Engineering the supply chain of BarCo Corporation

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Date

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**Introduction**

The report pertains to a response to a notification from Max Energy about the rapid depletion of natural gas, one of the production components used by BarCo Corporation. Noteworthy, the unprecedented heatwave/bushfires during summers in 2019 contributed significantly to the natural gas shortage. Besides, electrical generating plants operated at capacity to supply the power needed to run the air conditioning and refrigeration units during the unprecedented heatwave and bushfires during the summer, leading to increased depletion of the natural gas. Despite the long-existing plans called for the utility companies to convert to coal, oil, or nuclear fuels, natural gas remains the most dominant fuel used by the companies. Similarly, the extensive exploitation of natural gas has prompted the evident depletion of natural resources. BarCo Corporation is one of the company’s that uses natural gas in the production process. Thus., following the announcement by Max Energy, the General manager needed to have a contingency plan that would help the company tackle the anticipated natural gas shortage that would affect the company’s production process and the corresponding profitability of the company. The report developed various scenarios using a linear optimization model to help maximize the utilization and the consequent profitability, thereby making recommended supply chain action that would help promote the corporation’s sustainability.

**Business Problem**

The most challenging issue for the general manager BarCo’s revolved around determining the products that would have the most negligible effect on the natural gas curtailment plan. Based on the operation analysis and available data, BarCo’s use natural gas in the operation process; thus, a reduction in the commodity supply would culminate in severe operational issues. The shortage necessitated that Max Energy supplies natural gas in three main categories. The company demanded that the consumers initiate a reduction process to help minimize the impact of their industrial processes. The category by the Max Energy, the leading producer and distributor of the natural gas in the region in the statement, noted that it would allocate gas to consumer based on the provision of the Federal commission noting that

1. *The first priority*: comprises of residential and commercial heating and cooling consumers.
2. *The second priority:* would include the commercial and industrial firms that use natural gas as a source of raw material.
3. *The third priority:* would include the industrial firms that use natural gas as boiler fuel.

From the communication, it is apparent that most of Barco’s uses of natural gas fell in the second and third priority classification, implying that BarCo would become subject to “rolling brownouts,” including temporary and periodic curtailments of natural gas supplies.

**The Curtailment Plan**

Noteworthy, in the event of a brownout, all the BarCo complexes would be in the category of the curtailment region. The company used the purchased gas as the boiler’s fuel except for the ammonia operations from the case study. The ammonia plant uses natural gas as a raw material because it is less pollutant than other boiler fuels and aligns with BarCo’s future sustainability plan. Based on the available information, it is apparent that BarCo’s falls in the second and third priorities defined by Max Energy in the allocation procedure for natural gas in the region.

The table below illustrates the contribution to profit per product reported to the general manager BarCo’s Corporation.

Table 1: the table illustrates the contribution to profit ($ /Ton) per product

|  |  |
| --- | --- |
| **Product** | **Contribution to profit ($/Ton** |
| Ammonia | 134 |
| Ammonium phosphate | 80 |
| ammonium nitrate | 100 |
| Urea | 122 |
| Hydrofluoric acid | 96 |
| Chlorine | 110 |
| Caustic soda | 75 |
| Vinyl chloride monomer | 85 |

The table below illustrates the operation data indicating the max capacity (tons/day), the production rate (% of capacity), and the natural gas consumption (1,000 cu. ft/ton) by the company in the production of each of the products.

|  |  |  |  |
| --- | --- | --- | --- |
| **Product** | **Max Capacity (tons/day)** | **Production rate (% of capacity)** | **Natural Gas Consumption (1,000 cu.ft./ton)** |
| Ammonia | 600 | 90 | 19 |
| Ammonium phosphate | 1,600 | 80 | 13 |
| ammonium nitrate | 800 | 70 | 20 |
| Urea | 1,400 | 60 | 12 |
| Hydrofluoric acid | 200 | 80 | 19 |
| Chlorine | 1,500 | 80 | 11 |
| Caustic soda | 700 | 70 | 14 |
| Vinyl chloride monomer | 1,500 | 80 | 12 |

**Main Objective for the Development of a Contingency Plan**

The specific objective of BarCo following the announcement is to develop a contingency plan that would help minimize the impact on profit and overheads contribution through the supported allocation of the natural gas among the firms’ product if the curtailment materialized and became a reality in the region. Therefore, the primary focus of BarCo management is profit maximization as the contingency plan under the selected situation associated with the reduction of the natural gas supply.

