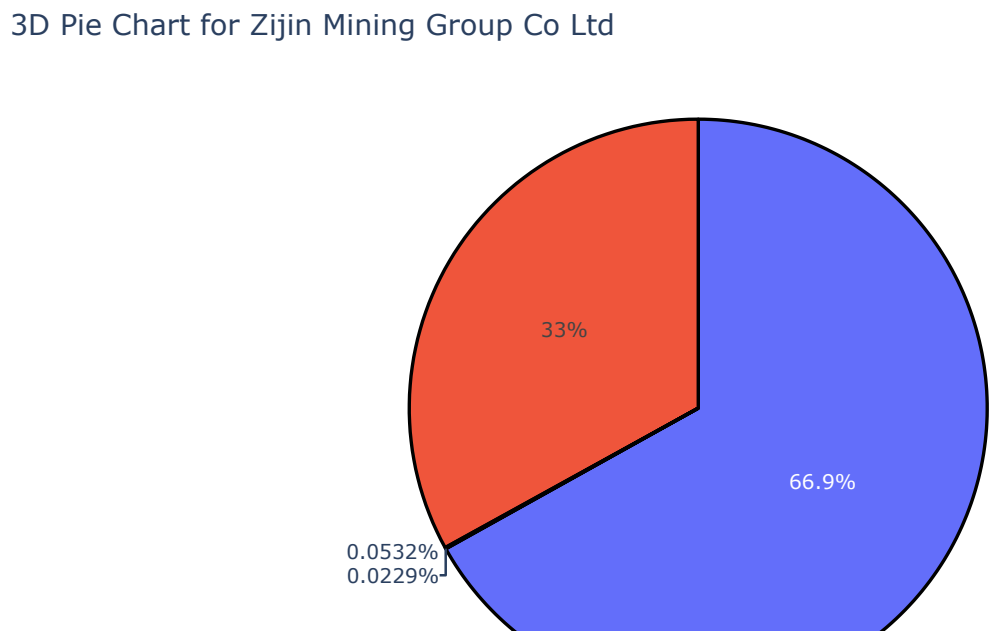
3D Scatter Plot for CMOC Group Ltd



3D Surface Plot for Zijin Mining Group Co Ltd



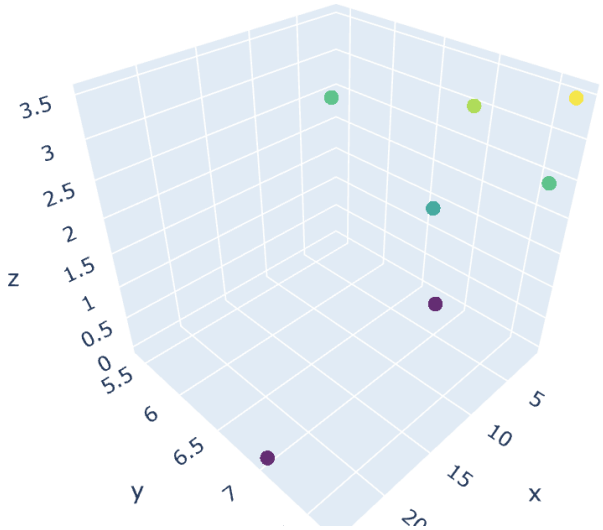
In [19]:
```
# Plot 3D pie chart for Zijin Mining Group Co Ltd
plot_3d_pie_chart(pie_df, 'Values', 'Indicators', '3D Pie Chart for Zijin Mining Group Co Ltd')
```



In [20]:
```
# !pip install pandas plotly
```

In [21]:
```python
import pandas as pd
import plotly.graph_objects as go

# Define a function to generate 3D scatter plots
def plot_3d_scatter(df, x_col, y_col, z_col, title):
    fig = go.Figure(data=[go.Scatter3d(
        x=df[x_col],
        y=df[y_col],
        z=df[z_col],
        mode='markers',
        marker=dict(
            size=5,
            color=df[z_col],                # set color to an array/list of desired values
            colorscale='Viridis',           # choose a colorscale
            opacity=0.8
        )
    )])
    fig.update_layout(title=title)
    fig.show()

# CMOC Group Ltd Data
cmoc_data = {
    "Year": [2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Nitrogen Oxide Emissions": [1.2, 1.9, 1.5, 1.8, 2.3, 24, 5.45],
    "Particulate Emissions": [7.6, 7.7, 6.9, 5.4, 6.8, 7, 6.9],
    "Sulphur Dioxide Emissions": [2.4, 3.5, 3, 2.4, 0, 0, 1.88],
    "GHG Scope 1": [370, 470, 480, 530, 360, 670, 480],
}

cmoc_df = pd.DataFrame(cmoc_data)

# Plot 3D scatter plot for CMOC Group Ltd
plot_3d_scatter(cmoc_df, 'Nitrogen Oxide Emissions', 'Particulate Emissions', 'Sulphur Dioxide Emis
```

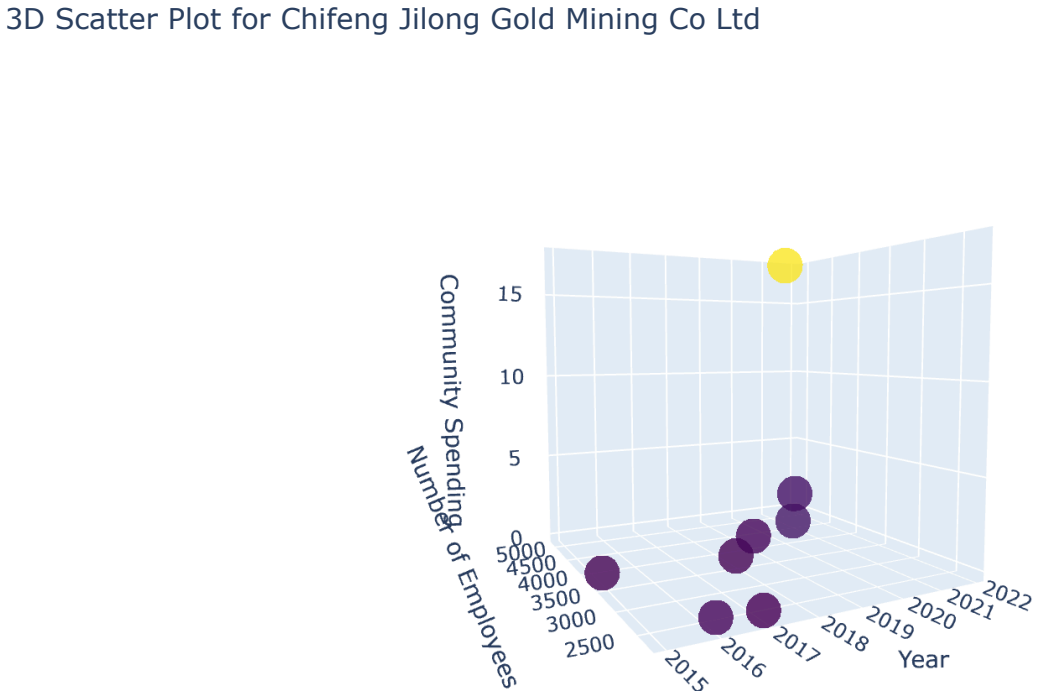
Scatter Plot for CMOC Group Ltd



In [22]:
```
import matplotlib.pyplot as plt
import seaborn as sns

# Set the style for seaborn
sns.set(style="whitegrid")

# Data for Hunan Gold Corp Ltd
hunan_gold_data = {
    'Year': list(range(2013, 2023)),
    'Nitrogen Oxide Emissions': [None, None, None, None, None, None, 0.01, 0.02, 0.01, None],
    'Sulphur Dioxide Emissions': [None, None, None, None, None, None, 0, 0.01, 0, None],
    'Number of Employees- CSR': [7123, 6559, 8765, 5829, 6257, 6511, 5362, 5340, 5051, 5087],
    'Employee Training Cost': [1.3, None, None, 3.17, None, None, None, None, None, None],
    'Number of Board Meetings for the Year': [8, 8, 8, 12, 8, 9, 7, 8, 8, 10],
    'Size of Compensation Committee': [4, 4, 4, 4, 4, 4, 4, 4, 3, 3],
    'Num of Independent Directors on Compensation Cmte': [2, 2, 2, 3, 3, 2, 2, 2, 2, 2],
    'Number of Compensation Committee Meetings': [None, None, None, None, None, None, None, None, 1
    'Age of the Oldest Director': [48, 49, 50, 51, 52, 53, 54, 55, 53, 55],
    'Number of Independent Directors': [3, 2, 3, 3, 3, 3, 3, 3, 3, 3],
    'Size of Nomination Committee': [4, 3, 4, 4, 4, 4, 4, 3, 3, 3],
    'Community Spending': [1.04, 1.79, 1, 1, 1.1, 1.28, 0.85, 1.16, 0.9, 4.75]
}

# Convert the dictionary to a DataFrame
df_hunan_gold = pd.DataFrame(hunan_gold_data)

# Function to plot trends for the given DataFrame
def plot_company_trends(df, company_name):
    df.plot(x='Year', subplots=True, layout=(6, 2), figsize=(15, 20), title=f'Trends Over the Years
    plt.tight_layout()
    plt.show()

# Plot trends for Hunan Gold Corp Ltd
plot_company_trends(df_hunan_gold, 'Hunan Gold Corp Ltd')
```

