Evaluation of Landfill Gas Wellfield Data for Maintenance Optimization

Avani Anne (TL-S), Sid Tchanyoum (TL-F), Wava Chan, Kopchon Sittithammachoti, Cristina Tzunun-Palomo (J-F), Leran Hu (J-S), Osa Omoregbe (J-S)
Advisor: Professor David Nembhard
Liaison: Kathy French '97, Madeleine Wass, Harold Emond

LS Power — Innovation and Investment in Energy

Harvey Mudd College

Project Overview

LS Power is an energy company with a robust **renewable division** dedicated to **power generation**, electric transmission, and energy infrastructure. The LS Power Clinic team is investigating data retrieved from landfill gas wellheads at **Twin Chimneys Power Plant** in Honea Path, SC, to develop a model to **streamline performance analysis** and **improve operational efficiency**. This model analyzes data using **SPC**, **machine learning**, and **data manipulation** to flag and predict problematic wells, with the aim to **increase plant output**.

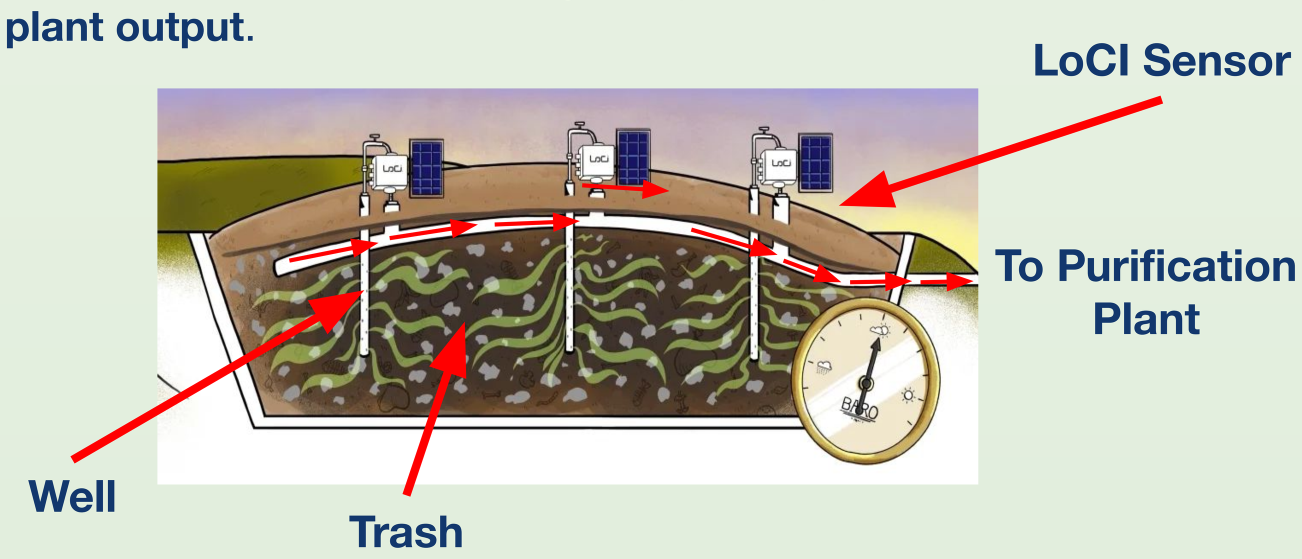

Figure 1. Landfill Gas with LoCI system (locicontrols.com)

Gas is collected from the landfill via wells drilled down into the substrate. Methane is produced when the municipal/household waste decomposes. The wells vacuum up the gas, and the LoCI module attached to each well collects data on that stream. The gas is aggregated in pipeline and sent to an on-site plant for purification and distribution.

