Accord Combustor

6th December 2023

Content

Project Overview

The Combustor development was undertaken as a 'Spark' project approved and managed by the Net Zero Technology Centre (NZTC) in Aberdeen and ran for a fixed 12-month period.

The goals of the project were to complete a series of Combustion Efficiency (CE) desktop modelling exercises and conduct a live field trial of the application – applying lessons learned, adding functionality and reporting capabilities along the way.

The project was supported by bp, Harbour Energy, Serica, Ithaca and TotalEnergies who all played a very large part in the successful completion of the project.

Desktop models of CE were completed for the bp Glen Lyon, Harbour Energy Britannia, Serica Bruce and Ithaca Captain operating facilities.

A live field trial version of Combustor has been running on the TotalEnergies Culzean asset since mid-October.

What is Combustor:

Combustor has been developed to calculate Combustion Efficiency, Carbon Dioxide (CO_2), Methane and Carbon Dioxide equivalent (CO_2e) emission rates and cumulative totals. Functionality to support the optimisation of emission rates and uncertainty estimates for CE have also been developed.

Combustor is based upon a publicly available, transparent and peer reviewed study published by the University of Alberta (UoA) in 2004.

The study was conducted within a closed loop wind tunnel; a fully controlled and enclosed test environment which allowed the capturing of all combustion products for analysis.

The UoA study provides a robust and repeatable methodology which has passed through rigorous academic scrutiny and is further supported by additional materials published in 2022.

The UoA methodology is referenced within the Oil and Gas Methane Partnership (OGMP) 2.0 documentation and within the Oil and Gas UK Methane Action Plan (OGUK MAP).
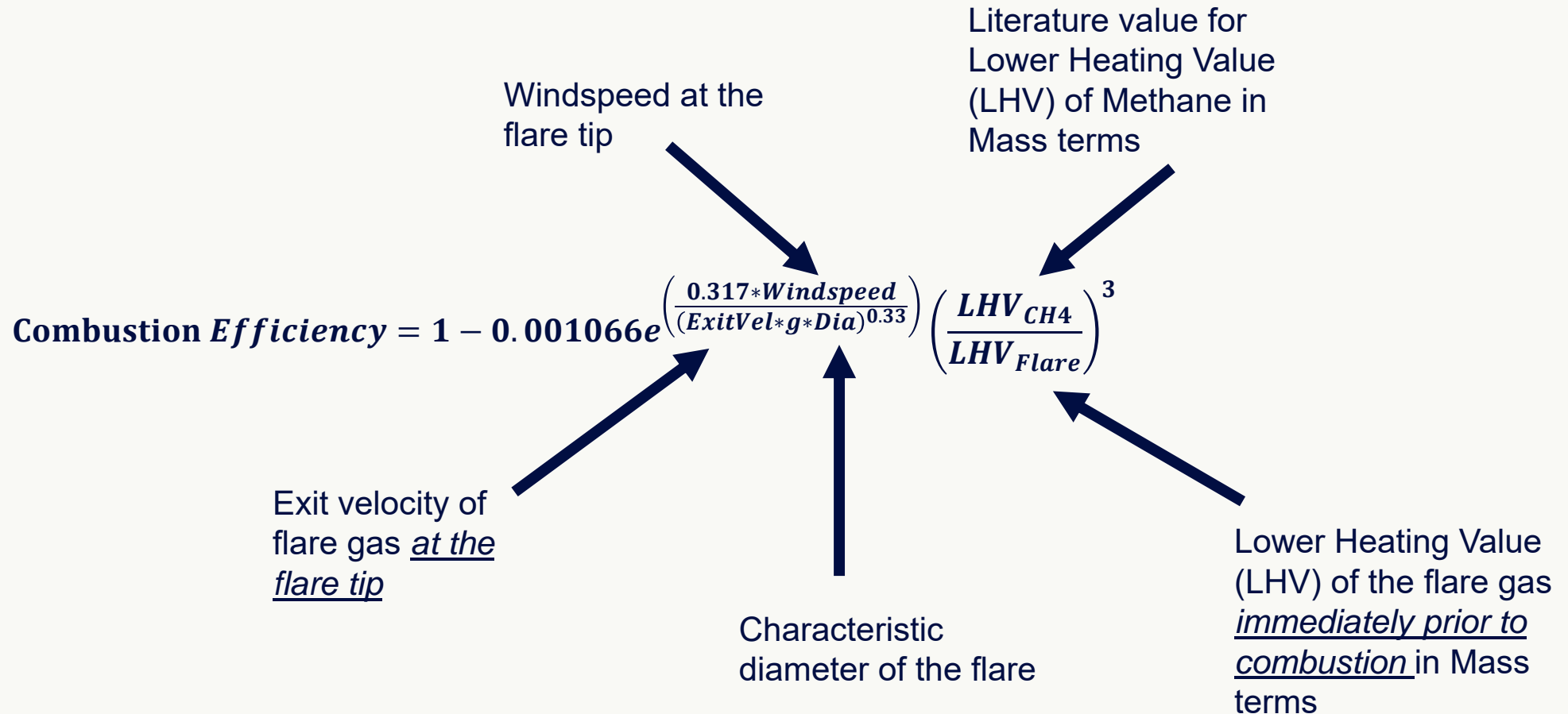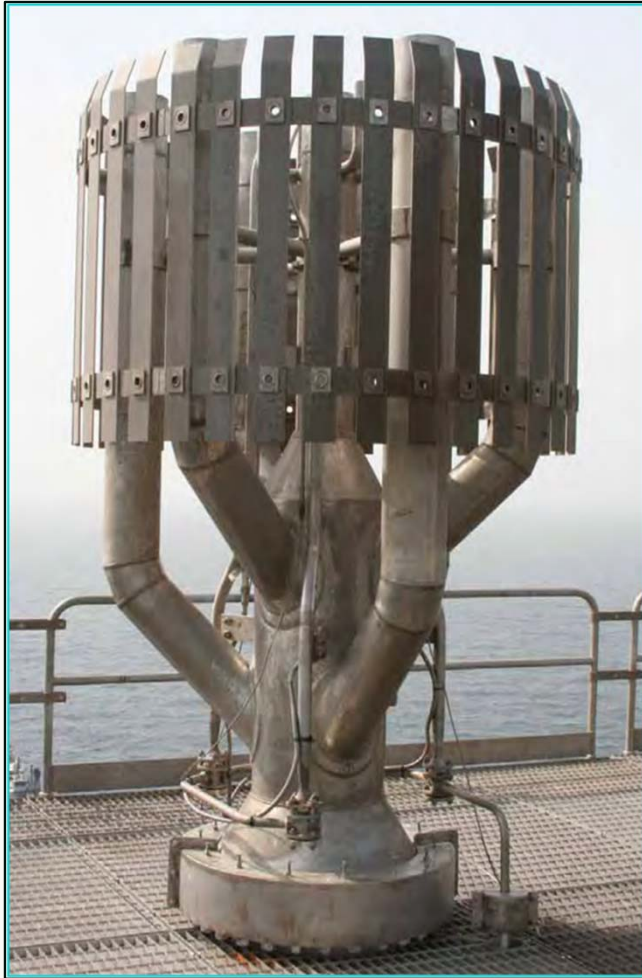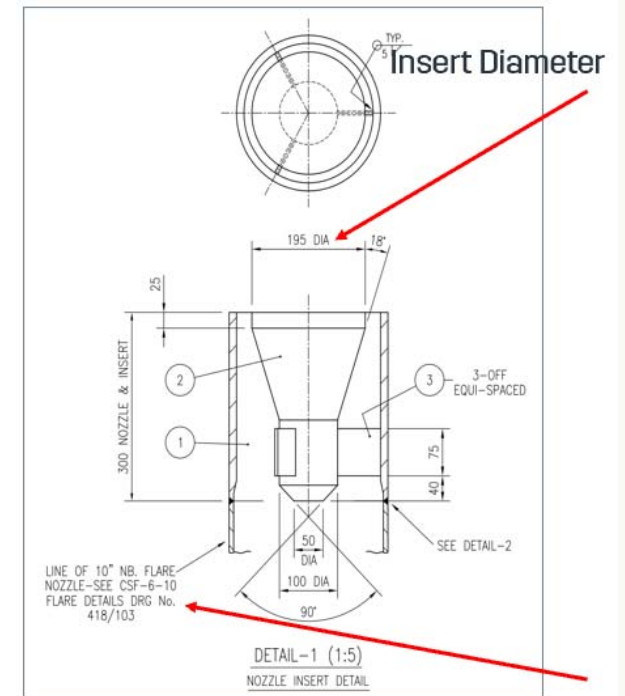
https://web.archive.org/web/20221222034340id