The primary challenge for BarCo is coming up with a production level for different products that would minimize the impact of the shortage in natural gas supply while maximizing the company’s profit. In this case, the process would involve developing a production model that would enhance the maximization of proceeds under the selected operational constraints.

**Linear Optimization for Production**

Cohen, Leung, Panchamgam, Perakis, and Smith (2017) pointed out that linear programming is one of the most used techniques for optimizing a linear objective function, based on corresponding constraints that may depict linear equality or inequality. Using the linear programming model enhances finding a point where the function has the smallest or largest value if such a point exists, whereby linear programming aid in promoting the attainment of optimum use of productive resources. Besides, linear programming enhances decision-making by employing practical factors by selecting and allocating resources based on the optimization aspect, improving the quality of adopted decisions.

In BarCo’s scenario that involves the possible curtailment of natural gas, one of the company’s components in the production process, linear optimization would allow the company’s general manager to make supported production decisions. In this case, linear programming would minimize natural gas reduction while maximizing the company’s profitability, necessary to guarantee the future sustainability plan. The linear objective function will maximize the contribution or profits from the different production lines, focusing on changing the production rate (% capacity) in linear programming performed on Ms. Excel solver. The anticipated results would be a significant change in the production, profit contribution, and natural gas consumption, whereby the constraints will include the limit of the supply of the natural gas consumption.

**Assumption**

In the development and solving the linear models, the solutions made the following assumptions:

1. The curtailment process would align with the consumers’ natural gas usage, allowing BarCo to attain a flexible utilization necessary to maximize profit while minimizing the distribution cost among the three plants.
2. The operation data is accurate and highly reliable.
3. The profit maximization forms the target objective.
4. The plant can operate at 100% production capacity
5. The natural gas curtailment plan does not influence other necessary raw materials.

**Linear models**

The table below illustrates the linear model letting the production rate be x1, x2…, xn.

|  |  |
| --- | --- |
| **Product** | **Production rate (% of capacity)** |
| Ammonia | x1 |
| Ammonium phosphate | x2 |
| Ammonium nitrate | x3 |
| Urea | x4 |
| Hydrofluoric acid | x5 |
| Chlorine | x6 |
| Caustic soda | x7 |
| Vinyl chloride monomer | x8 |

**Maximized base production**

From the table above, the linear objective function would be

Maximize Profit (P) = 600\*90x1 +1600\*80x2 +800\*70x3 +1400\*60x4 +200\*80x5 +1500\*80x6 +700\*70x7 +1500\*80x8

**Subject to:**

1. x1, x2, x3, x4, x5, x6, x7, x8 >= 0
2. x1, x2, x3, x4, x5, x6, x7, x8 <=100
3. 600\*90x1 +1600\*80x2 +800\*70x3 +1400\*60x4 +200\*80x5 +1500\*80x6 +700\*70x7 +1500\*80x8<=90,000

The function defines the variables x1 to x8, indicating the production capacity percentage for each product, with the linear function defining the aggregate profit contribution from the production in each product line. The table below illustrates the current BarCo’s profitability scenario based on the initial natural gas usage, the output per product, the capacity, and the contribution to profit for each product.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Product** | **Max Capacity** | **Natural Gas Consumption** | **Contribution to** | **Production rate** | **Production** | **Natural Gas Usage** | **Profit Contribution** |
| Ammonia | 600 | 19 | $134 | 90% | 540 | 10,260 | $72,360 |
| Ammonium phosphate | 1,600 | 13 | $80 | 80% | 1280 | 16,640 | $102,400 |
| Ammonium nitrate | 800 | 20 | $100 | 70% | 560 | 11,200 | $56,000 |
| Urea | 1,400 | 12 | $122 | 60% | 840 | 10,080 | $102,480 |
| Hydrofluoric acid | 200 | 19 | $96 | 80% | 160 | 3,040 | $15,360 |
| Chlorine | 1,500 | 11 | $110 | 80% | 1200 | 13,200 | $132,000 |
| Caustic soda | 700 | 14 | $75 | 70% | 490 | 6,860 | $36,750 |
| Vinyl chloride monomer | 1,500 | 12 | $85 | 80% | 1200 | 14,400 | $102,000 |
|  |  | **90,000** |  |  |  | **85,680** | **$619,350** |

**Explanation**

From the initial available operational data in the table above, it is apparent that the company’s aggregate profit is $619,350, with a natural gas consumption of 85,680 cubic units, less than the maximum available 90,000 cubic units.

