

Inventory Management

What Factors Contribute to Higher Inventory in Generation Warehouses?

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My inventory requirements are complex and drive me to keep a large number of unique parts, so it follows that I have higher inventory levels in my warehouse, right?

This article is the third in a series of articles examining common inventory management questions using statistical analysis of data compiled by the Utility Materials Management Benchmarking Consortium (UMMBC)¹ 2015 Warehouse Survey, which collected detailed data from 286 warehouses operated by 19 leading utilities. This article examines the validity of this common assumption and others related to inventory levels. Are inventory complexity, warehouse space, warehouse staffing, or inventory efficiency predictors of higher inventory levels? The data reveals the answers below.

Figure 1: Warehouse Participants by Business Unit

Utility Business Unit	Number of Warehouses
Fossil Generation – Coal	63
Fossil Generation – Gas	41
Fossil Generation – CT	26
Nuclear Generation	31
Hydro Generation	48
Distribution Only (Electric & Gas)	34
Transmission and Distribution Combined (Electric & Gas)	43
TOTAL	286

In the [first article in this series](#), we examined the question of whether more inventory on hand improves material availability. Statistical analysis demonstrates that it does, but somewhat counterintuitively, not by much. The [second article](#) examined whether material availability impacts operating performance. Results revealed it does and more so than you might imagine. This article seeks to identify which factors contribute to higher inventory in generation warehouses. To answer this question, the research team focused on 161 non-hydro generation warehouse data sets, as this was the only utility subset with an adequate number of responses across all of the potential research variables.

The research team used “Total On-Site Material per MW” as the dependent variable.² Normalizing the volume of inventory by plant size (in this case, MW of generation) allowed the research team to control

¹ The UMMBC was established in 2007 and currently consists of 56 leading utilities who periodically collaborate to develop information needed to critically examine and improve ongoing warehouse and inventory management operations in the electric & gas utility industry. Members participate in individual surveys on a voluntary basis. Comprehensive warehouse surveys were conducted in 2008, 2011, and 2015.

² Total On-Site Materials includes FERC 154 inventory, consigned materials, and non-costed capitalized material.

for the obvious impact of plant size. The following were selected as independent variables, or potential contributing factors to higher inventory:

- Inventory Complexity – Defined as the number of SKUs (unique parts) on site
 - Expected Relationship: POSITIVE – higher numbers of SKUs are expected to be associated with higher inventory levels
 - Rationale: Warehouses holding more SKUs generally reflect generating environments with multiple types of generators, each of which requires maintenance parts, increasing the volume of inventory that must be kept on hand
- Warehouse Space – Defined as total square feet of covered storage space
 - Expected Relationship: POSITIVE – more space is expected to be associated with more inventory
 - Rationale: Plants with more space tend to fill it up. Concerns over inventory levels often begin only when space becomes limited
- Warehouse Staffing – Defined as total warehouse staff in full-time equivalents per MW of generation.³ Staffing was normalized by plant size (using MW of generation)
 - Expected Relationship: NEGATIVE – higher staffing levels are expected to be associated with lower inventory levels
 - Rationale: Warehouses with higher staffing should have lower inventory levels since the staff will have more time to aggressively manage the inventory
- Inventory Efficiency – Defined as the turnover rate in total on-site material⁴
 - Expected Relationship: NEGATIVE – higher turnover rates are expected to be associated with lower inventory levels
 - Rationale: Inventory turnover measures how fast inventory is cycled through the warehouse. Low turnover is generally associated with higher volumes of slow-moving or non-moving inventory which, in turn, indicates the presence of excess or obsolete inventory

Correlation Analysis

The team began by examining the relationship of each independent variable to the dependent variable. The tool used for this purpose was correlation analysis. Correlation is a statistical technique used to measure and describe the *strength* and *direction* of the relationship between two variables. A positive correlation indicates the extent to which those variables increase or decrease in parallel, while a negative correlation indicates the extent to which one variable increases as the other decreases.⁵ Correlation

³ Warehouse staff includes warehouse management, materials management analysts and coordinators, materials management storekeepers, material handlers, materialmen and materials management (tool room personnel), materials quality control, and administrative personnel.

⁴ Inventory Turnover Rate is defined as the Total \$ Value of Inventory Issued during the year divided by the Total Value of All Inventory on Site.

⁵ In preparing this analysis, the research team used the Pearson product-moment correlation coefficient, which measures the strength of the *linear association* between variables. Line plots were examined in each case to determine if a non-linear relationship might exist.

coefficients can range from -1.0 to +1.0, depending upon the strength and direction of the relationship. The correlation coefficients for the variables described above are presented in Figure 2.