https://www.sciencedirect.com/science/article/pii/S1743967122001210

https://auprf.ptac.org/wp-content/uploads/2015/11/Final-Report-040826.pdf

The UoA Algorithm

Windspeed at the flare tip

Literature value for Lower Heating Value (LHV) of Methane in Mass terms

$$\text{Combustion } Efficiency = 1 - 0.001066 e^{\left(\frac{0.317 * Windspeed}{(ExitVel * g * Dia)^{0.33}}\right)} \left(\frac{LHV_{CH4}}{LHV_{Flare}}\right)^3$$

Exit velocity of flare gas _at the flare tip_

Characteristic diameter of the flare

Lower Heating Value (LHV) of the flare gas _immediately prior to combustion_ in Mass terms
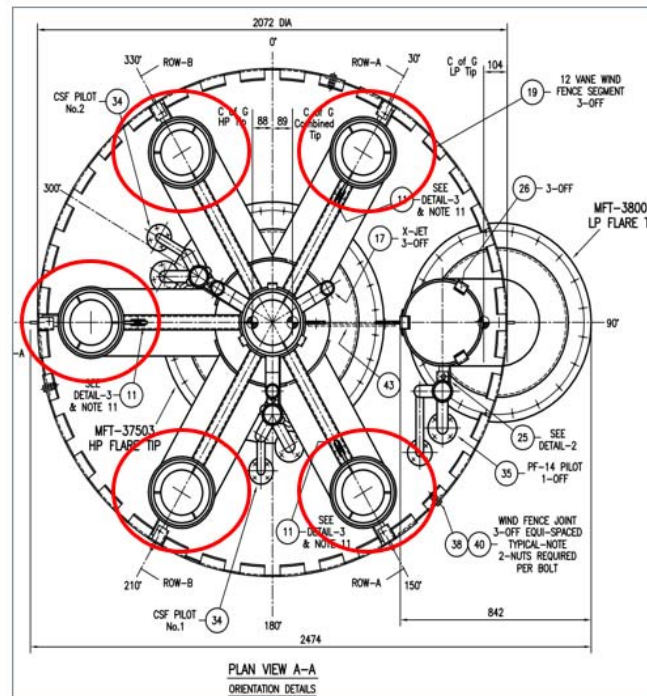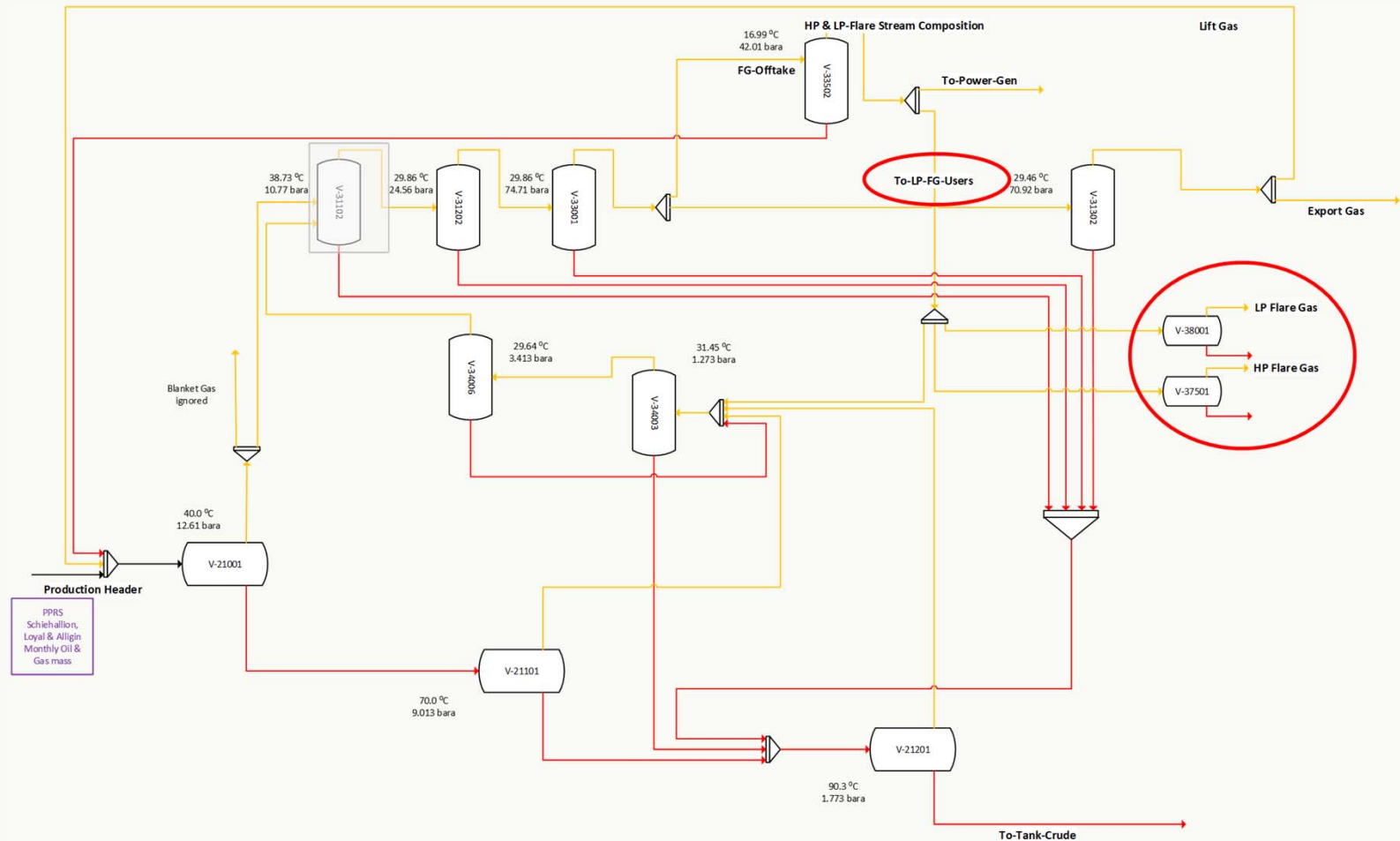
bp Glen Lyon

HP and LP Flare GA

Insert Diameter

Nozzle Diameter

bp Glen Lyon

- HYSYS model & PFDs with standard operating conditions

- Schiehallion, Loyal, Alligin production data: downloaded from NSTA and averaged