Raw Data

Follow Up Priority

Current measurement of well quality:
- Green → Good
- Yellow → Danger
- Red → In need of immediate repair

Measured Metrics

- Gas balance (O_2, CH_4, CO_2, and balance gas)
- Gas flow rate
- Temperature
- Vacuum

Detected Issues

- Only 6% of values are currently categorized as Red (imbalanced data)
- Lots of missing data

Computational Model

The computational model aims to detect and predict problematic wells (specifically focusing on TCGW wells). To create our model, we incorporate 3 main layers as can be seen in Figure 2 below:

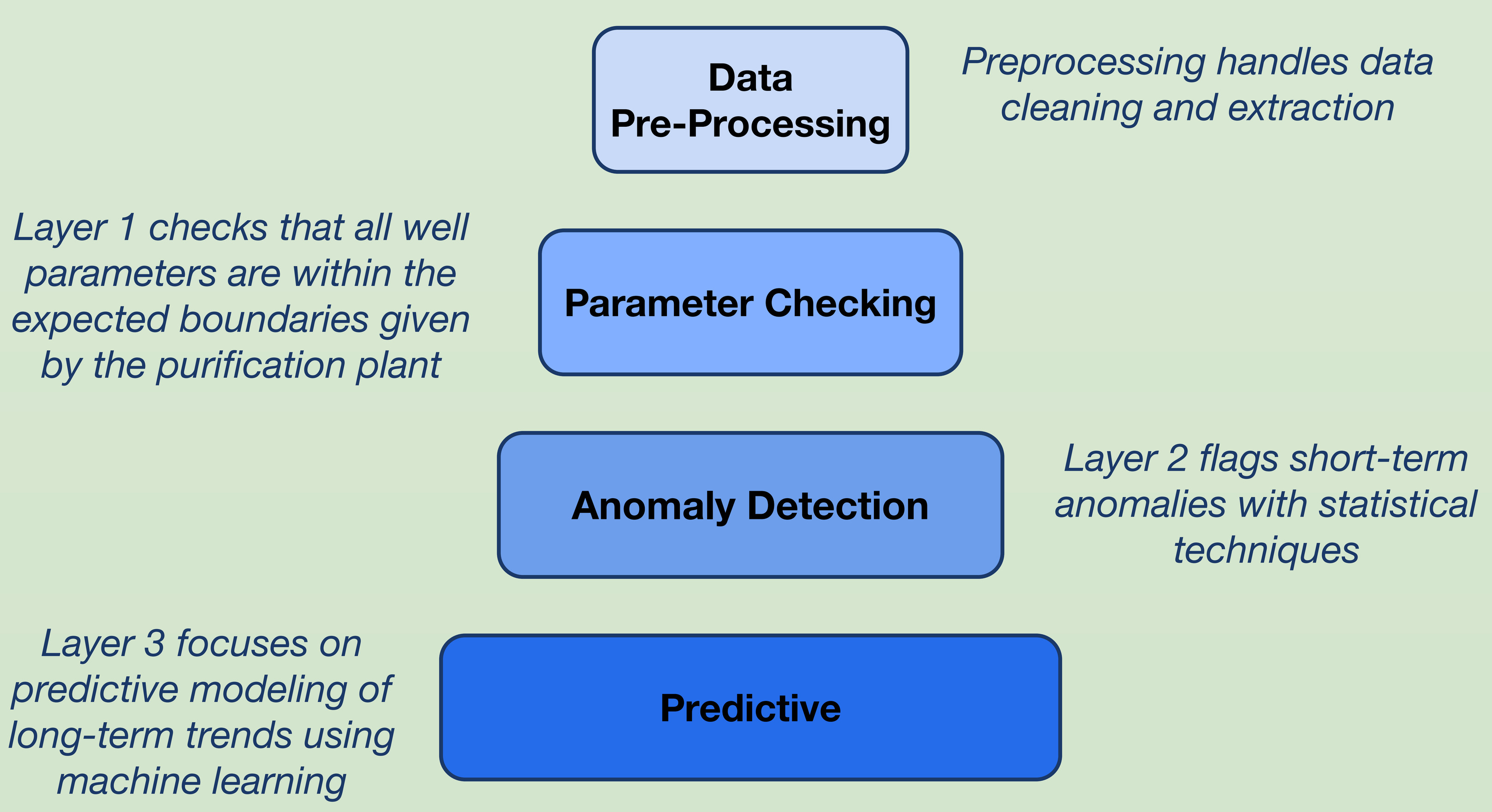

Figure 2. In depth view into data processing layers

Anomaly Detection

Statistical Process Control (SPC) is an analytical tool to monitor and identify trends in landfill gas (LFG) for proactive wellfield management.