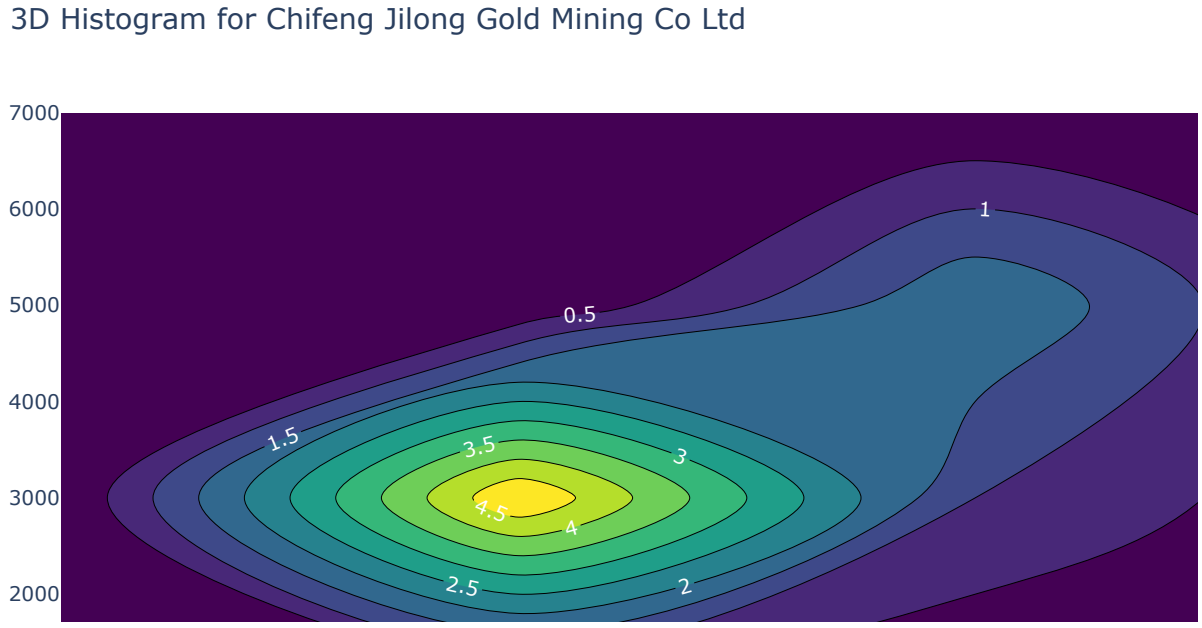

Trends Over the Years for Hunan Gold Corp Ltd
Nitrogen Oxide Emissions
Sulphur Dioxide Emissions
Number of Employees- CSR
Employee Training Cost
Number of Board Meetings for the Year
Size of Compensation Committee
Num of Independent Directors on Compensation Cmte
Number of Compensation Committee Meetings
Age of the Oldest Director
Number of Independent Directors
Size of Nomination Committee
Community Spending
Year
Year

In [23]:
```
import pandas as pd
import plotly.graph_objects as go

# Chifeng Jilong Gold Mining Co Ltd Data
chifeng_data = {
    "Year": [2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Number of Employees - CSR": [3667, 2268, 2303, 3546, 3956, 3863, 4715, 5137],
    "Audit Committee Meetings": [9, 5, 4, 5, 7, 6, 6, 5],
    "Board Size": [7, 7, 7, 9, 8, 11, 11, 14],
    "Number of Executives / Company Managers": [5, 6, 6, 5, 4, 6, 7, 8],
    "Number of Non Executive Directors on Board": [4, 5, 5, 5, 6, 6, 6, 9],
    "Number of Board Meetings for the Year": [15, 11, 6, 12, 12, 15, 11, 12],
    "Size of Compensation Committee": [3, 3, 3, 3, 2, 5, 5, 4],
    "Num of Independent Directors on Compensation Cmte": [2, 2, 2, 2, 2, 3, 3, 3],
    "Age of the Youngest Director": [39, 40, 41, 42, 43, 44, 45, 46],
    "Age of the Oldest Director": [61, 62, 63, 62, 63, 64, 65, 67],
    "Number of Independent Directors": [3, 3, 3, 3, 3, 4, 4, 4],
    "Size of Nomination Committee": [3, 3, 3, 3, 3, 3, 3, 4],
    "Community Spending": [0.13, 0.23, 0.02, 0.17, 0.38, 1.15, 17.35, 0.94]
}

chifeng_df = pd.DataFrame(chifeng_data)

# Function to plot 3D scatter plot
def plot_3d_scatter(df, x_col, y_col, z_col, title):
    fig = go.Figure(data=[go.Scatter3d(
        x=df[x_col],
        y=df[y_col],
        z=df[z_col],
        mode='markers',
        marker=dict(
            size=12,
            color=df[z_col],                # set color to an array/list of desired values
            colorscale='Viridis',           # choose a colorscale
            opacity=0.8
        )
    )])
    fig.update_layout(
        title=title,
        scene=dict(
            xaxis_title=x_col,
            yaxis_title=y_col,
            zaxis_title=z_col,
        )
    )
    fig.show()

# Plot 3D scatter plot for Chifeng Jilong Gold Mining Co Ltd
plot_3d_scatter(chifeng_df, 'Year', 'Number of Employees - CSR', 'Community Spending', '3D Scatter
```


3D Scatter Plot for Chifeng Jilong Gold Mining Co Ltd
Community Spending
15
10
5
0
Number of Employees
5000
4500
4000
3500
3000
2500
Year
2015
2016
2017
2018
2019
2020
2021
2022

In [ ]:

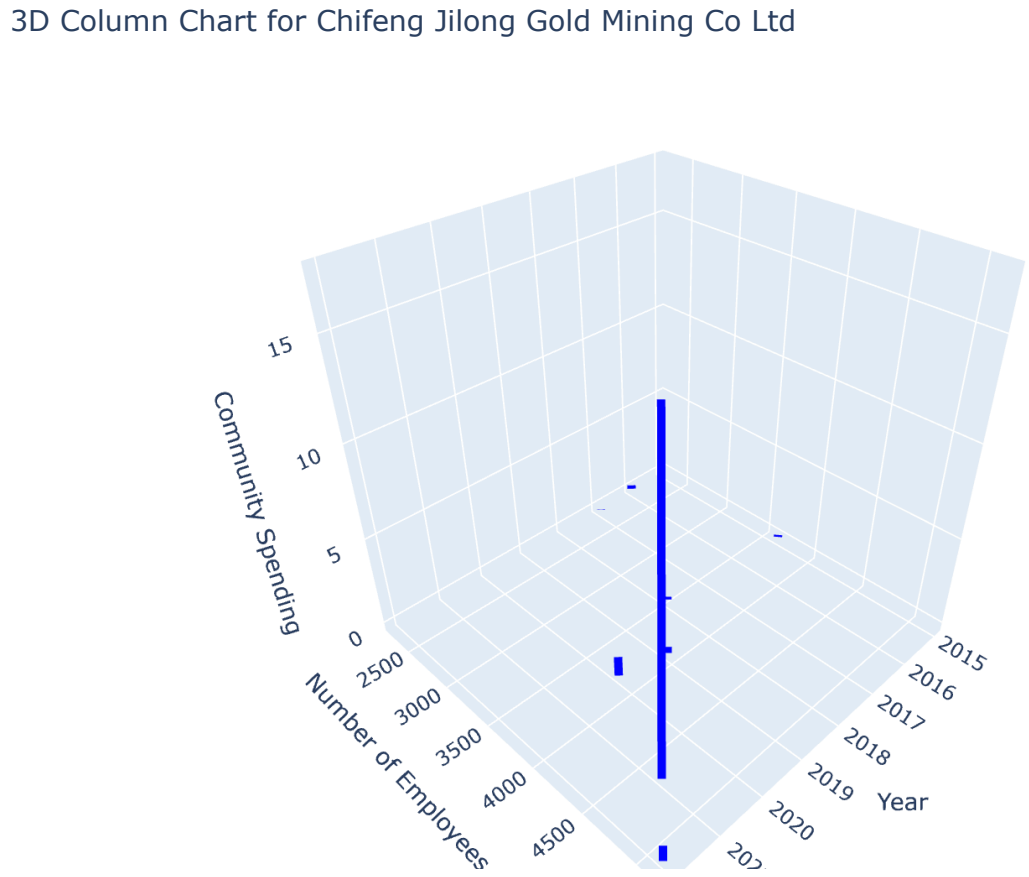
In [24]:
```
import pandas as pd
import plotly.graph_objects as go

# Chifeng Jilong Gold Mining Co Ltd Data
chifeng_data = {
    "Year": [2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Number of Employees - CSR": [3667, 2268, 2303, 3546, 3956, 3863, 4715, 5137],
    "Audit Committee Meetings": [9, 5, 4, 5, 7, 6, 6, 5],
    "Board Size": [7, 7, 7, 9, 8, 11, 11, 14],
    "Number of Executives / Company Managers": [5, 6, 6, 5, 4, 6, 7, 8],
    "Number of Non Executive Directors on Board": [4, 5, 5, 5, 6, 6, 6, 9],
    "Number of Board Meetings for the Year": [15, 11, 6, 12, 12, 15, 11, 12],
    "Size of Compensation Committee": [3, 3, 3, 3, 2, 5, 5, 4],
    "Num of Independent Directors on Compensation Cmte": [2, 2, 2, 2, 2, 3, 3, 3],
    "Age of the Youngest Director": [39, 40, 41, 42, 43, 44, 45, 46],
    "Age of the Oldest Director": [61, 62, 63, 62, 63, 64, 65, 67],
    "Number of Independent Directors": [3, 3, 3, 3, 3, 4, 4, 4],
    "Size of Nomination Committee": [3, 3, 3, 3, 3, 3, 3, 4],
    "Community Spending": [0.13, 0.23, 0.02, 0.17, 0.38, 1.15, 17.35, 0.94]
}

chifeng_df = pd.DataFrame(chifeng_data)

# Function to plot 3D histogram
def plot_3d_histogram(df, x_col, y_col, z_col, title):
    fig = go.Figure(data=[go.Histogram2dContour(
        x=df[x_col],
        y=df[y_col],
        z=df[z_col],
        colorscale='Viridis',
        showscale=True,
        contours=dict(
            showlabels=True,
            labelfont=dict(
                size=12,
                color='white',
            )
        )
    )])
    fig.update_layout(
        title=title,
        scene=dict(
            xaxis_title=x_col,
            yaxis_title=y_col,
            zaxis_title=z_col,
        )
    )
    fig.show()

# Plot 3D histogram for Chifeng Jilong Gold Mining Co Ltd
plot_3d_histogram(chifeng_df, 'Year', 'Number of Employees - CSR', 'Community Spending', '3D Histogr
```


3D Histogram for Chifeng Jilong Gold Mining Co Ltd
7000
6000
5000
4000
3000
2000
0.5
1
1.5
2
2.5
3
3.5
4
4.5

In [26]:
```
ort pandas as pd
ort plotly.graph_objects as go

hifeng Jilong Gold Mining Co Ltd Data
feng_data = {
 "Year": [2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022],
 "Number of Employees - CSR": [3667, 2268, 2303, 3546, 3956, 3863, 4715, 5137],
 "Community Spending": [0.13, 0.23, 0.02, 0.17, 0.38, 1.15, 17.35, 0.94]


feng_df = pd.DataFrame(chifeng_data)

unction to plot 3D-like column chart
 plot_3d_like_column_chart(df, x_col, y_col, z_col, title):
 fig = go.Figure()

 # Adding a 3D-like bar trace
 fig.add_trace(go.Bar(
     x=df[x_col],
     y=df[z_col],
     name='Community Spending',
     marker=dict(color='rgba(58, 71, 80, 0.6)')
 ))

 fig.update_layout(
     title=title,
     scene=dict(
         xaxis_title=x_col,
         yaxis_title=z_col,
         zaxis_title=y_col,
     ),
     margin=dict(l=0, r=0, b=0, t=50)
 )

 fig.show()

lot 3D-like column chart for Chifeng Jilong Gold Mining Co Ltd
t_3d_like_column_chart(chifeng_df, 'Year', 'Number of Employees - CSR', 'Community Spending', '3D Co
```