- Field compositions as per HYSYS model

- Daily fuel gas usage

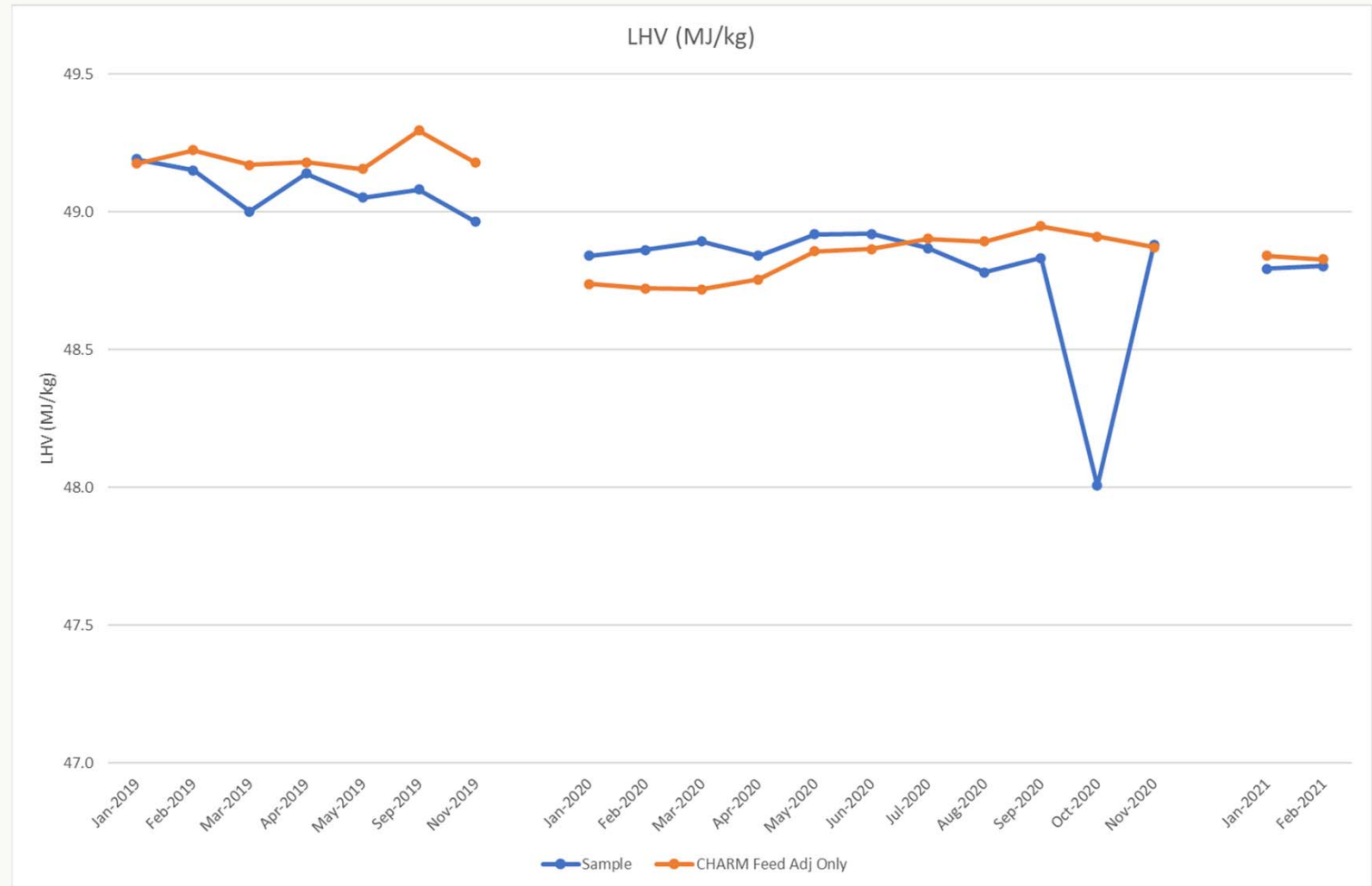- Daily average plant operating conditions
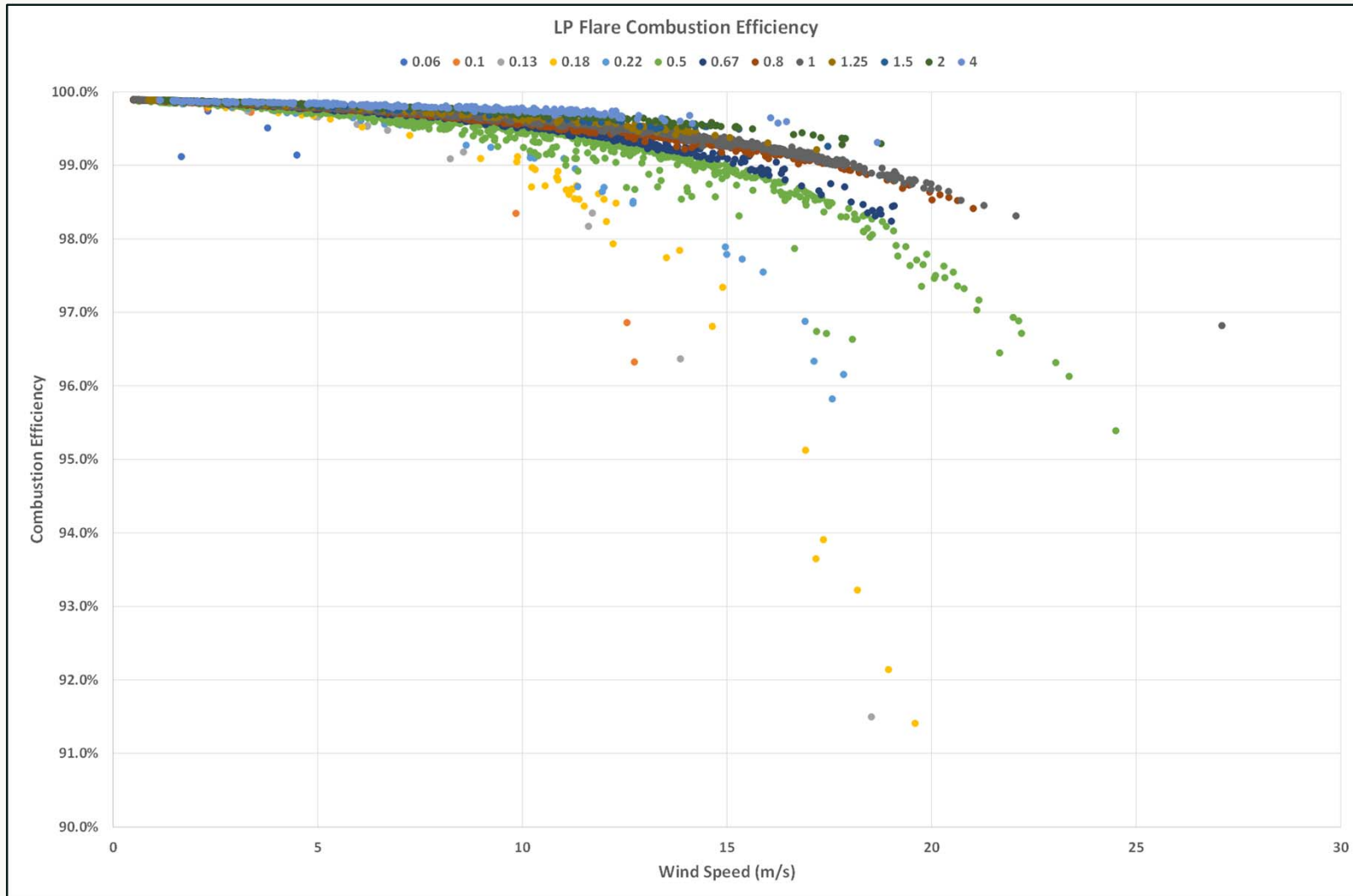
bp Glen Lyon