Figure 2: Correlations Between \$ Value of Total On-Site Material/MW and Selected Warehouse Variables

		Coal	Gas	CT	Nuclear	TOTAL
Number of Warehouses		53	23	6	13	86
Variables Examined:	Expected Relationship					
Inventory Complexity	Positive (+)	-0.112	0.295	0.239	0.735	0.765
Warehouse Space	Positive (+)	-0.065	0.366	0.228	0.436	0.414
Warehouse Staffing	Negative (-)	0.581	0.663	0.823	0.079	0.369
Inventory Efficiency	Negative (-)	-0.151	-0.16	0.192	-0.684	-0.17

Based upon the correlation coefficients for all 86 plants taken together, it appears that the *direction* (+/-) of the expected relationship proved true for the following three relationships:

- More inventory complexity (number of SKUs) is associated with more material per MW
- More warehouse space is associated with more material per MW
- Greater inventory efficiency is associated with less material per MW

However, warehouse staffing was not correlated with inventory levels as we expected. Instead, more warehouse staff appears to be associated with more inventory despite the fact that warehouse staffing levels were normalized for plant size.

The *strength* of the relationship was relatively strong for all variables except inventory efficiency.

Multiple Regression Analysis

Having examined the individual relationship between each of the variables and inventory levels, the research team then attempted to examine the *combined* impact of all five variables working together. The tool used for this purpose was multiple regression analysis.⁶ Multiple regression is a statistical technique used to measure the relationship between one dependent variable and several independent variables operating in unison. It attempts to measure the individual impact of each variable after controlling for any correlations between the variables themselves. The results are shown in Figure 3.

⁶ Multiple linear regression (MLR) is a statistical technique that used several explanatory variables to predict the outcome of a response variable. The goal of MLR is to mode the relationship between the explanatory and response variables.

Figure 3: Multiple Regression Results for \$ Value of Total On-Site Material/MW and selected Warehouse Variables

Variable	Coal	Gas	CT	Nuclear	TOTAL
Number of Cases	53	23	6	13	86
R Square	0.358	0.493	0.831	0.651	0.709
Adjusted R Square	0.304	0.380	0.154	0.476	0.694
Y-Axis Intercept	8,447.8	4,074.6	-6,148.8	21,622.5	1,683.1
Reg. Coeff. – Inventory Complexity	-0.011	-0.388	-2.002	0.301	0.403
Reg. Coeff. – Warehouse Space	0.028	0.209	0.599	0.017	0.031
Reg. Coeff. – Warehouse Staffing	1,095,519.9	1,921,599.0	2,618,139.1	2,422,751.3	1,311,931.6
Reg. Coeff. – Inventory Efficiency	-1,032.7	-1,295.9	6,580.1	-32,378.1	-1,322.9

When viewed as an integrated model, the four variables examined “explain” 69.4% of the variation in the \$ Value of Total On-Site Material/MW based upon the value of the Adjusted R Square.⁷ This is a relatively robust model, and for real-world phenomena, which are usually messy, 69.4% is a very strong result. On the flip side, our model still leaves approximately 30% of the variation in material levels unexplained. These unexplained variables likely include: warehouse policies and practices, the sophistication of the inventory management software used, the training and experience of the materials management team, and the company’s focus on inventory management in general.

Conclusion

To the best of our knowledge, the analysis described in this article is the first attempt to model quantifiable factors that may contribute to generation inventory levels. The results indicate that the variables examined explain approximately 70% of the variation in inventory levels and that the following relationships hold true:

- Variables Contributing to More On-Site Material/MW
 - Inventory Complexity: More SKUs drive more on-site material/MW (Strong Relationship)
 - Warehouse Space: If you build it, material will fill it (Moderate Relationship)
 - Warehouse Staffing: The more people assigned to the warehouse, the more material/MW you will have (Moderate Relationship)
- Variables Contributing to Less On-Site Material/MW
 - Inventory Efficiency: The better you manage your inventory, the less you will have (Moderately Strong Relationship)

The clear take-away is that simplifying the number of different SKUs and increasing inventory turnover rates contribute to reduced inventory levels. It is less clear as to exactly why more warehouse staff per MW contributes to more material on site per MW since both variables are normalized for plant size. Our working theory, not yet tested by additional research, is that in some cases more staff is correlated with

⁷ R-square measures the proportion of the variation in the dependent variable (Y) explained by the independent variables (X_n) for a linear regression model. Adjusted R-square modifies the statistic based upon the number of independent variables in the model, giving a better predictor of true modeling accuracy.

poorer inventory management practices. That is, in the absence of a clear understanding of service-level or operational performance deficiencies, companies throw people at perceived problems. This can result in continuing sub-par performance with the added burden of increased costs. In any case, increasing warehouse staff does not seem to be an effective approach to reducing inventory levels.

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