3D Column Chart for Chifeng Jilong Gold Mining Co Ltd
18
16
14
12
10
8
6

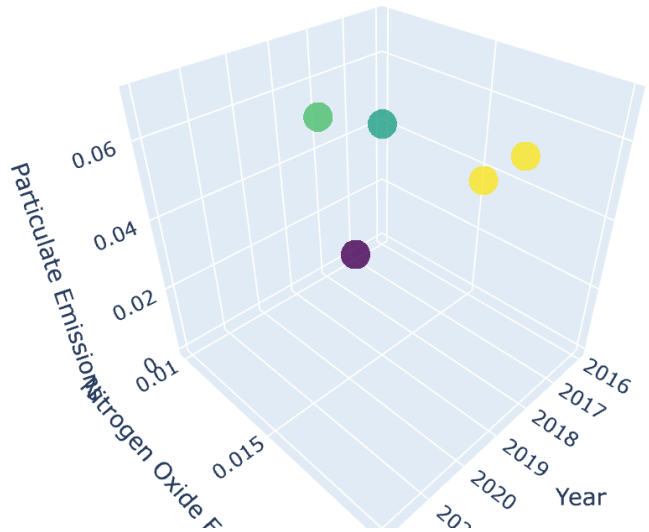
In [27]:
```
rt pandas as pd
rt plotly.graph_objects as go

ifeng Jilong Gold Mining Co Ltd Data
eng_data = {
"Year": [2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022],
"Number of Employees - CSR": [3667, 2268, 2303, 3546, 3956, 3863, 4715, 5137],
"Community Spending": [0.13, 0.23, 0.02, 0.17, 0.38, 1.15, 17.35, 0.94]


eng_df = pd.DataFrame(chifeng_data)

nction to plot 3D column chart
plot_3d_column_chart(df, x_col, y_col, z_col, title):
fig = go.Figure()

for i in range(len(df)):
    fig.add_trace(go.Scatter3d(
        x=[df[x_col][i], df[x_col][i]],
        y=[df[y_col][i], df[y_col][i]],
        z=[0, df[z_col][i]],
        mode='lines',
        line=dict(color='blue', width=10)
    ))

fig.update_layout(
    title=title,
    scene=dict(
        xaxis_title=x_col,
        yaxis_title=y_col,
        zaxis_title=z_col,
        camera=dict(
            eye=dict(x=1.25, y=1.25, z=1.25)
        )
    ),
    margin=dict(l=0, r=0, b=0, t=50)
)

fig.show()

ot 3D column chart for Chifeng Jilong Gold Mining Co Ltd
_3d_column_chart(chifeng_df, 'Year', 'Number of Employees - CSR', 'Community Spending', '3D Column C
```


3D Column Chart for Chifeng Jilong Gold Mining Co Ltd
Community Spending
15
10
5
0
Number of Employees
2500
3000
3500
4000
4500
Year
2015
2016
2017
2018
2019
2020

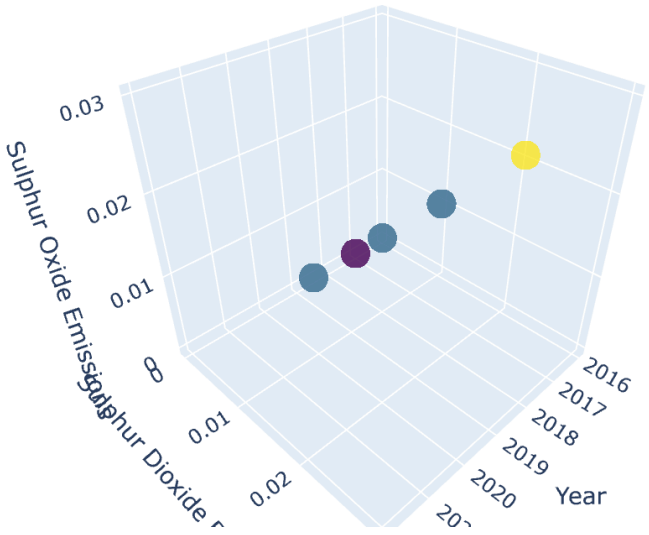
In [ ]:

In [28]:
```
import pandas as pd
import plotly.graph_objects as go

# Shandong Gold Mining Co Ltd Data
shandong_data = {
    "Year": [2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Nitrogen Oxide Emissions": [0.01, 0.01, 0.01, 0.02, 0.02, None, None],
    "Particulate Emissions": [0.04, 0, 0.05, 0.07, 0.07, None, None],
    "Sulphur Dioxide Emissions": [0.01, 0, 0.01, 0.03, 0.01, None, None],
    "Sulphur Oxide Emissions": [0.01, 0, 0.01, 0.03, 0.01, None, None],
    "GHG Scope 1": [None, None, None, 72.3, 112.9, 168.3, None],
    "GHG Scope 2": [None, None, None, 716.8, 854.5, 1126.8, None],
    "Electricity Used": [761.9, 871.95, 1009.88, 915.2, 101.21, 991.82, 1317.74],
    "Fuel Used - Coal/Lignite": [15.36, 13.03, 3.5, 3, 7.17, 4.96, 12.89],
    "Fuel Used - Natural Gas": [None, None, None, 1691.3, 1695.1, 2021.3, 1949.1],
    "Fuel Used - Crude Oil/Diesel": [28.98, 15.3, 15.66, 14.8, 18.99, 17.21, 25.77],
    "Hazardous Waste": [None, None, None, 1435.4, 1636.1, 0.15, 0.14],
    "Total Water Withdrawal": [None, None, None, 5844.5, 1196, 6639.8, None],
    "Total Water Discharged": [None, None, None, 17713.5, 28924.9, 29198.2, None],
    "Pct Women in Workforce": [20.3, 20.94, 19.93, 19.99, 19.61, 19.2, 18.09],
    "Number of Employees - CSR": [13251, 12985, 12793, 14739, 14378, 16032, 16134],
    "Community Spending": [2.77, 1.11, None, 2.07, 2.1, 1, 0.62]
}

shandong_df = pd.DataFrame(shandong_data)

# Function to plot 3D scatter plot
def plot_3d_scatter(df, x_col, y_col, z_col, title):
    fig = go.Figure(data=[go.Scatter3d(
        x=df[x_col],
        y=df[y_col],
        z=df[z_col],
        mode='markers',
        marker=dict(
            size=10,
            color=df[z_col],
            colorscale='Viridis',
            opacity=0.8
        )
    )])
    fig.update_layout(
        title=title,
        scene=dict(
            xaxis_title=x_col,
            yaxis_title=y_col,
            zaxis_title=z_col
        )
    )
    fig.show()


# Plot 3D scatter plots for Shandong Gold Mining Co Ltd
plot_3d_scatter(shandong_df, 'Year', 'Nitrogen Oxide Emissions', 'Particulate Emissions', '3D Scatt
plot_3d_scatter(shandong_df, 'Year', 'Sulphur Dioxide Emissions', 'Sulphur Oxide Emissions', '3D Sc
```