The table below reveals the finding from the Excel solver with the production rate set at 100 %.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Product** | **Max Capacity** | **Natural Gas Consumption** | **Contribution to profit** | **Production** | **Natural Gas Usage** | **Profit Contribution** | **Production rate** |
| Ammonia | 600 | 19 | $134 | 600 | 11,400 | $80,400 | 100 |
| Ammonium phosphate | 1,600 | 13 | $80 | 1600 | 20,800 | $128,000 | 100 |
| Ammonium nitrate | 800 | 20 | $100 | 0 | - | $0 | 0 |
| Urea | 1,400 | 12 | $122 | 1400 | 16,800 | $170,800 | 100 |
| Hydrofluoric acid | 200 | 19 | $96 | 0 | - | $0 | 0 |
| Chlorine | 1,500 | 11 | $110 | 1500 | 16,500 | $165,000 | 100 |
| Caustic soda | 700 | 14 | $75 | 464.2857143 | 6,500 | $34,821 | 66 |
| Vinyl chloride monomer | 1,500 | 12 | $85 | 1500 | 18,000 | $127,500 | 100 |
|  |  | **90,000** |  |  | **90,000** | **$706,521** |  |

From the table above, the maximized profit would $706,521, greater than $619,350, with a production rate of 100 % except for Ammonium nitrate, Hydrofluoric acid, and Caustic soda that depict a production rate of 0 percent and 66 %, respectively. At the same time, the production would utilize all the natural gas, 90,000 cubic units, which is the maximum amount specified by Max Energy.

**Production Plan for 20% Curtailment Usage**

In the case of a 20 % curtailment, the maximum natural gas available for usage would be

= (1-0.20) \*90,000

=72,000 cubic units.

As a result, the linear objective function would be

Maximize Profit (P) = 600\*90x1 +1600\*80x2 +800\*70x3 +1400\*60x4 +200\*80x5 +1500\*80x6 +700\*70x7 +1500\*80x8

**Subject to:**

1. x1, x2, x3, x4, x5, x6, x7, x8 >= 0
2. x1, x2, x3, x4, x5, x6, x7, x8 <=100
3. 600\*90x1 +1600\*80x2 +800\*70x3 +1400\*60x4 +200\*80x5 +1500\*80x6 +700\*70x7 +1500\*80x8<=72,000

The linear optimization function above implies that the production rate constraints would remain between 0 percent and the 100 % for each of the products. Nonetheless, the special constraints in the model would the natural gas consumption which would be 72,000 cubic unit illustrating a 20 % reduction form the initial 90,000 cubic units.

Using the Ms. Excel solver, the table below illustrates the optimized profits for the scenario subject to the defined constraints.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Product** | **Max Capacity** | **Natural Gas Consumption** | **Contribution to profit** | **Production** | **Natural Gas Usage** | **Profit Contribution** | **Production rate** |
| Ammonia | 600 | 19 | $134 | 600 | 11,400 | $80,400 | 100 |
| Ammonium phosphate | 1,600 | 13 | $80 | 715 | 9,300 | $57,231 | 45 |
| Ammonium nitrate | 800 | 20 | $100 | - | - | $0 | 0 |
| Urea | 1,400 | 12 | $122 | 1,400 | 16,800 | $170,800 | 100 |
| Hydrofluoric acid | 200 | 19 | $96 | - | - | $0 | 0 |
| Chlorine | 1,500 | 11 | $110 | 1,500 | 16,500 | $165,000 | 100 |
| Caustic soda | 700 | 14 | $75 | - | - | $0 | 0 |
| Vinyl chloride monomer | 1,500 | 12 | $85 | 1,500 | 18,000 | $127,500 | 100 |
|  |  | **72,000** |  |  | **72,000** | **$600,931** |  |

Based on the scenario involving a reduction of the natural gas usage by 20 %, the company would realize a lowered profit amount of US$ 600,931, compared to the initial profit of $619,350 before the curtailment plan for natural gas, reducing the supply by 20 %.