The team chose to use X-bar (Figure 3) and S (Figure 4) charts as control charts (focusing specifically on gas parameters, CH_4 and O_2). The steps are:

1. Find the central line, upper control limit, and lower control limit of the control period.
2. Use Shewhart rules to detect anomalies for the test data based on these limits.
3. The site technicians could use the results to pay attention on potential problematic well.

Shewhart rules:
- Any single point outside control limits
- Nine consecutive points on one side of the central line
- Six consecutive points increasing or decreasing
- Fourteen consecutive points alternating up and down

Input: Hourly data with known control period

Output: Date-time and well that violate Shewhart rules

Future: Need to know the appropriate control period of each well

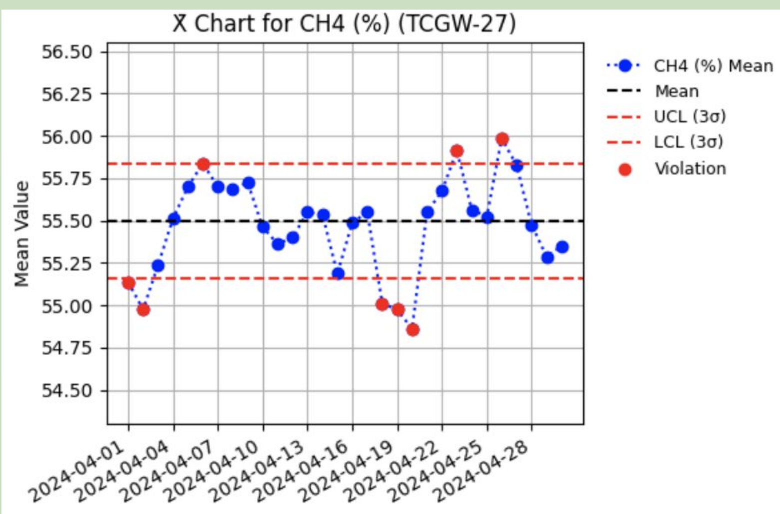

Figure 3. X-bar charts for CH_4 (%)

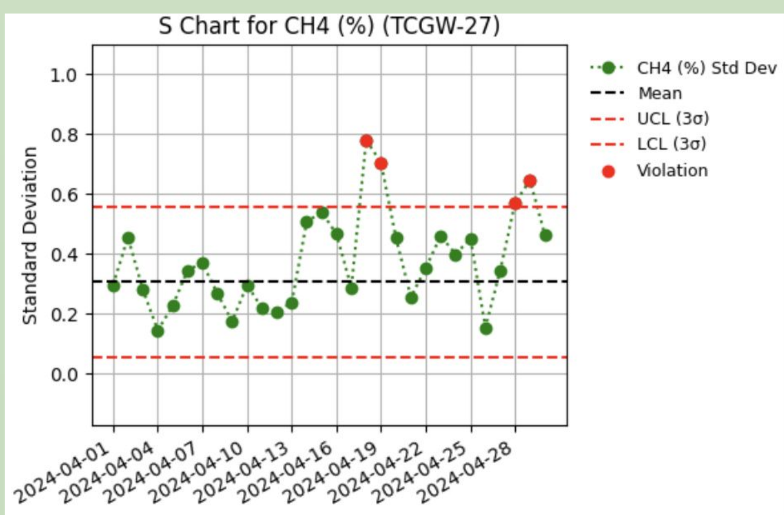

Figure 4. S charts for CH_4 (%)

Predictive

Machine learning (ML) assists in developing predictive tools to flag potentially problematic wells, with the goal of detecting "Red" wells earlier than the current system.