3D Scatter Plot for Nitrogen Oxide vs Particulate Emissions

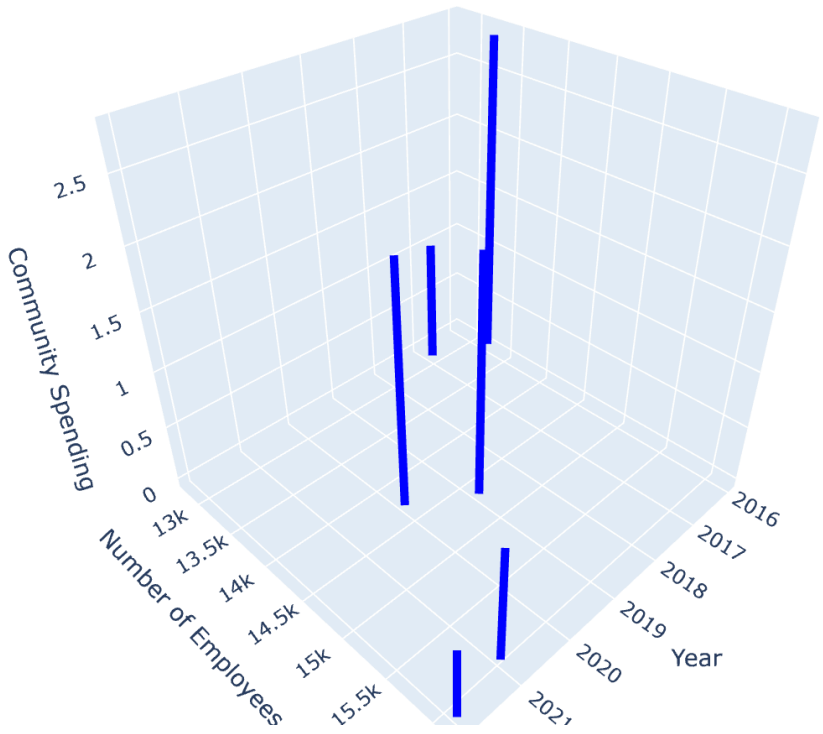


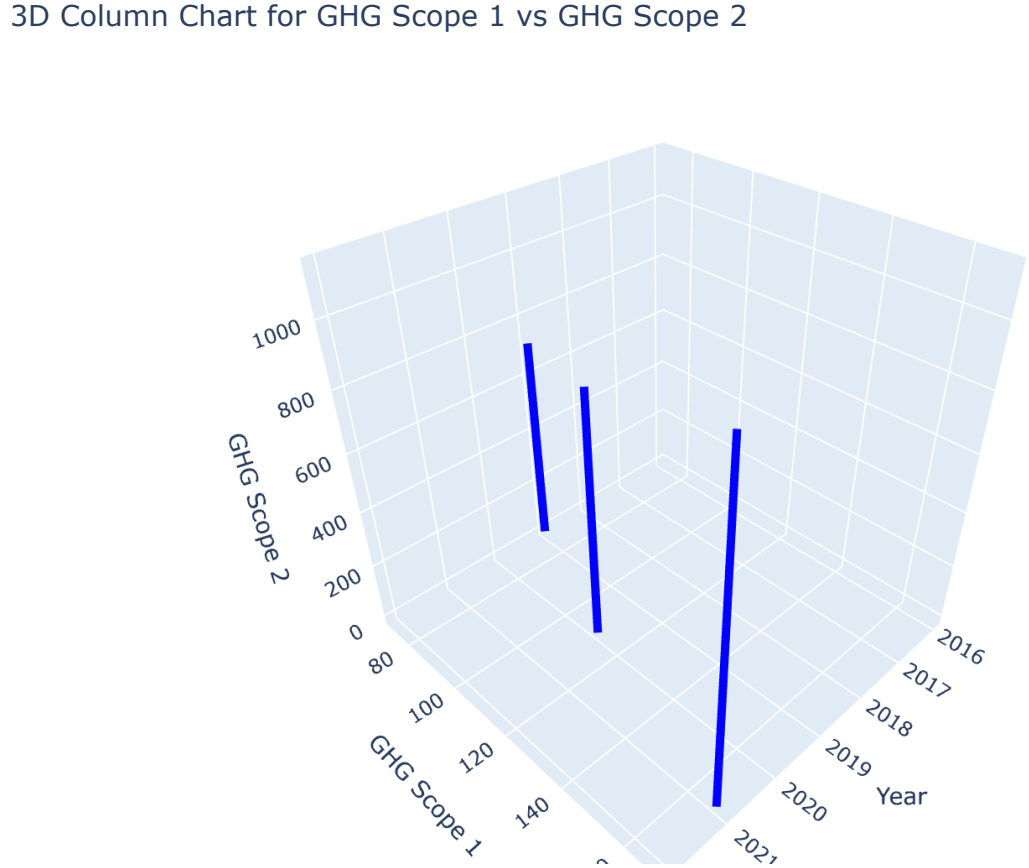
3D Scatter Plot for Sulphur Dioxide vs Sulphur Oxide Emissions



In [29]:
```
# Function to plot 3D column chart
def plot_3d_column_chart(df, x_col, y_col, z_col, title):
    fig = go.Figure()

    for i in range(len(df)):
        fig.add_trace(go.Scatter3d(
            x=[df[x_col][i], df[x_col][i]],
            y=[df[y_col][i], df[y_col][i]],
            z=[0, df[z_col][i]],
            mode='lines',
            line=dict(color='blue', width=10)
        ))

    fig.update_layout(
        title=title,
        scene=dict(
            xaxis_title=x_col,
            yaxis_title=y_col,
            zaxis_title=z_col,
            camera=dict(
                eye=dict(x=1.25, y=1.25, z=1.25)
            )
        ),
        margin=dict(l=0, r=0, b=0, t=50)
    )

    fig.show()
# Plot 3D column charts for Shandong Gold Mining Co Ltd
plot_3d_column_chart(shandong_df, 'Year', 'Number of Employees - CSR', 'Community Spending', '3D Co
plot_3d_column_chart(shandong_df, 'Year', 'GHG Scope 1', 'GHG Scope 2', '3D Column Chart for GHG Sc
```

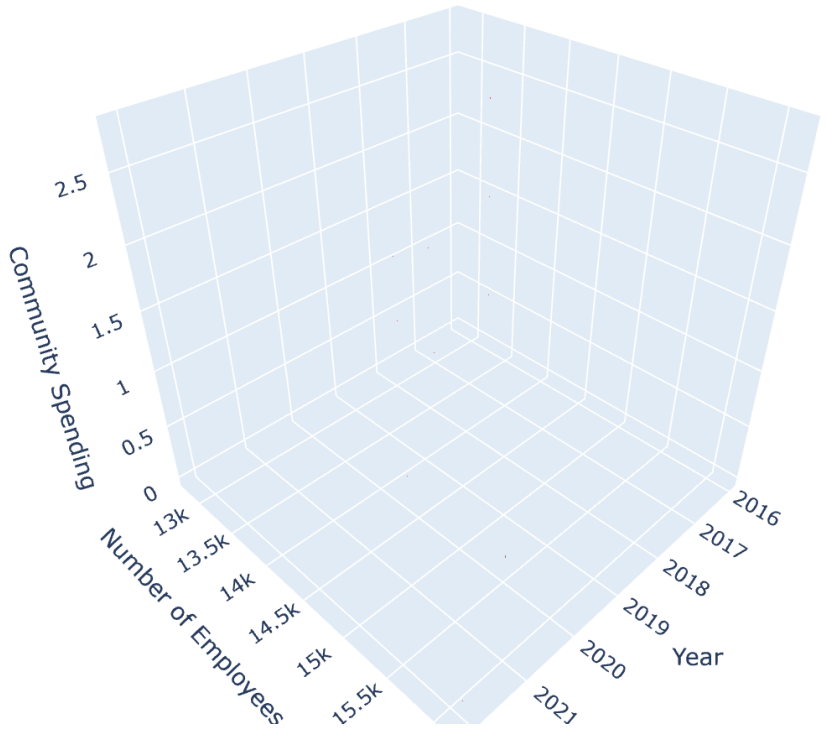
3D Column Chart for Number of Employees vs Community Spending



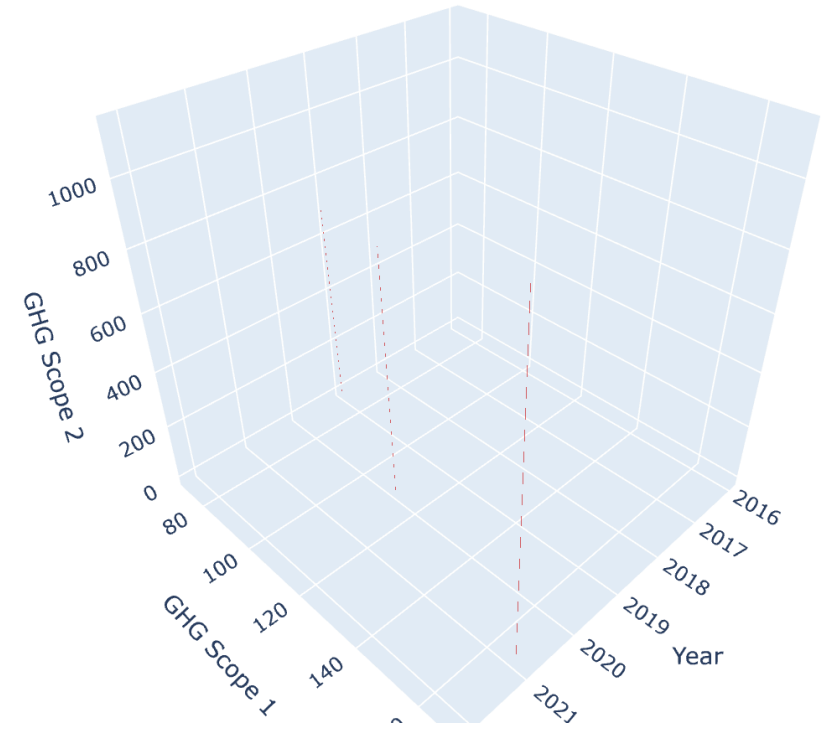

3D Column Chart for GHG Scope 1 vs GHG Scope 2
GHG Scope 2
1000
800
600
400
200
0
GHG Scope 1
80
100
120
140
Year
2016
2017
2018
2019
2020
2021

In [37]:
```
import pandas as pd
import plotly.graph_objects as go

# Sample data for Shandong Gold Mining Co Ltd
shandong_data = {
    "Year": [2016, 2017, 2018, 2019, 2020, 2021, 2022],
    "Nitrogen Oxide Emissions": [0.01, 0.01, 0.01, 0.02, 0.02, None, None],
    "Particulate Emissions": [0.04, 0, 0.05, 0.07, 0.07, None, None],
    "Sulphur Dioxide Emissions": [0.01, 0, 0.01, 0.03, 0.01, None, None],
    "Sulphur Oxide Emissions": [0.01, 0, 0.01, 0.03, 0.01, None, None],
    "GHG Scope 1": [None, None, None, 72.3, 112.9, 168.3, None],
    "GHG Scope 2": [None, None, None, 716.8, 854.5, 1126.8, None],
    "Electricity Used": [761.9, 871.95, 1009.88, 915.2, 101.21, 991.82, 1317.74],
    "Fuel Used - Coal/Lignite": [15.36, 13.03, 3.5, 3, 7.17, 4.96, 12.89],
    "Fuel Used - Natural Gas": [None, None, None, 1691.3, 1695.1, 2021.3, 1949.1],
    "Fuel Used - Crude Oil/Diesel": [28.98, 15.3, 15.66, 14.8, 18.99, 17.21, 25.77],
    "Hazardous Waste": [None, None, None, 1435.4, 1636.1, 0.15, 0.14],
    "Total Water Withdrawal": [None, None, None, 5844.5, 1196, 6639.8, None],
    "Total Water Discharged": [None, None, None, 17713.5, 28924.9, 29198.2, None],
    "Pct Women in Workforce": [20.3, 20.94, 19.93, 19.99, 19.61, 19.2, 18.09],
    "Number of Employees - CSR": [13251, 12985, 12793, 14739, 14378, 16032, 16134],
    "Community Spending": [2.77, 1.11, None, 2.07, 2.1, 1, 0.62]
}

shandong_df = pd.DataFrame(shandong_data)

# Function to plot 3D column chart using Mesh3d
def plot_3d_column_chart(df, x_col, y_col, z_col, title):
    fig = go.Figure()

    for i in range(len(df)):
        # Create a 3D column as a Mesh3d object
        fig.add_trace(go.Mesh3d(
            x=[df[x_col][i], df[x_col][i], df[x_col][i]+0.1, df[x_col][i]+0.1, df[x_col][i], df[x_c
            y=[df[y_col][i], df[y_col][i], df[y_col][i], df[y_col][i], df[y_col][i]+0.1, df[y_col][
            z=[0, df[z_col][i], df[z_col][i], 0, 0, df[z_col][i], df[z_col][i], 0],
            color='red',
            opacity=0.6
        ))

    fig.update_layout(
        title=title,
        scene=dict(
            xaxis_title=x_col,
            yaxis_title=y_col,
            zaxis_title=z_col,
            camera=dict(
                eye=dict(x=1.25, y=1.25, z=1.25)
            )
        ),
        margin=dict(l=0, r=0, b=0, t=50)
    )

    fig.show()

# Plot 3D column charts for Shandong Gold Mining Co Ltd
plot_3d_column_chart(shandong_df, 'Year', 'Number of Employees - CSR', 'Community Spending', '3D Co
plot_3d_column_chart(shandong_df, 'Year', 'GHG Scope 1', 'GHG Scope 2', '3D Column Chart for GHG Sc
```