**Production Plan for 40% Curtailment Usage**

In the case of a 40 % curtailment in the supply of natural gas to BarCo, the maximum natural gas available for usage would be

=(1-0.40)\*90,000

=54,000 cubic units.

In this case, the new linear objective function would be

Maximize Profit (P) = 600\*90x1 +1600\*80x2 +800\*70x3 +1400\*60x4 +200\*80x5 +1500\*80x6 +700\*70x7 +1500\*80x8

**Subject to:**

1. x1, x2, x3, x4, x5, x6, x7, x8 >= 0
2. x1, x2, x3, x4, x5, x6, x7, x8 <=100
3. 600\*90x1 +1600\*80x2 +800\*70x3 +1400\*60x4 +200\*80x5 +1500\*80x6 +700\*70x7 +1500\*80x8<=54,000

The linear optimization function production rate constraints would remain between 0 percent and the 100 % for each of the products, with a special constraints in the model would the natural gas consumption which would be 54,000 cubic unit depicting a 40 % reduction form the initial 90,000 cubic units.

Using the Ms. Excel solver, the table below reveals the optimized profits for the scenario subject to the defined constraints.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Product** | **Max Capacity** | **Natural Gas Consumption** | **Contribution to profit** | **Production** | **Natural Gas Usage** | **Profit Contribution** | **Production rate** |
| Ammonia | 600 | 19 | $134 | 142 | 2,700 | $19,042 | 24 |
| Ammonium phosphate | 1,600 | 13 | $80 | - | - | $0 | 0 |
| Ammonium nitrate | 800 | 20 | $100 | - | - | $0 | 0 |
| Urea | 1,400 | 12 | $122 | 1,400 | 16,800 | $170,800 | 100 |
| Hydrofluoric acid | 200 | 19 | $96 | - | - | $0 | 0 |
| Chlorine | 1,500 | 11 | $110 | 1,500 | 16,500 | $165,000 | 100 |
| Caustic soda | 700 | 14 | $75 | - | - | $0 | 0 |
| Vinyl chloride monomer | 1,500 | 12 | $85 | 1,500 | 18,000 | $127,500 | 100 |
|  |  | **54,000** |  |  | **54,000** | **$482,342** |  |

From the table above, the maximized profit, BarCo would attain a profit amounting to $482,342 less than the base profit amount of $619,350, after the curtailment plan reduction of the natural gas supply to the company by 40%.

**Linear Optimization for Distribution**

The table below illustrates the distribution cost ($/unit) and the supply and demand data for BarCo’s three manufacturing plants A, B, and C, and the Max Energy Supply locations I, J, K.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Plant A | Plant B | Plant C | Supply |
| I | $1.30 | $1.20 | $1.60 | 20,000 |
| J | $1.20 | $1.40 | $1.50 | 40,000 |
| K | $1.80 | $1.60 | $1.40 | 25,680 |
| Demand | 20,000 | 50,000 | 15,680 |  |

Decision variable for the transportation linear problem formulation

IA= #unit shipped from location I to plant A

IB= #unit shipped from location I to plant B

IC= #unit shipped from location I to plant C

JA= #unit shipped from location J to plant A

JB= #unit shipped from location J to plant B

JC= #unit shipped from location J to plant C

KA= #unit shipped from location K to plant A

KB= #unit shipped from location K to plant B

KC= #unit shipped from location K to plant C

**Objective function**

Min (cost) = 1.3ia+1.2ib+1.6ic+1.2ja+1.4jb+1.5jc+1.8ka+1.6kb+1.4kc

**Subject to**

**Supply location**

1. IA+IB+IC=20,000 (location I)
2. JA+JB+JC =40,000 (Location J)
3. KA+KB+KC =25,680 (Location K)

Plant’s demand

1. IA+JA+KA=20,000 (Plant A)
2. IB+JB+KB=50,000 (Plant B)
3. IC+JC+KC=15,680 (Plant C)

For non-negative

Ia, ib,ic, ja, jb, jc, ka, kb, kc >=0

**Distribution cost for the case Scenario**

Note, because the supply and demand are equal, we use an equal sign for all the constraints in the model. From Ms. Excel Solver, the table below illustrates the best-case scenario for the minimized distribution cost.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Decision Table** | | | | | | |
|  | Plant A | Plant B | Plant C | Supply |  | Supply Limit |
| I | $0 | $20,000 | $0 | 20000 | = | 20,000 |
| J | $20,000 | $20,000 | $0 | 40000 | = | 40,000 |
| K | $0 | $10,000 | $15,680 | 25680 | = | 25,680 |
| Demand limits | 20000 | 50000 | 15680 | $113,952 |  |  |
|  | = | = | = |  |  |  |
| Demand | 20,000 | 50,000 | 15,680 |  |  |  |

