



## Energy Management Training: Working with The ADDC CUSUM spreadsheet



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# What is CUSUM analysis?

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CUSUM is a powerful technique for developing management information regarding the energy performance of a plant, or an energy-consuming system such as an oven or furnace, for example. It distinguishes between significant events affecting performance—faults or improvements—and noise.

CUSUM stands for '**CU**mulative **SUM** of differences', where 'difference' refers to differences between the actual consumption and the consumption you would have expected on the basis of some previously established pattern (baseline).

# CUSUM analysis for power

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- Define a baseline period when the process was known to be stable:
  - no changes in product type, equipment or process settings other than variations in production volumes.
- From linear regression develop a model to relate production output to energy consumed.
- Use the model to predict energy consumption based on product output.
- Predicted consumption is then compared with ACTUAL consumption.
- The cumulative sum of the difference between actual and expected consumption is plotted to identify the total surplus consumption and changes in the slope of the accumulation curve.

# Regression analysis of energy versus production

Step 1: Carry out regression analysis to determine the functional relationship between energy consumption (kWh) and the Production (Tonne) over a specific baseline “a period of consistent performance” ( In this case the first 60 days were chosen) > Use excel regression tool to obtain the regression coefficients

Date	Production (Tonne)	Energy Consumption (kWh)	Specific Energy (kWh/Tonne)
4/22/2018	745.0	283,154	380.1
4/23/2018	848.7	278,838	328.6
4/24/2018	881.4	281,216	319.0
4/25/2018	718.2	289,208	402.7
4/26/2018	704.7	285,451	405.0
4/27/2018	775.7	288,682	372.1
4/28/2018	821.8	286,803	349.0
4/29/2018	736.3	282,402	383.6
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Regression Coefficients:	
Intercept	168950.455
Slope	150.984

# Predicted energy consumption

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Step 2: Use the regression coefficients derived from the baseline to calculate “predicted” energy consumption based on the actual values of the independent variable, which is the production tonnage:

$$\text{Predicted Energy (kWh)} = \text{Slope} * \text{production tonnage} + \text{intercept}$$

$$\text{Predicted Energy (kWh)} = 150.984 * \text{production tonnage} + 168950.5$$

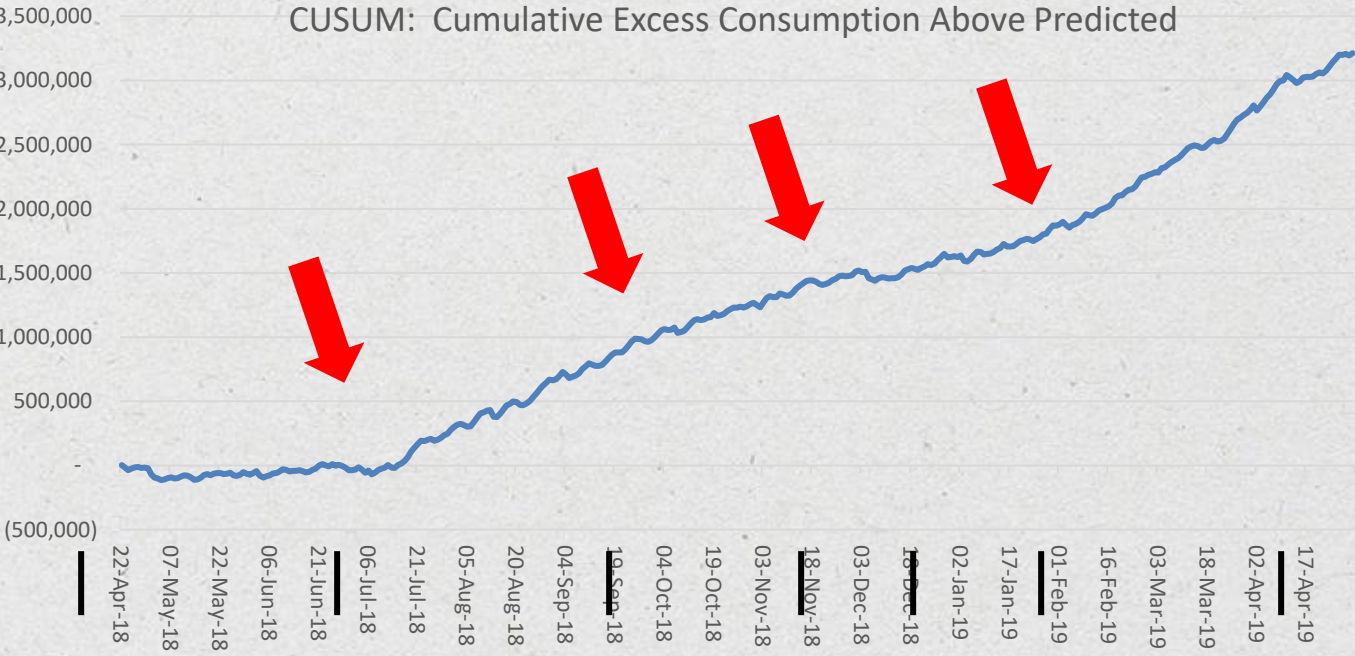
Date	Production (Tonne)	Predicted Energy (kWh)
4/22/2018	745.0	281,435
4/23/2018	848.7	297,088
4/24/2018	881.4	302,031
4/25/2018	718.2	277,391
4/26/2018	704.7	275,354
4/27/2018	775.7	286,073
4/28/2018	821.8	293,024
4/29/2018	736.3	280,117
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# Developing the CUSUM

Step 3: Determine the difference between the predicted and the actual energy consumption, and the cumulative sum of the differences (CUSUM).