3D Column Chart for Number of Employees vs Community Spending



3D Column Chart for GHG Scope 1 vs GHG Scope 2

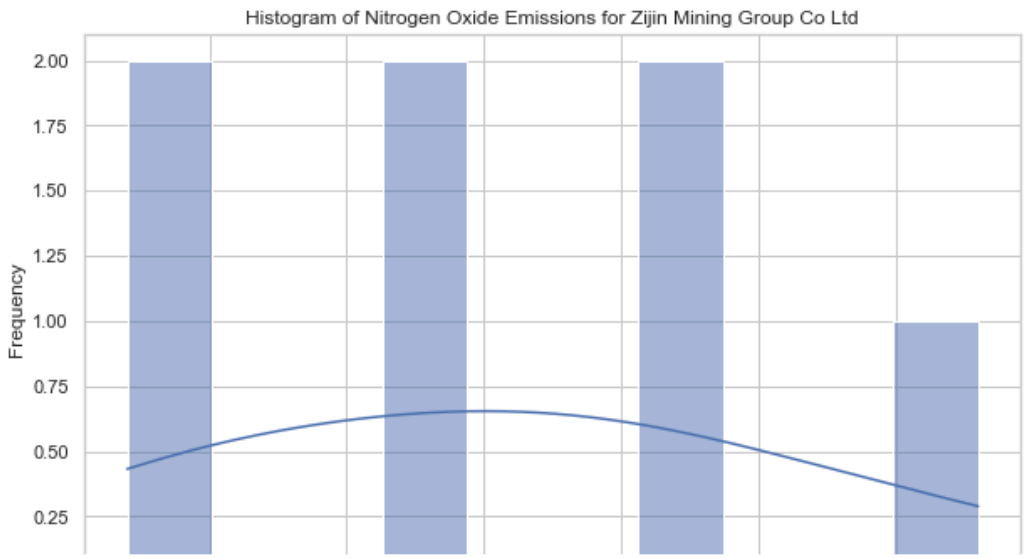



```
The Explanation of charts
-zijin_data: Dictionary containing the data for Zijin Mining Group Co Ltd.
```

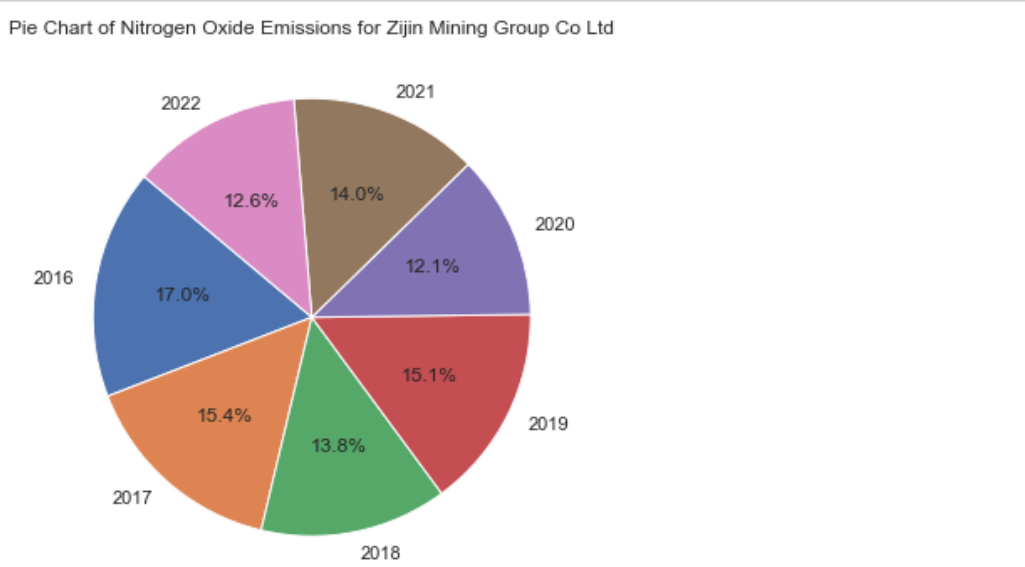
```
-df_zijin: Converted the dictionary to a pandas DataFrame.
-plot_company_histograms: Function to generate histograms for the given DataFrame. It plots
histograms for each indicator.
-plot_company_pie_charts: Function to generate pie charts for the given DataFrame. It plots pie
charts for each indicator.
-Plot histograms and pie charts: The functions plot_company_histograms and plot_company_pie_charts
are called with the DataFrame and company name to generate the plots.
This code will basically generate histograms and pie charts for each indicator in the Zijin Mining
Group Co Ltd dataset, allowing you to visualize the distributions and proportions of various
indicators for this company.
```

In [31]:
```
import matplotlib.pyplot as plt
import seaborn as sns

# Set the style for seaborn
sns.set(style="whitegrid")

# Data for Zijin Mining Group Co Ltd
zijin_data = {
    'Year': list(range(2013, 2023)),
    'Nitrogen Oxide Emissions': [None, None, None, 1.08, 0.98, 0.88, 0.96, 0.77, 0.89, 0.8],
    'Particulate Emissions': [None, None, None, None, None, None, 0.64, 0.65, 0.75, 0.62],
    'Sulphur Dioxide Emissions': [None, None, None, 2.1, 1.93, 1.33, 1.38, 1.34, 1.48, 1.25],
    'CO2 Scope 1': [None, None, None, 350.16, 418.42, 449.77, 692.29, 1628.49, 2206.14, None],
    'CO2 Scope 2': [None, None, None, 1348.32, 1491.01, 1674.69, 1725.25, 2401.67, 3002.28, None],
    'Total Energy Consumption': [None, None, None, 3356.76, 3753.26, 4253.3, 4900.56, 6669, 12574.7,
    'Fuel Used - Coal/Lignite': [None, None, None, 58.56, 62.36, 68.01, 40.75, 591.65, 840.64, 830.8
    'Fuel Used - Natural Gas': [None, None, None, 2364.21, 7311.22, 4727.07, 3194.63, 4439.33, 1583
    'Fuel Used - Crude Oil/Diesel': [None, None, None, 86.91, 89.86, 101.78, 90.73, 249.92, 313.07,
    'Hazardous Waste': [None, None, None, 285.95, 259.51, 309.82, 414.01, 79.29, 357.21, 320.81],
    'Total Waste': [None, None, None, 156045, 239326, 191792, 538624, 652259, 756425, 868611],
    'Total Water Withdrawal': [None, None, None, None, None, None, 45230, 50780, 60560, 72710],
    'Total Water Discharged': [None, None, None, None, None, None, 20560, 20820, 42290, 51520],
    'Pct Women in Workforce': [None, None, None, None, None, None, 16.12, 16.14, 15.61, 14.92],
    'Number of Employees- CSR': [23883, 23224, 19011, 17445, 26407, 28179, 36605, 36860, 43876, 488
    'Employee Turnover': [None, None, None, None, 8.74, 6.33, 7.68, 9.31, 7.57, 8.66],
    'Total Hours Spent by Firm - Employee Training': [None, None, None, 19843.2, 29973, None, None,
    'Number of Independent Directors on Audit Committee': [4, 4, 4, 4, 4, 4, 4, 5, 5, 5],
    'Audit Committee Meetings': [4, 4, 5, 6, 7, 6, 5, 7, 7, 7],
    'Board Size': [11, 11, 12, 11, 11, 11, 11, 13, 13, 13],
    'Number of Executives / Company Managers': [9, 9, 10, 10, 10, 10, 14, 12, 12, 13],
    'Number of Non Executive Directors on Board': [5, 5, 5, 5, 5, 5, 6, 7, 7, 7],
    'Number of Board Meetings for the Year': [21, 22, 37, 24, 21, 19, 22, 31, 17, 25],
    'Board Meeting Attendance Pct': [100, 100, 99.32, 100, 98.26, 95.69, 95.88, 100, 100, 100],
    'Size of Compensation Committee': [6, 6, 6, 6, 6, 6, 6, 6, 6, 5],
    'Num of Independent Directors on Compensation Cmte': [4, 4, 4, 4, 4, 4, 4, 4, 4, 3],
    'Number of Compensation Committee Meetings': [3, 2, 2, 4, 2, 1, 2, 3, 1, 3],
    'Age of the Youngest Director': [37, 39, 40, 41, 42, 43, 44, 45, 46, 47],
    'Age of the Oldest Director': [66, 67, 68, 74, 75, 76, 65, 66, 67, 68],
    'Number of Independent Directors': [4, 4, 4, 4, 4, 4, 5, 6, 6, 6],
    'Size of Nomination Committee': [6, 6, 6, 6, 6, 6, 6, 6, 6, 5],
    'Board Duration (Years)': [3, 3, 3, 3, 3, 3, 3, 3, 3, 3],
    'Community Spending': [230, 186, 119.51, 102.11, 154, 207, 166.28, 178, 268.24, 250.67]
}

# Convert the dictionary to a DataFrame
df_zijin = pd.DataFrame(zijin_data)

# Function to plot histograms for the given DataFrame
def plot_company_histograms(df, company_name):
    columns = df.columns[1:]  # Exclude the 'Year' column
    for column in columns:
        plt.figure(figsize=(10, 6))
        sns.histplot(df[column].dropna(), bins=10, kde=True)
        plt.title(f'Histogram of {column} for {company_name}')
        plt.xlabel(column)
        plt.ylabel('Frequency')
        plt.show()

# Function to plot pie charts for the given DataFrame
def plot_company_pie_charts(df, company_name):
    columns = df.columns[1:]  # Exclude the 'Year' column
    for column in columns:
        plt.figure(figsize=(10, 6))
        data = df[column].dropna()
        plt.pie(data, labels=df['Year'][data.index], autopct='%1.1f%%', startangle=140)
        plt.title(f'Pie Chart of {column} for {company_name}')
        plt.show()
```