To evaluate an ML model's performance, the team focuses on the recall metric, which assesses how effectively the model identifies true positive cases. The formula for recall is:

$$Recall = True\ Positives / (True\ Positives + False\ Negatives)$$

We experimented with several different models and parameters. The plots below aim to give insight into the decisions behind our model choice:

Determining the model:

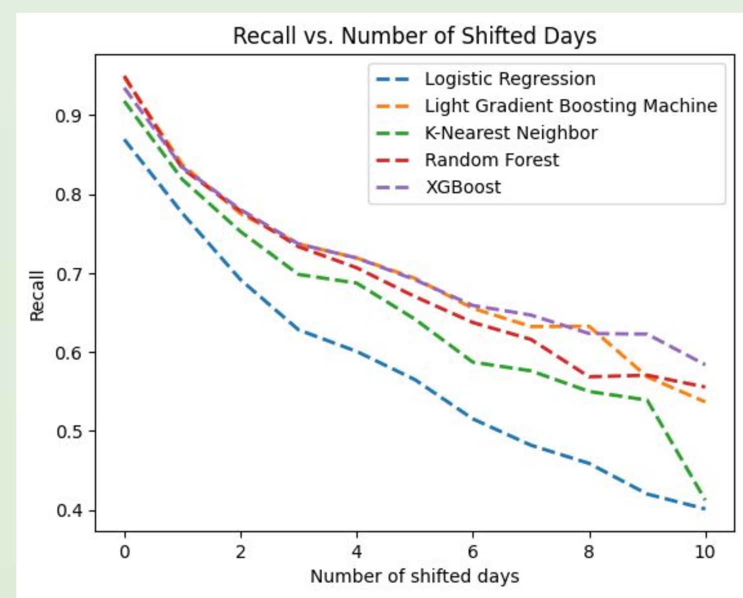

Figure 5. Recall values for predicting "Red" days a number of "shifted days" in advance

Determining optimal shift + inputs:

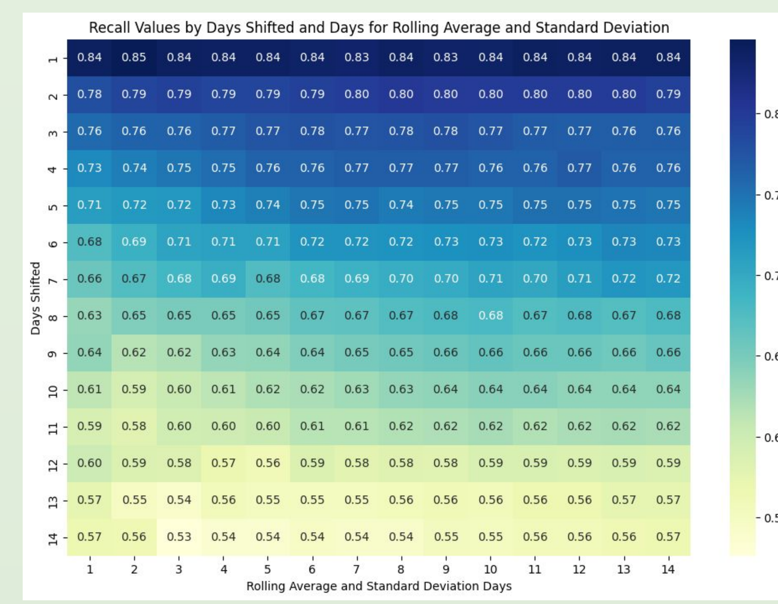

Figure 6. Recall values from XGBoost to determine optimal number of days involved in rolling average and standard deviation for gas values (used as model variables)

Our model uses XGBoost with input parameters for gas, 14-day gas rolling averages, and 14-day gas standard deviations aiming to predict "Red" wells 7 days before the current flags.