From the table above, the minimized distribution cost for natural gas supply by Max Energy to the three plants and from the three locations would be $ 113,952.

**Distribution cost After 20% Curtailment Plan**

**Objective function**

Min (cost) = 1.3ia+1.2ib+1.6ic+1.2ja+1.4jb+1.5jc+1.8ka+1.6kb+1.4kc

**Subject to**

**Supply location**

1. IA+IB+IC= 16,000 (location I)
2. JA+JB+JC =32,000 (Location J)
3. KA+KB+KC =20,544 (Location K)

Plant’s demand

1. IA+JA+KA <=20,000 (Plant A)
2. IB+JB+KB <=50,000 (Plant B)
3. IC+JC+KC <=15,680 (Plant C)

For non-negative

Ia, ib, ic, ja, jb, jc, ka, kb, kc >=0

Since the supply is less than the demand, we use less than or equal to sign demand constraints in the model. From Ms. Excel Solver, the table below depicts the minimized distribution cost.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Decision Table** | | | | | | |
|  | Plant A | Plant B | Plant C | Supply |  | Supply Limit |
| I | $0 | $16,000 | $0 | 16000 | = | 16,000 |
| J | $20,000 | $12,000 | $0 | 32000 | = | 32,000 |
| K | $0 | $4,864 | $15,680 | 20544 | = | 20,544 |
| Demand limits | 20000 | 32864 | 15680 | $89,734 |  |  |
|  | <= | <= | <= |  |  |  |
| Demand | 20,000 | 50,000 | 15,680 |  |  |  |

From the table above, the minimized distribution cost for natural gas supply by Max Energy to the three plants and from the three locations, based on a 20% curtailment plan for gas supply, would be $ 89,734.

**Distribution cost After 40% Curtailment Plan**

**Objective function**

Min (cost) = 1.3ia+1.2ib+1.6ic+1.2ja+1.4jb+1.5jc+1.8ka+1.6kb+1.4kc

**Subject to**

**Supply location**

1. IA+IB+IC= 12,000 (location I)
2. JA+JB+JC =24,000 (Location J)
3. KA+KB+KC = 15,408 (Location K)

Plants demand

1. IA+JA+KA <=20,000 (Plant A)
2. IB+JB+KB <=50,000 (Plant B)
3. IC+JC+KC <=15,680 (Plant C)

For non-negative

Ia, ib,ic, ja, jb, jc, ka, kb, kc >=0

Since the supply is less than the demand, we use less than or equal to sign demand constraints in the model. From Ms. Excel Solver, the table below depicts the minimized distribution cost.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Decision Table 40% Curtailment Plan** | | | | | | |
|  | Plant A | Plant B | Plant C | Supply |  | Supply Limit |
| I | $0 | $12,000 | $0 | 12000 | = | 12,000 |
| J | $20,000 | $4,000 | $0 | 24000 | = | 24,000 |
| K | $0 | $0 | $15,408 | 15408 | = | 15,408 |
| Demand limits | 20000 | 16000 | 15408 | $65,571 |  |  |
|  | <= | <= | <= |  |  |  |
| Demand | 20,000 | 50,000 | 15,680 |  |  |  |

The minimized distribution cost for natural gas supply by Max Energy to the three plants and from the three locations, based on a 40% curtailment plan for gas supply, would be $ 65,571.

**Discussion**

The discussion session summarizes the findings from the linear programming for both the production scenarios and distribution cost scenario that would help BarCo optimize the profits while minimizing the distribution cost for the three plants and three Max energy distribution locations.