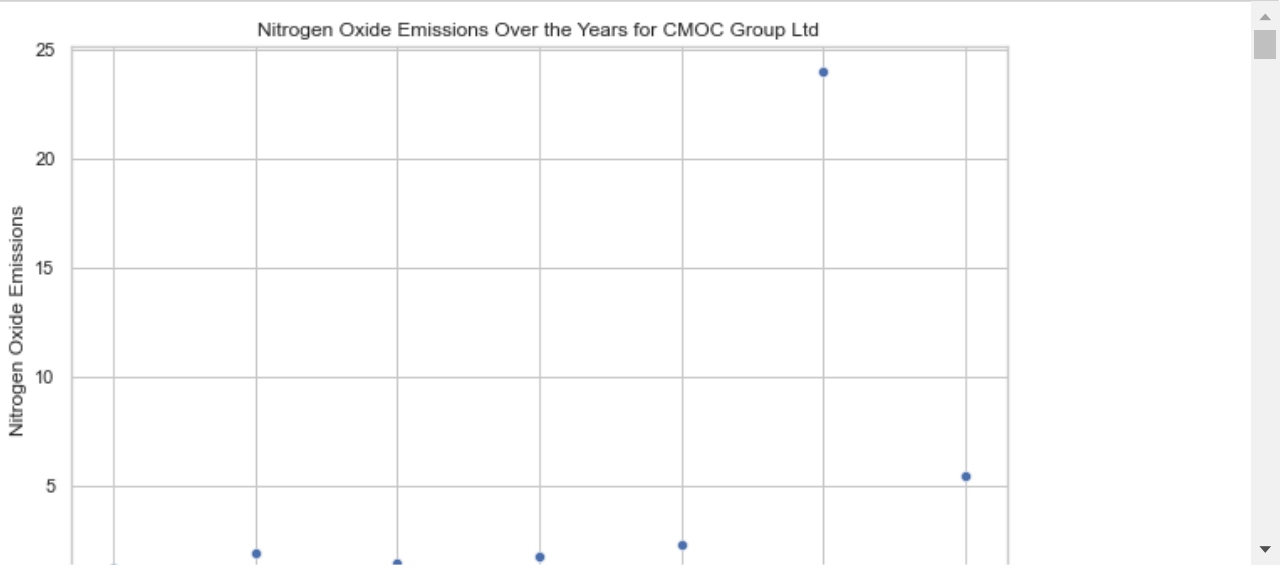
```
# Plot histograms for Zijin Mining Group Co Ltd
plot_company_histograms(df_zijin, 'Zijin Mining Group Co Ltd')
```



In [32]:
```
# Plot pie charts for Zijin Mining Group Co Ltd
plot_company_pie_charts(df_zijin, 'Zijin Mining Group Co Ltd')
```



In [33]:
```
import matplotlib.pyplot as plt
import seaborn as sns

# Set the style for seaborn
sns.set(style="whitegrid")

# Data for CMOC Group Ltd
cmoc_data = {
    'Year': list(range(2013, 2023)),
    'Nitrogen Oxide Emissions': [None, None, None, 1.2, 1.9, 1.5, 1.8, 2.3, 24, 5.45],
    'Particulate Emissions': [None, None, None, 7.6, 7.7, 6.9, 5.4, 6.8, 7, 6.9],
    'Sulphur Dioxide emissions': [None, None, None, 2.4, 3.5, 3, 2.4, 0, 0, 1.883333333],
    'GHG Scope 1/CO2 Scope 1': [None, None, None, 370, 470, 480, 530, 360, 670, 480],
    'GHG Scope 2/CO2 Scope 2': [None, None, None, 620, 510, 490, 500, 560, 560, 540],
    'Total Energy Consumption': [None, None, None, 2874, 3080, 3170, 3290, 3800, 1929.32, 3023.8866
    'Fuel Used - Coal/Lignite': [None, None, None, 1891, None, None, None, None, None, 1891],
    'Fuel Used - Natural Gas': [None, None, None, 12845, None, None, None, None, 48780.5, 30812.75]
    'Fuel Used - Crude Oil/Diesel': [None, None, None, None, None, None, None, None, 246.87, 246.87
    'Hazardous Waste': [None, None, None, 5.2, 4, 4, 7, 26, 51, 16.2],
    'Total Waste': [None, None, None, 107385, 101615, 136020, 150026, 175047, 309047, 163190],
    'Total Water Withdrawal': [None, None, None, 26902.2, 26375, 24570, 23168, 30723, 24066, 25967.1
    'Number of Employees- CSR': [8427, 7207, 6389, 11566, 11226, 10900, 10850, 10956, 11472, 17479]
    'Employee Turnover': [None, None, None, None, 7686, 8048, 10684, 13222, 20186, 11965.2],
    'Community Spending': [15.69, 4.15, 18.04, 21.91, 22.55, 45.26, 7.06, 31.24, 22.2, 364]
}

# Convert the dictionary to a DataFrame
df_cmoc = pd.DataFrame(cmoc_data)

# Function to plot scatter plots for the given DataFrame
def plot_company_scatter(df, company_name):
    columns = df.columns[1:]  # Exclude the 'Year' column
    for column in columns:
        plt.figure(figsize=(10, 6))
        sns.scatterplot(x='Year', y=column, data=df)
        plt.title(f'{column} Over the Years for {company_name}')
        plt.xlabel('Year')
        plt.ylabel(column)
        plt.show()

# Plot scatter plots for CMOC Group Ltd
plot_company_scatter(df_cmoc, 'CMOC Group Ltd')
```



In [34]:
```
#THE PROJECTION PURSUIT ENTROPY MODEL
```

The Projection Pursuit Entropy Model

```
We will construct the Projection Pursuit Entropy model for each company's data.
The projection_pursuit_entropy function raises a ValueError if NaN values are detected before
processing the data.
```

In [35]:
```python
# Function to compute projection pursuit entropy
def projection_pursuit_entropy(df):
    # Select only numeric columns for processing
    numeric_columns = df.select_dtypes(include=[np.number]).columns
    df_numeric = df[numeric_columns]

    # Ensure no NaN values are present before proceeding
    if df_numeric.isna().any().any():
        raise ValueError("NaN values detected in numeric data.")

    # Number of samples and indicators
    n_samples, n_indicators = df_numeric.shape

    # Random projection direction
    projection_direction = np.random.rand(n_indicators)
    projection_direction /= np.linalg.norm(projection_direction)  # Normalize to unit vector

    # Project the data
    projected_data = np.dot(df_numeric, projection_direction)

    # Ensure the projected data does not contain NaN values
    if np.isnan(projected_data).any():
        raise ValueError("NaN values detected in projected data.")

    # Calculate entropy
    hist, bin_edges = np.histogram(projected_data, bins='auto', density=True)
    hist += np.finfo(float).eps  # Avoid log(0)
    entropy = -np.sum(hist * np.log(hist))

    return entropy, projection_direction

# Apply projection pursuit entropy to each company's data
projections = {}
for company in data:
    try:
        entropy, direction = projection_pursuit_entropy(data[company])
        projections[company] = (entropy, direction)
        print(f"\n{company} Projection Entropy: {entropy}\nProjection Direction: {direction}")
    except ValueError as e:
        print(f"Error processing {company}: {e}")
```

```
Chengtun Mining Group Co Ltd盛屯矿业 Projection Entropy: -14.078893895422297
Projection Direction: [0.49657443 0.18547017 0.46724186 0.01289751 0.19320136 0.45381521
 0.07901512 0.29200597 0.19003333 0.018562   0.35956954]
Error processing Chifeng Jilong Gold Mining Co Ltd赤峰黄金: NaN values detected in numeric data.

China Nonferrous Metal Industry's Foreign Engineering and Construction Co Ltd中色股份 Projection En
tropy: -10.320187656964766
Projection Direction: [0.50897627 0.23264417 0.12987399 0.30004475 0.19201628 0.24635005
 0.39160324 0.00651878 0.39052814 0.35689635 0.2215498 ]

CMOC Group Ltd洛阳钼业 Projection Entropy: -18.67575648310916
Projection Direction: [0.41279215 0.04934146 0.29512566 0.02706488 0.06748475 0.50403897
 0.2152779  0.61160715 0.03642375 0.05475608 0.23663078]

Hunan Gold Corp Ltd湖南黄金 Projection Entropy: -28.147825984628582
Projection Direction: [0.03443187 0.10828339 0.17112327 0.28754455 0.36472416 0.30443177
 0.11848926 0.32870203 0.60853049 0.38054148 0.11052507]

Jinduicheng Molybdenum Co Ltd金钼股份 Projection Entropy: -33.28893157443566
Projection Direction: [0.25380949 0.39403114 0.12868385 0.08600053 0.02047989 0.50948365
 0.08026666 0.45578184 0.51636723 0.01114183 0.12422756]

RISING NONFERROUS METAL SH广晟有色 Projection Entropy: -13.814469042159715
Projection Direction: [0.23125481 0.45153126 0.2556097  0.04444712 0.01629873 0.17683527
 0.33378278 0.20052778 0.49620668 0.29938249 0.39537227]

SHANDONG GOLD MINING CO LT山东黄金 Projection Entropy: -31.548330117368117
Projection Direction: [0.00612982 0.28738282 0.16423137 0.26882558 0.43896705 0.42833627
 0.04387493 0.22918442 0.22082803 0.39930016 0.42345512]

Shengda Resources Co Ltd盛达资源 Projection Entropy: -33.41056133909593
Projection Direction: [0.43990762 0.08759745 0.07501132 0.14999768 0.21475433 0.49070234
 0.23104128 0.02288033 0.33384123 0.37672442 0.42011775]

Western Mining Co Ltd西部矿业 Projection Entropy: -17.12989861538703
Projection Direction: [0.04508308 0.04535089 0.43472039 0.24893588 0.38858949 0.09249475
 0.24186447 0.26238157 0.07122972 0.48880516 0.46266207]
Error processing Xizang Zhufeng Resources Co Ltd西藏珠峰: NaN values detected in numeric data.
Error processing Yintai Gold Co Ltd银泰黄金: NaN values detected in numeric data.
Error processing Youngy Co Ltd融捷健康: NaN values detected in numeric data.

Yunnan Chihong Zinc&Germanium Co Ltd驰宏锌锗 Projection Entropy: -12.24492762968832
Projection Direction: [0.26966838 0.20685271 0.48246641 0.23887519 0.43117658 0.38949732
 0.16744128 0.1203284  0.25943918 0.23242907 0.3052652 ]

Zhongjin Gold Corp Ltd中金黄金 Projection Entropy: -15.001036016568609
Projection Direction: [0.30417741 0.425107   0.20153612 0.1799793  0.19477531 0.32033036
 0.37480393 0.38007048 0.17411069 0.44488505 0.00574649]

Zijin Mining Group Co Ltd紫金矿业 Projection Entropy: -18.94452845916971
Projection Direction: [0.07770531 0.359349   0.46631057 0.05450458 0.10783792 0.27022837
 0.35805365 0.28049456 0.09390166 0.40050426 0.42855652]
```