- Flare sample data supplied by BP
  - 2019: 7 samples
  - 2020: 10 samples
  - 2021: 2 samples

- Compared the CHARM predicted LHV and C1 content for the flare stream with monthly sample data supplied by BP

- CHARM model based on supplied HYSYS model
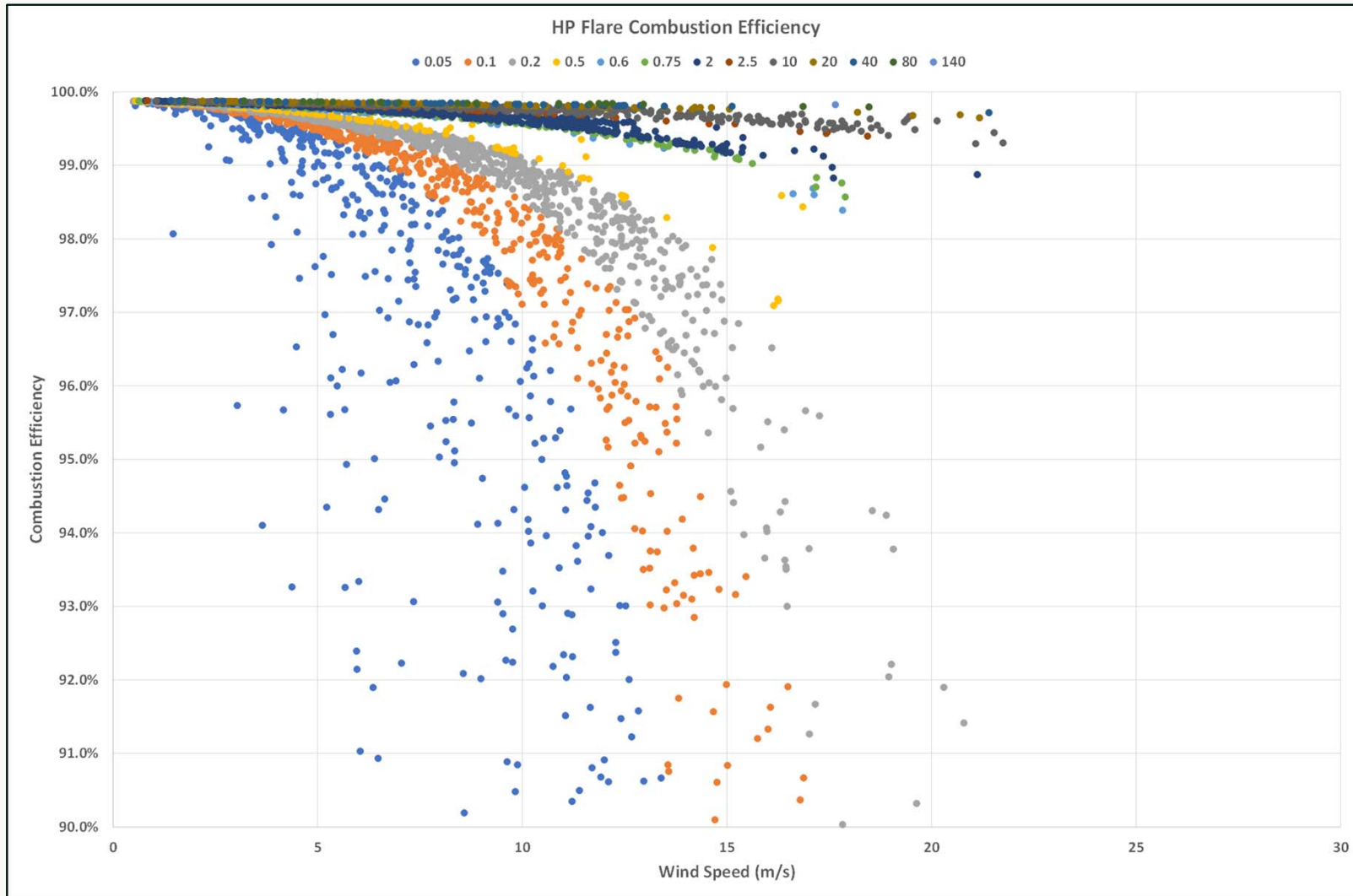
Monte Carlo Uncertainties Run	
Mean LHV	49.13 MJ/kg
Uncertainty	+/-0.28MJ/kg
Relative	+/-0.56%