Interface

The computational model produces and predicts underperforming wells. This information is pushed to a spreadsheet containing all the past well issues/fixes. The interface displays this information in a readable way, and allows technicians to input well issues//fixes themselves, which is also recorded on the tracking spreadsheet.

We utilize Google Appsheet for our interface:

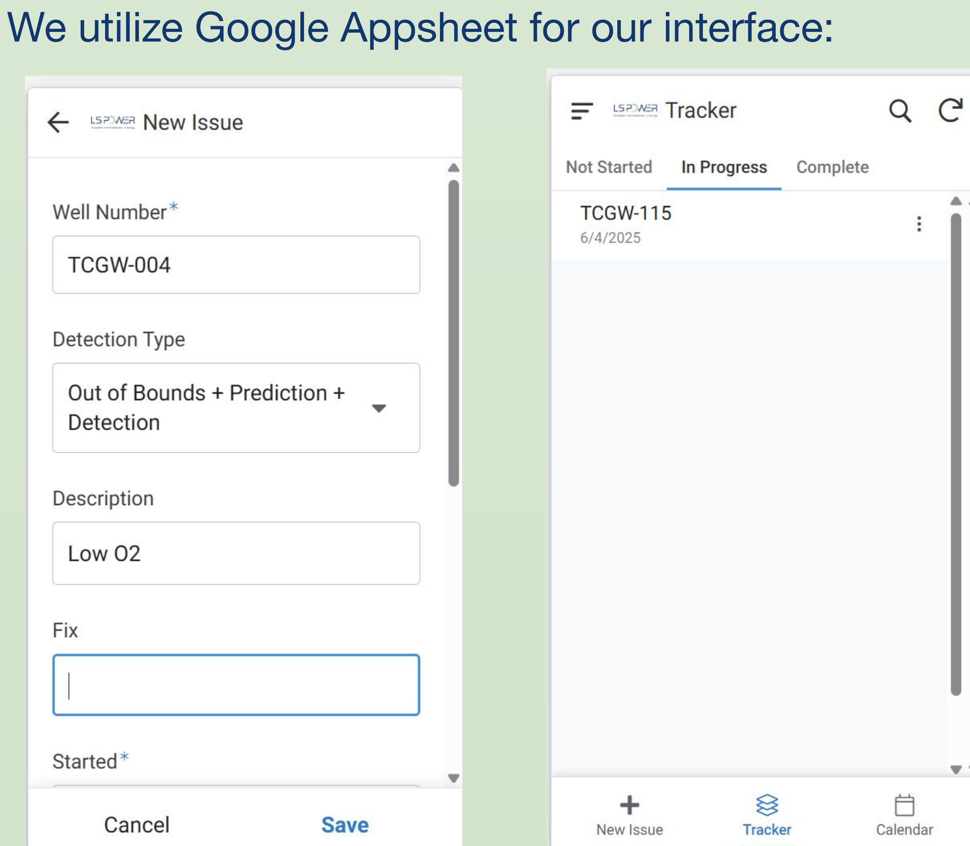

Figure 6. Screenshot of developing interface

Features

- Alert technicians of underperforming wells.
- Communicate results of data analysis.
- Allow technicians to track/report well issues and well repairs.
- Collect data on time of issue/fix, what the issue was, what was done to fix it.

Impact

- **Increase the revenue** through greater amount of captured landfill gas
  - At present, the landfill is only producing at about 45-50% capacity.
  - **Increase of 50 SCFM landfill gas → 25 SCFM of CH_4 → ~$1,350/day**
- **Reduce greenhouse gas emission** since CH_4 has a drastically higher global warming potential than CO_2 on a 100 year scale by a factor of 30.
- **Automate well monitoring improves efficiency**
  - Save technicians hours while cutting potential methane release.

Future Work

__Anomaly Detection:__ Adjust control limits in real time and automate the derivation of Shewhart thresholds from live data, to not rely on static, batch-oriented charts.

__Prediction:__ Solicit technician feedback to improve model performance.

__Interface:__ Incorporate feedback – which issues were correctly vs. incorrectly predicted and how to make interface more useable

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