In [36]:
```
# Function to plot a heatmap of correlations between indicators for a specific company
def plot_heatmap(data, company):
    df = data[company]
    numeric_columns = df.select_dtypes(include=[np.number]).columns
    df = df[numeric_columns]
    corr = df.corr()
    plt.figure(figsize=(12, 8))
    sns.heatmap(corr, annot=True, cmap='coolwarm', vmin=-1, vmax=1)
    plt.title(f'Correlation Heatmap for {company}')
    plt.show()
company_name = 'Chengtun Mining Group Co Ltd盛屯矿业'
indicator_name = 'Nitrogen Oxide Emissions'

# Plot a heatmap of correlations between indicators for a specific company
plot_heatmap(data, company_name)
```

```
C:\Users\n\anaconda3\lib\site-packages\seaborn\utils.py:95: UserWarning:

Glyph 22343 (\N{CJK UNIFIED IDEOGRAPH-5747}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\seaborn\utils.py:95: UserWarning:

Glyph 20540 (\N{CJK UNIFIED IDEOGRAPH-503C}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning:

Glyph 30427 (\N{CJK UNIFIED IDEOGRAPH-76DB}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning:

Glyph 23663 (\N{CJK UNIFIED IDEOGRAPH-5C6F}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning:

Glyph 30719 (\N{CJK UNIFIED IDEOGRAPH-77FF}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning:

Glyph 19994 (\N{CJK UNIFIED IDEOGRAPH-4E1A}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning:

Glyph 22343 (\N{CJK UNIFIED IDEOGRAPH-5747}) missing from current font.

C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning:

Glyph 20540 (\N{CJK UNIFIED IDEOGRAPH-503C}) missing from current font.
```

RAIGA Optimization

```
The RAIGA (Real-coded Accelerating Immune Genetic Algorithm) will be implemented to optimize the
projection pursuit model. This involves several steps including population initialization, fitness
evaluation, selection, crossover, mutation, and immune operations.
```

```
The RAIGA Explanation
-Population Initialization: Randomly initializes a population of candidate solutions.
-Fitness Evaluation: Projects the data onto each individual's projection direction, calculates the
histogram, and computes the entropy.
-Selection: Selects the best half of the population based on fitness.
-Crossover: Combines pairs of individuals to create offspring.
-Mutation: Introduces random variations into individuals.
-Immune Operation: Combines the best individual with some variations to create immune individuals.
-Optimization Loop: Runs the above steps for a specified number of generations, keeping track of
the best solution.
    This code optimizes the projection pursuit model for each company’s dataset using the RAIGA
algorithm. Let me know if you need further adjustments or explanations!
```

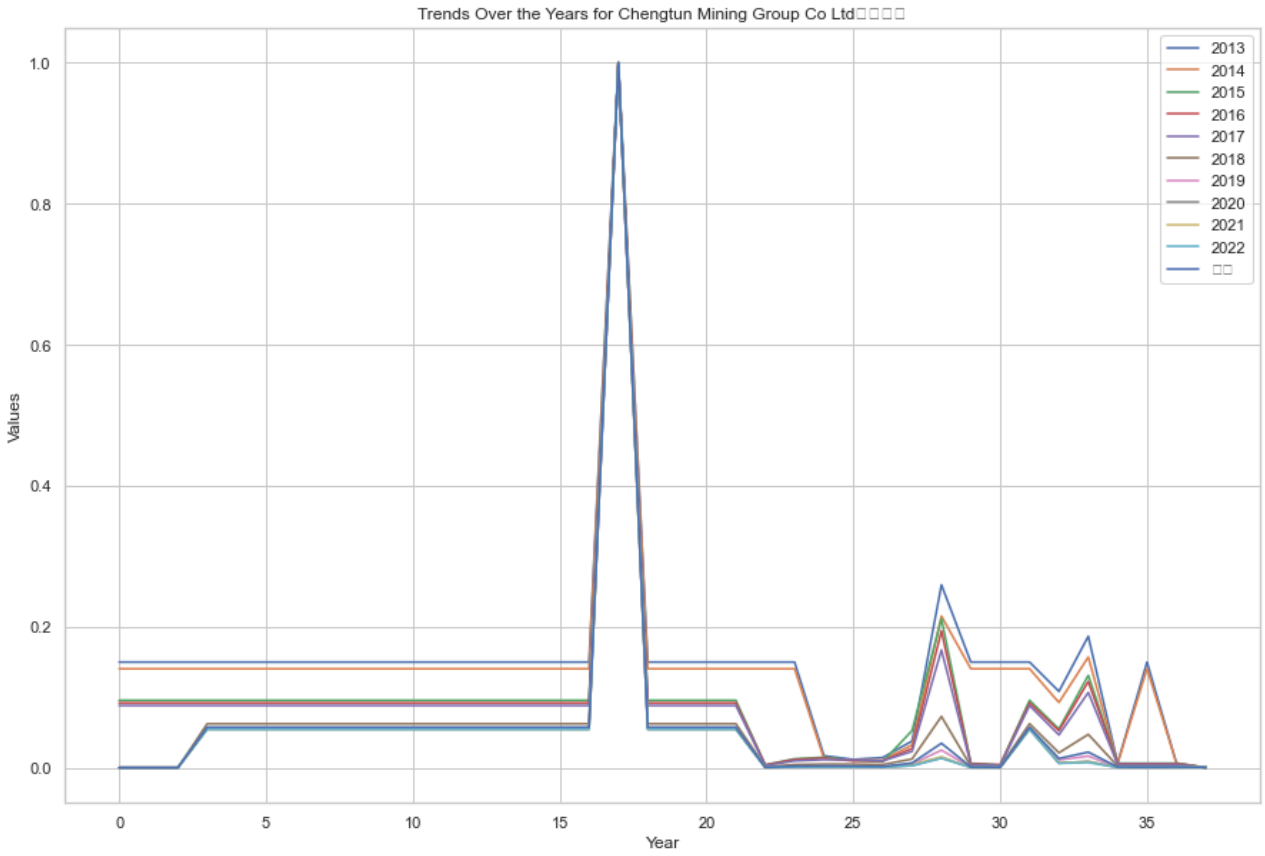
In [82]:
```
import numpy as np
import random

# Function to initialize the population
def initialize_population(pop_size, dim):
    return np.random.rand(pop_size, dim)

# Function to evaluate fitness
def evaluate_fitness(population, data):
    fitness = []
    for individual in population:
        projected_data = np.dot(data, individual / np.linalg.norm(individual))
        hist, _ = np.histogram(projected_data, bins='auto', density=True)
        hist += np.finfo(float).eps  # Avoid log(0)
        entropy = -np.sum(hist * np.log(hist))
        fitness.append(entropy)
    return np.array(fitness)

# Function for selection
def select_population(population, fitness, num_selected):
    selected_indices = np.argsort(fitness)[:num_selected]
    return population[selected_indices]

# Function for crossover
def crossover(parent1, parent2):
    alpha = random.random()
    child1 = alpha * parent1 + (1 - alpha) * parent2
    child2 = alpha * parent2 + (1 - alpha) * parent1
    return child1, child2

# Function for mutation
def mutate(individual, mutation_rate):
    for i in range(len(individual)):
        if random.random() < mutation_rate:
            individual[i] += np.random.normal()
    return individual

# Function for immune operation
def immune_operation(population, best_individual):
    immune_population = []
    for individual in population:
        if random.random() < 0.5:
            individual = best_individual + np.random.normal(0, 0.1, size=individual.shape)
        immune_population.append(individual)
    return np.array(immune_population)

# RAIGA function
def raiga_optimization(data, pop_size=50, num_generations=100, mutation_rate=0.01):
    n_samples, n_indicators = data.shape
    population = initialize_population(pop_size, n_indicators)
    best_fitness = float('inf')
    best_individual = None

    for generation in range(num_generations):
        fitness = evaluate_fitness(population, data)

        if np.min(fitness) < best_fitness:
            best_fitness = np.min(fitness)
            best_individual = population[np.argmin(fitness)]

        selected_population = select_population(population, fitness, pop_size // 2)
        new_population = []

        for i in range(0, len(selected_population), 2):
            if i + 1 < len(selected_population):
                child1, child2 = crossover(selected_population[i], selected_population[i + 1])
                new_population.append(mutate(child1, mutation_rate))
                new_population.append(mutate(child2, mutation_rate))
```

```
        population = np.array(new_population)
        population = immune_operation(population, best_individual)

    return best_individual, best_fitness

# Apply RAIGA optimization to each company's data
optimized_projections = {}
for company in data:
    try:
        best_projection, best_fitness = raiga_optimization(data[company].select_dtypes(include=[np.
        optimized_projections[company] = (best_projection, best_fitness)
        print(f"\n{company} Best Fitness: {best_fitness}\nBest Projection Direction: {best_projecti
    except ValueError as e:
        print(f"Error processing {company}: {e}")
```

```
Chengtun Mining Group Co Ltd盛屯矿业 Best Fitness: -7793121.20750994
Best Projection Direction: [ 0.36796224  1.09393936 -0.09309428  0.63955323 -0.67273263 -0.0073147
4
 -0.365604    0.29383659  0.50382181 -0.31348995 -0.09800564]
Error processing Chifeng Jilong Gold Mining Co Ltd赤峰黄金: autodetected range of [nan, nan] is not
finite

China Nonferrous Metal Industry's Foreign Engineering and Construction Co Ltd中色股份 Best Fitness:
-98327.68179267956
Best Projection Direction: [-0.49702695  0.29734321  0.55048096 -0.49502718  0.70237105 -0.1725987
2
  0.19317799 -0.15477092  1.20504207 -1.57482429  0.48604412]

CMOC Group Ltd洛阳钼业 Best Fitness: -12576.870405625887
Best Projection Direction: [-1.71058831  0.71361725  0.78372021  0.69195947 -0.10287658 -0.1021939
2
  0.25085941  0.48782978  0.38940011 -0.29232146 -0.63861697]

Hunan Gold Corp Ltd湖南黄金 Best Fitness: -1420962.3054856334
Best Projection Direction: [ 0.52540551  0.07196754  0.37681853  0.24321194  0.78195678 -0.2395715
7
  0.14393306 -0.09154363  0.1109102   0.44386521 -0.50531555]

Jinduicheng Molybdenum Co Ltd金钼股份 Best Fitness: -20651.756123400268
Best Projection Direction: [-0.22419842  0.22434154 -0.06956903 -1.03879233  0.60164115  0.4501441
2
  0.20378537 -0.01104268  1.50577806  0.84466735  1.0534379 ]

RISING NONFERROUS METAL SH广晟有色 Best Fitness: -28009.633571170976
Best Projection Direction: [ 0.88304699  0.21336277  0.27340687 -0.14735605 -0.03705585 -0.0811280
1
 -0.28353515  0.30935409  0.39647974  0.45289288 -1.15633221]

SHANDONG GOLD MINING CO LT山东黄金 Best Fitness: -4591.586017697976
Best Projection Direction: [ 1.15128936  0.59884791  0.01154876  0.11005379 -0.12150838 -0.2807087
3
  0.07651394  0.26317905  0.65917742  1.1753533   0.52816658]

Shengda Resources Co Ltd盛达资源 Best Fitness: -154046.0143224339
Best Projection Direction: [ 0.41964353  0.99613638 -0.02216016  0.18534709  0.36516474  0.7748476
4
  1.03504996  0.2993054   0.09169829 -0.13457176  0.04206486]

Western Mining Co Ltd西部矿业 Best Fitness: -13775.77204351063
Best Projection Direction: [ 0.03801909 -0.1447246   0.71203247 -0.03941642 -0.10401438 -0.5159788
8
 -0.834516    0.2631065  -0.33421927  0.34363233  0.59094419]
Error processing Xizang Zhufeng Resources Co Ltd西藏珠峰: autodetected range of [nan, nan] is not f
inite
Error processing Yintai Gold Co Ltd银泰黄金: autodetected range of [nan, nan] is not finite
Error processing Youngy Co Ltd融捷健康: autodetected range of [nan, nan] is not finite

Yunnan Chihong Zinc&Germanium Co Ltd驰宏锌锗 Best Fitness: -22246.712446139125
Best Projection Direction: [ 0.07973571 -0.06968454  0.36743644 -0.44316113  0.1005089   1.0740493
1
 -2.09720237  0.7811566  -0.21544721  0.98879724  0.52594603]

Zhongjin Gold Corp Ltd中金黄金 Best Fitness: -47443.83589292147
Best Projection Direction: [-0.91261097  1.39244758 -1.40543013  0.30275162  0.02640689 -0.2875269
9
  0.90848368 -0.30555978 -0.05655522  0.86033907 -0.40991694]

Zijin Mining Group Co Ltd紫金矿业 Best Fitness: -12902.360181046222
Best Projection Direction: [ 1.69831926e+00 -2.13673679e+00 -1.38860481e-01  1.93400892e-01
  7.89998913e-01 -2.09550092e-01  2.95329429e-01  2.20578783e-01
  4.70230785e-01  1.87204259e-03  5.17602328e-01]
```