LHV (MJ/kg)

bp Glen Lyon

LP Flare Combustion Efficiency

bp Glen Lyon

HP Flare Combustion Efficiency

Serica Bruce

1st Stage HP Flare   2nd Stage HP Flare   LP Flare

HP Flare
- Single meter measuring total stream to 1st & 2nd stage flare

1st Stage HP Flare
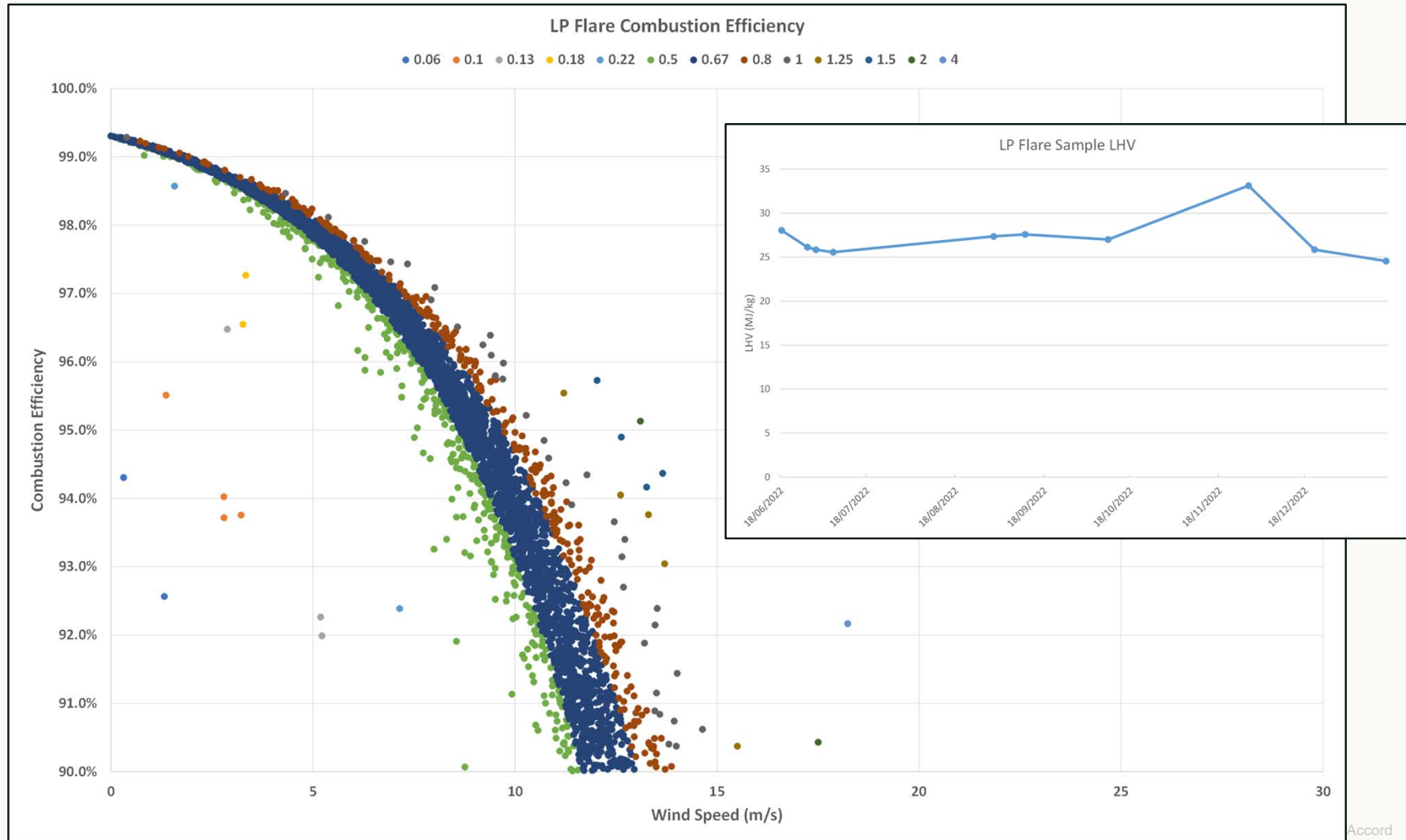- Routine operations

2nd Stage HP Flare
- Start-up / Shutdown / Safety usage
- Coanda array 9 x 'Tulip' Flare tips
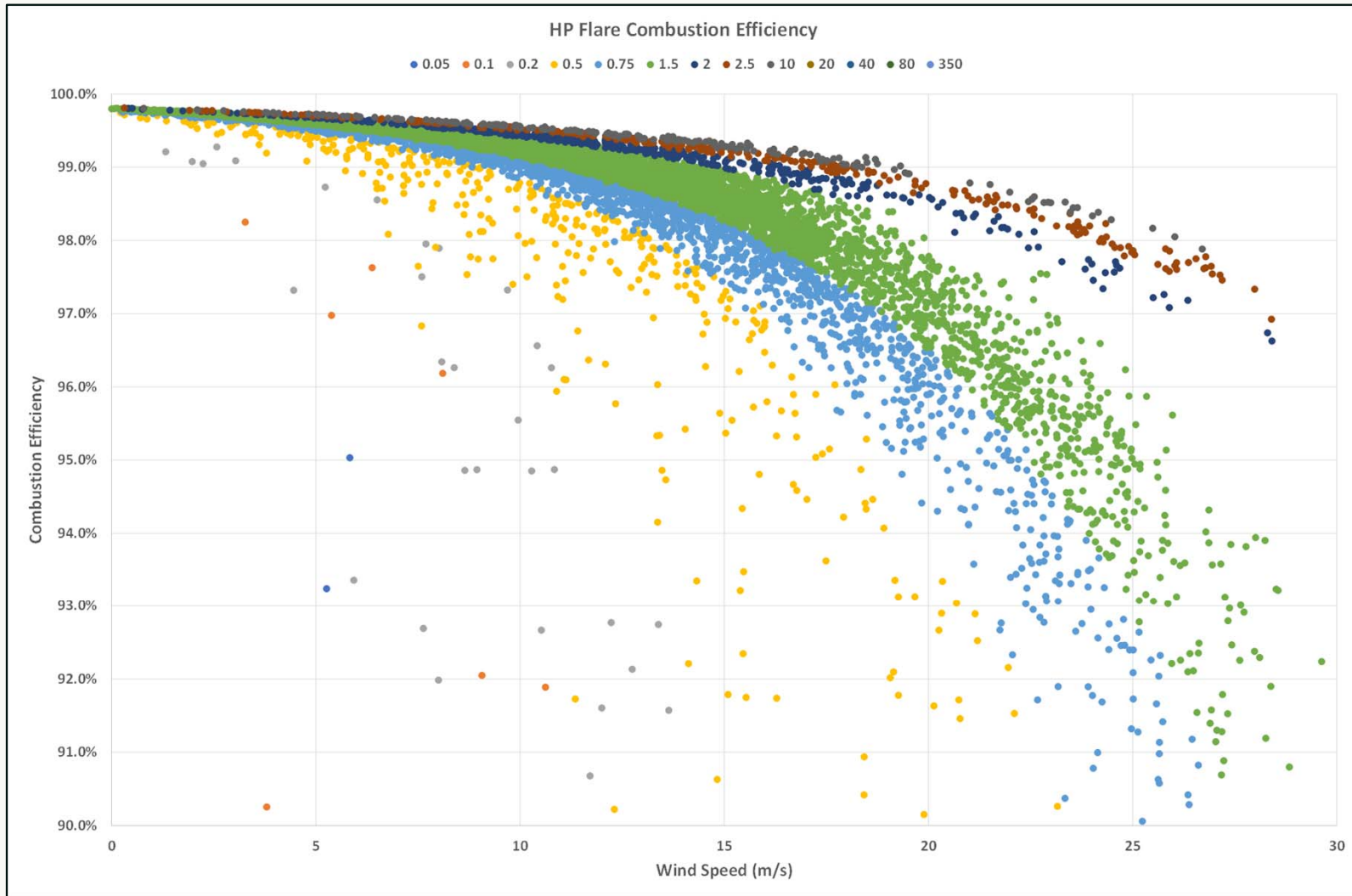- HP Flare > 1000 m^3/h excluded from analysis