Date	Production (Tonne)	Actual Energy Consumption (kWh)	Predicted Energy (kWh)	Actual minus Predicted Energy Consumption (kWh)	CUSUM
					-
4/22/2018	745.0	283,154	281,435	1,720	1,720
4/23/2018	848.7	278,838	297,088	(18,250)	(16,530)
4/24/2018	881.4	281,216	302,031	(20,815)	(37,345)
4/25/2018	718.2	289,208	277,391	11,817	(25,528)
4/26/2018	704.7	285,451	275,354	10,097	(15,431)
4/27/2018	775.7	288,682	286,073	2,609	(12,822)
4/28/2018	821.8	286,803	293,024	(6,221)	(19,043)
4/29/2018	736.3	282,402	280,117	2,285	(16,758)
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# Construct and interpret the CUSUM curve



# How to interpret the CUSUM plot

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If consumption continues to follow the established pattern, the differences between the actual consumption and the established pattern will be small and randomly either positive or negative. The **cumulative sum** of these differences over time, CUSUM, will stay near zero.

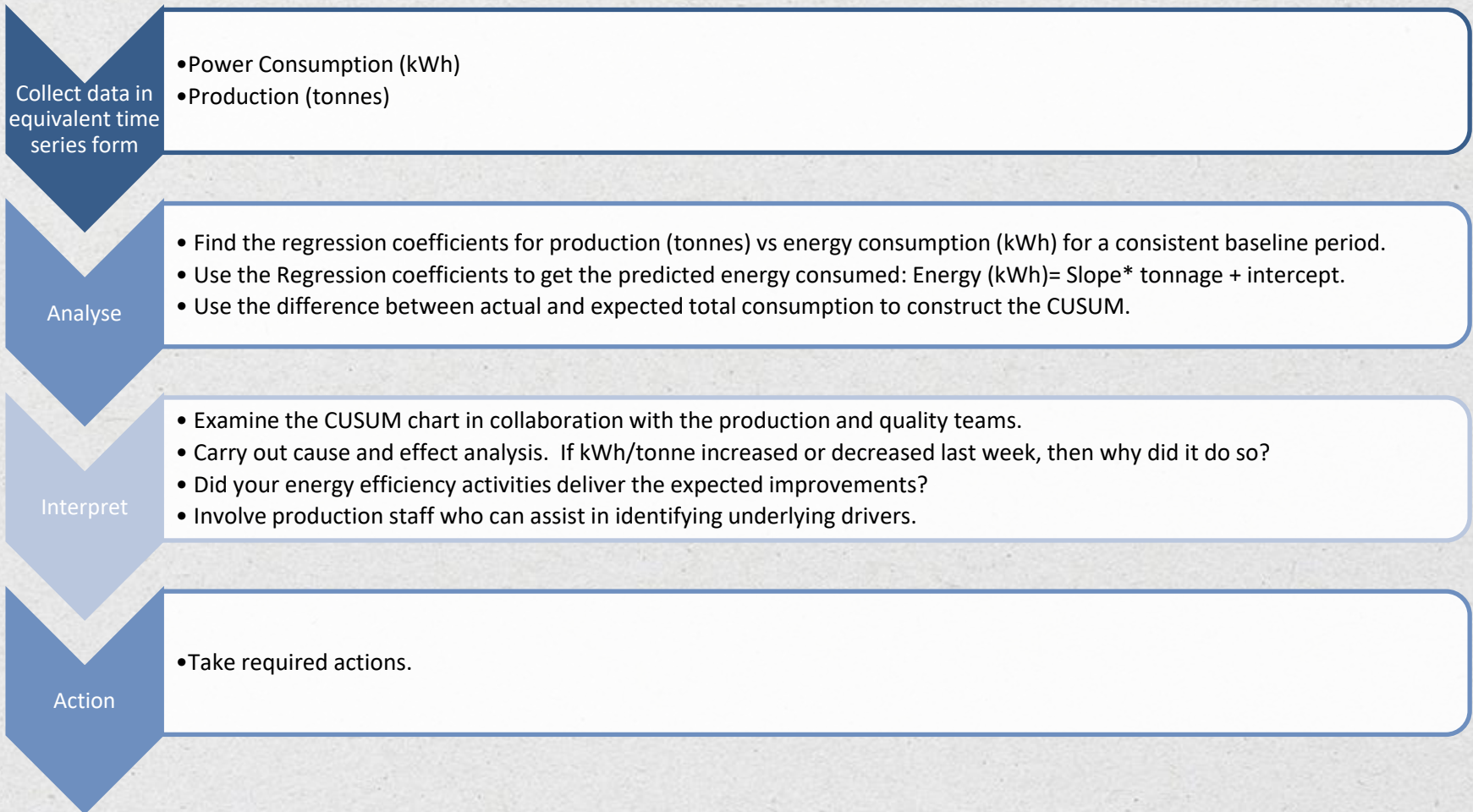
Once a systematic change in energy consumption occurs due to the presence of a fault or to some improvement in the process being monitored, the distribution of the differences about zero becomes less symmetrical and their cumulative sum, CUSUM, increases or decreases with time. The CUSUM graph therefore frequently consists of straight sections separated by changes in slope.

- Each change in slope is associated with a change in the energy intensity of the process.
- Each linear section of the curve is associated with a time when the pattern of consumption is stable.
- If the curve levels off, parallel to the time axis, this means that process energy consumption has returned to the same level as during the baseline.
- If the curve heads towards the time axis it means that energy consumption per unit of production is lower than during the baseline period.



# Summary of steps

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