In [83]:
```
#Some EDA charts before the Coupling Coordination Degree Analysis
import matplotlib.pyplot as plt
import seaborn as sns

# Example usage of the functions
company_name = 'Chengtun Mining Group Co Ltd盛屯矿业'
indicator_name = 'Nitrogen Oxide Emissions'

# Set the style for seaborn
sns.set(style="whitegrid")

# Function to plot trends over the years for a specific company
def plot_trends(data, company):
    df = data[company]
    numeric_columns = df.select_dtypes(include=[np.number]).columns
    df = df[numeric_columns]
    df.plot(figsize=(15, 10))
    plt.title(f'Trends Over the Years for {company}')
    plt.xlabel('Year')
    plt.ylabel('Values')
    plt.legend(loc='best')
    plt.show()
# Plot trends over the years for a specific company
plot_trends(data, company_name)
```

```
C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning: Glyph 30427
(\N{CJK UNIFIED IDEOGRAPH-76DB}) missing from current font.
  fig.canvas.print_figure(bytes_io, **kw)
C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning: Glyph 23663
(\N{CJK UNIFIED IDEOGRAPH-5C6F}) missing from current font.
  fig.canvas.print_figure(bytes_io, **kw)
C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning: Glyph 30719
(\N{CJK UNIFIED IDEOGRAPH-77FF}) missing from current font.
  fig.canvas.print_figure(bytes_io, **kw)
C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning: Glyph 19994
(\N{CJK UNIFIED IDEOGRAPH-4E1A}) missing from current font.
  fig.canvas.print_figure(bytes_io, **kw)
C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning: Glyph 22343
(\N{CJK UNIFIED IDEOGRAPH-5747}) missing from current font.
  fig.canvas.print_figure(bytes_io, **kw)
C:\Users\n\anaconda3\lib\site-packages\IPython\core\pylabtools.py:151: UserWarning: Glyph 20540
(\N{CJK UNIFIED IDEOGRAPH-503C}) missing from current font.
  fig.canvas.print_figure(bytes_io, **kw)
```



Coupling Coordination Degree Analysis

We will analyze the interaction of the indicators and subsystems using the Coupling Coordination Degree Analysis Model.

The Explanation
1) calculate_coupling_degree: Adds a small epsilon value to avoid division by zero when calculating B.
2) coupling_coordination_analysis: Adds epsilon to the normalization step to ensure no division by zero occurs.
3) Weights: Ensures the weights are correctly aligned with the number of features.
4) Robust Error Handling: Includes additional error handling to catch and report any unexpected issues.

In [84]:
```
import numpy as np

# Function to calculate the coupling degree
def calculate_coupling_degree(subsystems):
    n = len(subsystems)
    subsystems_with_eps = subsystems + np.finfo(float).eps  # Add epsilon to avoid zero values
    A = np.prod(subsystems_with_eps)
    B = np.sum([np.prod(subsystems_with_eps) / subsystems_with_eps[i] for i in range(n)])  # Adding
    C = (A / B) ** (1 / n)
    return C

# Function to calculate the coordination degree
def calculate_coordination_degree(subsystems, weights):
    T = np.dot(subsystems, weights)
    D = np.sqrt(np.sum(weights * ((subsystems / (T + np.finfo(float).eps)) ** 2)))  # Adding epsilo
    return D

# Function to perform Coupling Coordination Degree Analysis
def coupling_coordination_analysis(data, weights):
    # Select only numeric columns for processing
    numeric_columns = data.select_dtypes(include=[np.number]).columns
    df_numeric = data[numeric_columns]

    # Calculate subsystems values
    subsystems = df_numeric.mean(axis=0).values  # Mean values for each indicator as subsystem valu

    # Normalize the subsystems values
    subsystems_range = subsystems.max() - subsystems.min()
    if subsystems_range == 0:  # If the range is zero, avoid division by zero
        subsystems_range = np.finfo(float).eps
    subsystems = (subsystems - subsystems.min()) / subsystems_range

    # Calculate the coupling degree
    coupling_degree = calculate_coupling_degree(subsystems)

    # Calculate the coordination degree
    coordination_degree = calculate_coordination_degree(subsystems, weights)

    return coupling_degree, coordination_degree

# Define weights for each indicator (assuming equal weights for simplicity)
num_indicators = len(data['Chengtun Mining Group Co Ltd盛屯矿业'].select_dtypes(include=[np.number]))
weights = np.ones(num_indicators) / num_indicators

# Apply Coupling Coordination Degree Analysis to each company's data
coordination_results = {}
for company in data:
    try:
        coupling_degree, coordination_degree = coupling_coordination_analysis(data[company], weight
        coordination_results[company] = (coupling_degree, coordination_degree)
        print(f"\n{company} Coupling Degree: {coupling_degree}\nCoordination Degree: {coordination_
    except ValueError as e:
        print(f"Error processing {company}: {e}")
    except Exception as e:
        print(f"Unexpected error processing {company}: {e}")
```

```
Chengtun Mining Group Co Ltd盛屯矿业 Coupling Degree: 0.03775279513763828
Coordination Degree: 1.55936788234145
Error processing Chifeng Jilong Gold Mining Co Ltd赤峰黄金: shapes (12,) and (11,) not aligned: 12
(dim 0) != 11 (dim 0)

China Nonferrous Metal Industry's Foreign Engineering and Construction Co Ltd中色股份 Coupling Degr
ee: 0.03775279513763895
Coordination Degree: 1.2382731357041459

CMOC Group Ltd洛阳钼业 Coupling Degree: 0.03775279513763889
Coordination Degree: 1.5777778009018244

Hunan Gold Corp Ltd湖南黄金 Coupling Degree: 0.037752795137638955
Coordination Degree: 1.1537616783740072

Jinduicheng Molybdenum Co Ltd金钼股份 Coupling Degree: 0.03775279513763894
Coordination Degree: 1.3051964851916042

RISING NONFERROUS METAL SH广晟有色 Coupling Degree: 0.037752795137638955
Coordination Degree: 1.204127434663966

SHANDONG GOLD MINING CO LT山东黄金 Coupling Degree: 0.037752795137638746
Coordination Degree: 1.552201452610545

Shengda Resources Co Ltd盛达资源 Coupling Degree: 0.03775279513763819
Coordination Degree: 1.2747824513565722

Western Mining Co Ltd西部矿业 Coupling Degree: 0.03775279513763891
Coordination Degree: 1.5292172754921993

Xizang Zhufeng Resources Co Ltd西藏珠峰 Coupling Degree: nan
Coordination Degree: nan

Yintai Gold Co Ltd银泰黄金 Coupling Degree: nan
Coordination Degree: nan

Youngy Co Ltd融捷健康 Coupling Degree: nan
Coordination Degree: nan

Yunnan Chihong Zinc&Germanium Co Ltd驰宏锌锗 Coupling Degree: 0.037752795137638774
Coordination Degree: 1.3014526828819393

Zhongjin Gold Corp Ltd中金黄金 Coupling Degree: 0.037752795137638934
Coordination Degree: 1.349109106893506

Zijin Mining Group Co Ltd紫金矿业 Coupling Degree: 0.03775279513763896
Coordination Degree: 1.1421027206235892
```

SUMMARY

The Multi-Stage ESG Analysis and Optimization process begins with the loading and initial inspection of datasets from 16 companies, covering various environmental, social, and governance (ESG) indicators. The data is preprocessed to fill missing values, normalize the features, and ensure consistency. Projection Pursuit Entropy is applied to the cleaned datasets to identify the most informative projections, helping to reduce dimensionality while preserving the structure of the data. This step ensures that the most critical indicators are retained for further analysis. Following this, the RAIGA (Real-Coded Adaptive Range Genetic Algorithm) optimization method is employed to fine-tune the projections, enhancing the entropy and optimizing the indicator selection for more robust and insightful results.

The final step involves calculating the Coupling Coordination Degree (CCD) to assess the interplay between different ESG dimensions. This metric provides insights into the harmonious development and sustainability of the companies by evaluating the strength and stability of the interactions among various indicators. The analysis is supplemented with visualizations, including line plots, scatter plots, histograms, and pie charts, to illustrate the distribution and relationships of the ESG indicators across the different companies. These comprehensive steps collectively provide a detailed and optimized view of the ESG performance, supporting better decision-making and strategy formulation for sustainable development.

*THE END