**Profits.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Natural Gas Consumption (1,000 cu. ft./ton) Constraint** | **Natural Gas Consumption (1,000 cu. ft./ton) Utilization** | **Profits** |
| Current Scenario | $90,000 | 85,680 | $619,350 |
| Maximized base Scenario | 90,000 | 90,000 | $706,521 |
| 20% Reduction | 72,000 | 72,000 | $600,931 |
| 40% Reduction | 54,000 | 54,000 | $482,342 |

From the table, BarCo is not achieving the maximization of profit objective in all scenarios. For instance, the company can maximize profit from $619,350 to $706,521 under the 90,000 cubic units of natural gas supplied. The finding indicates possible operational inefficiency and lack of use of data before the Max Energy announcement on possible natural gas supply reduction following a continued depletion of the natural resource. Besides, the company would profit further decline following supply of natural gas curtailment actualization, and BarCo receives either 20 or 40 percent reduction on the amount of natural gas supplied in cubic units. Based on the table above, the company would record profits lower than maximized based on the company’s agreed 90,000 cubic units of natural gas by Max Energy.

**Production Rating**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Production Rate % of capacity** | | | | |
|  | **Current Scenario** | **Maximized base** | **20% Reduction** | **40% Reduction** |
| Ammonia | 90 | 100 | 100 | 24 |
| Ammonium phosphate | 80 | 100 | 45 | 0 |
| Ammonium nitrate | 70 | 0 | 0 | 0 |
| Urea | 60 | 100 | 100 | 100 |
| Hydrofluoric acid | 80 | 0 | 0 | 0 |
| Chlorine | 80 | 100 | 100 | 100 |
| Caustic soda | 70 | 66 | 0 | 0 |
| Vinyl chloride monomer | 80 | 100 | 100 | 100 |

Similarly, from the table above, the company should operate at 100 % production capacity for product Urea, Chlorine, and Vinyl Chloride monomer production while averting the production of Ammonium nitrate and Hydrofluoric acid in case of a maximized base profit. In the case of a 20 % curtailment plan, the company should focus on manufacturing all the products except Ammonium nitrate, Hydrofluoric acid, and Caustic soda, which illustrated 0 % production rate based on the linear optimization model and subject to the underlying limits. Lastly, BarCo should focus on producing four product that maximizes profit in the case of 40% natural gas supply curtailment plan, which are Ammonia, Urea, Chlorine, and Vinyl chloride monomer.

**Summary Distribution Cost**

|  |  |  |  |
| --- | --- | --- | --- |
| Plant | Current Scenario | 20% Curtailment Plan | 40% Curtailment Plan |
| A | 20,000 | 20,000 | 20000 |
| B | 50,000 | 32,864 | 16000 |
| C | 15,680 | 15,680 | 15408 |
| Distribution cost | $113,952 | $89,734 | $65,571 |

From the table above, the demand that would minimize the distribution cost for BarCo’s Plants A, B, and C would be 20,000, 50,000, and 15,680 cubic units under the current scenario, depicting a distribution cost of $113,952. Moreover, in the case of a 20% reduction in supplied natural gas by Max Energy, the plant would utilize 20,000, 32,864, and 15,680 cubic units, with only plant B realizing a decline from 50,000 to 32,864 cubic units of the supplied natural gas at a minimized distribution cost amounting to $ 89,734. On the other hand, a 40% curtailment plan would provide 20,000, 16,000, and 15,408 cubic units of natural gas, respectively, to plants A, B, and C, minimizing the distribution cost further to $ 65,571.

**Sensitivity Analysis Reports**

**Base Scenario Production**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Cells | | |  |  |  |  |  |
|  |  |  | **Final** | **Reduced** | **Objective** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Cost** | **Coefficient** | **Increase** | **Decrease** |
|  | $I$27 | Ammonia Production rate | 100 | 193.286 | 804 | 1E+30 | 193.286 |
|  | $I$28 | Ammonium phosphate Production rate | 100 | 165.714 | 1280 | 1E+30 | 165.714 |
|  | $I$29 | ammonium nitrate Production rate | 0 | -57.143 | 800 | 57.143 | 1E+30 |
|  | $I$30 | Urea Production rate | 100 | 808 | 1708 | 1E+30 | 808 |
|  | $I$31 | Hydrofluoric acid Production rate | 0 | -11.571 | 192 | 11.571 | 1E+30 |
|  | $I$32 | Chlorine Production rate | 100 | 766.071 | 1650 | 1E+30 | 766.071 |
|  | $I$33 | Caustic soda Production rate | 66.327 | 0 | 525 | 78.077 | 29.842 |
|  | $I$34 | Vinyl chloride monomer Production rate | 100 | 310.714 | 1275 | 1E+30 | 310.714 |
|  |  |  |  |  |  |  |  |
| Constraints | | |  |  |  |  |  |
|  |  |  | **Final** | **Shadow** | **Constraint** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Price** | **R.H. Side** | **Increase** | **Decrease** |
|  | $G$35 | Natural Gas Usage | 90000 | 5.357 | 90000 | 3300 | 6500 |

From the sensitivity table above, the column final value indicated the production capacity that BarCo, would utilize in the base scenario, for the production of the corresponding product. In this case, the production would be 100% the products Ammonia, Ammonium Phosphate, Urea, Chlorine, and Vinyl chloride monomer while the Caustic soda production would 66.327 %. Nonetheless, the company could avoid the Ammonium nitrate, and Hydrofluoric acid in the mean to maximize profitability. The production rate is subject to natural gas supply of 90,000 cu. Ft \* 103 per day.

**Base Distribution Cost**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Cells | | |  |  |  |  |  |
|  |  |  | **Final** | **Reduced** | **Objective** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Cost** | **Coefficient** | **Increase** | **Decrease** |
|  | $C$11 | I Plant A | 0 | 0.3 | 1.3 | 1E+30 | 0.3 |
|  | $D$11 | I Plant B | 20000 | 0 | 1.2 | 0.3 | 1E+30 |
|  | $E$11 | I Plant C | 0 | 0.6 | 1.6 | 1E+30 | 0.6 |
|  | $C$12 | J Plant A | 20000 | 0 | 1.2 | 0.3 | 1E+30 |
|  | $D$12 | J Plant B | 20000 | 0 | 1.4 | 0.3 | 0.3 |
|  | $E$12 | J Plant C | 0 | 0.3 | 1.5 | 1E+30 | 0.3 |
|  | $C$13 | K Plant A | 0 | 0.4 | 1.8 | 1E+30 | 0.4 |
|  | $D$13 | K Plant B | 10000 | 0 | 1.6 | 0.4 | 0.3 |
|  | $E$13 | K Plant C | 15680 | 0 | 1.4 | 0.3 | 1E+30 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Constraints | | |  |  |  |  |  |
|  |  |  | **Final** | **Shadow** | **Constraint** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Price** | **R.H. Side** | **Increase** | **Decrease** |
|  | $C$14 | Demand limits Plant A | 20000 | 1.2 | 20000 | 0 | 20000 |
|  | $D$14 | Demand limits Plant B | 50000 | 1.4 | 50000 | 0 | 20000 |
|  | $E$14 | Demand limits Plant C | 15680 | 1.2 | 15680 | 0 | 15680 |
|  | $F$11 | I Supply | 20000 | -0.2 | 20000 | 20000 | 0 |
|  | $F$12 | J Supply | 40000 | 0 | 40000 | 0 | 1E+30 |
|  | $F$13 | K Supply | 25680 | 0.2 | 25680 | 20000 | 0 |

Similarly, the table above illustrates the final value for the demand and supply for the minimized distribution cost subject to the provided constraints for the supply.

**Recommendation**

From the exploration using the linear programming model, subject to various constraints, BarCo’s Management should first maximize the base scenario to help attain the profit optimization objective. In the process, the company would increase the profits to $706,521 from the current $619,350. The company would achieve the profit maximization objective by ensuring that the company attains a production rate of 100 % for the following products, Ammonia, Ammonium phosphate, Urea, Chlorine, and Vinyl chloride monomer. In comparison, Caustic soda would realize a production capacity of 66 %. Nevertheless, BarCo would avert the production of Ammonium nitrate and Hydrofluoric acid. If the Max Energy curtailment plan happens, leading to reduction of supplied natural gas to BarCo by 20 % or 40 %, then the management is recommended to use the generated production capacity percentage to help realize the maximized profits under either of the two curtailment plans.

References

Cohen, M. C., Leung, N. H. Z., Panchamgam, K., Perakis, G., & Smith, A. (2017). The impact of linear optimization on promotion planning. *Operations Research*, *65*(2), 446-468.