LP flare
- Routine operations

Serica Bruce LP Flare

Serica Bruce HP Flare
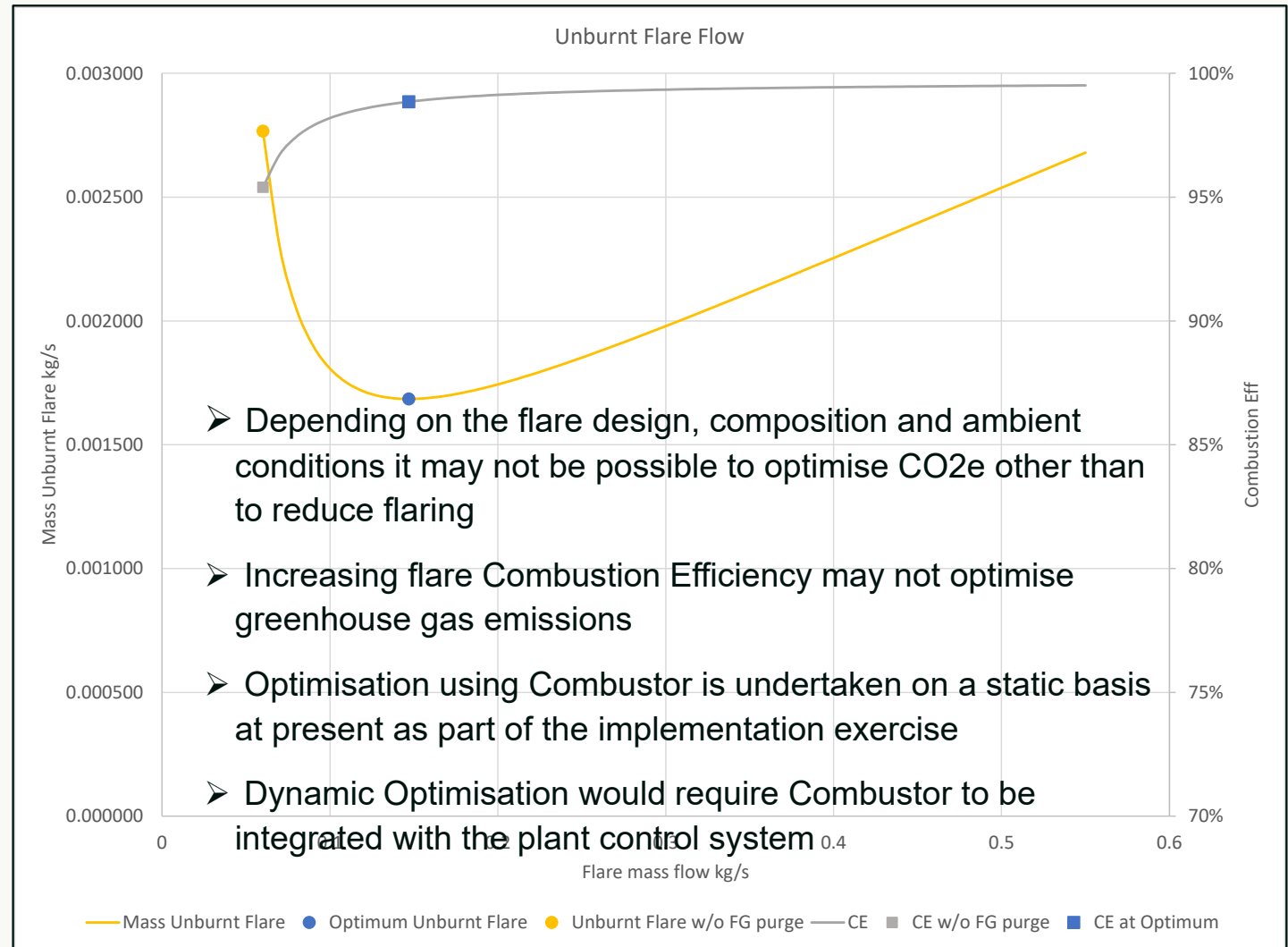

HP Flare Combustion Efficiency

Optimisation

What should be optimised?

- Combustion Efficiency?
- Unburned Hydrocarbons?
- CO2e mass?
- CO2e $?

Some examples of Serica Bruce LP Flare optimisation

Example conditions	
Flare rate	170 Sm3/h (190 kg/h)
N2 purge	No
Fuel Gas LHV	42 MJ/kg
Wind Speed	10 m/s (22.4 mph)
CE	95.4%
Unburnt flare rate	10.0 kg/h (0.24 tonne/day)

Optimum unburnt flare conditions	
Fuel gas purge	385 Sm3/h (313 kg/h)
CE	98.8%
Unburnt flare rate	6.1 kg/h (0.15 tonne/day)
Absolute reduction	3.9 kg/h (0.09 tonne/day)
% reduction	39 %

Unburnt Flare Flow

➢ Depending on the flare design, composition and ambient conditions it may not be possible to optimise CO2e other than to reduce flaring

➢ Increasing flare Combustion Efficiency may not optimise greenhouse gas emissions

➢ Optimisation using Combustor is undertaken on a static basis at present as part of the implementation exercise

➢ Dynamic Optimisation would require Combustor to be integrated with the plant control system

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Uncertainty

Calculated in two recognised ways:

- Analytically using the GUM, propagation of uncertainties using Taylor Series Method
- Monte Carlo, cross check

LHV_f ±0.6% Flare gas LHV from CHARM (MJ/kg)
U_w ±1% Wind speed (m/s)
U_f ±7.5% Flare exit velocity (m/s)
d   ±1% Flare outer diameter (m)
A   UoA equation constant
B   UoA equation constant
AB   Covariance term

$$CE = 1 - A\left(\frac{LHV_{CH4}}{LHV_f}\right)^3 e^{\left(\frac{B\,U_w}{(U_f g d)^{1/3}}\right)}$$
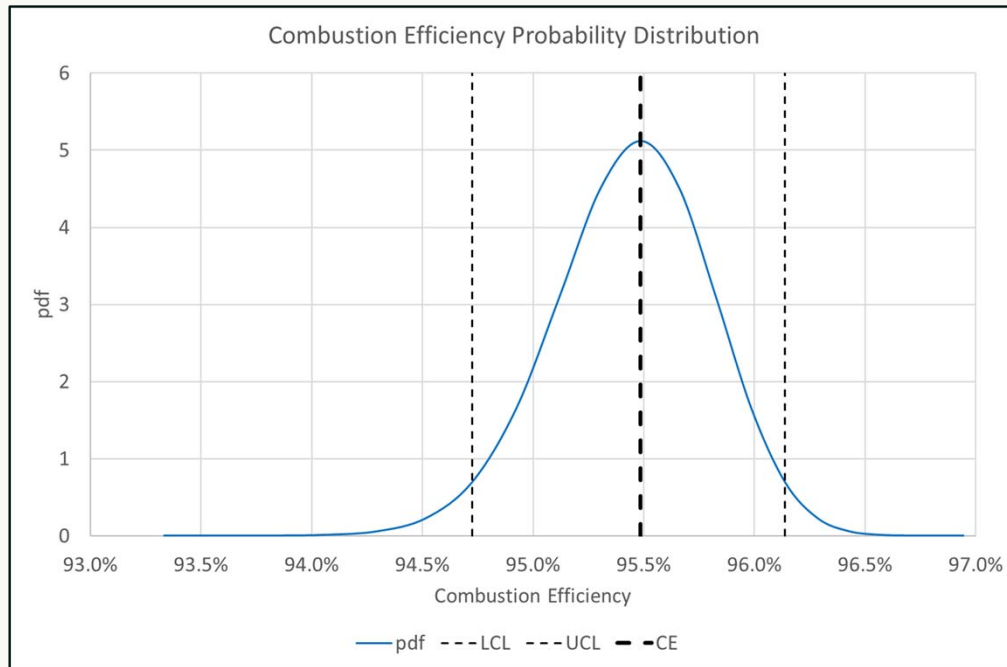
$$C_i = \frac{\partial CE}{\partial X_i}$$
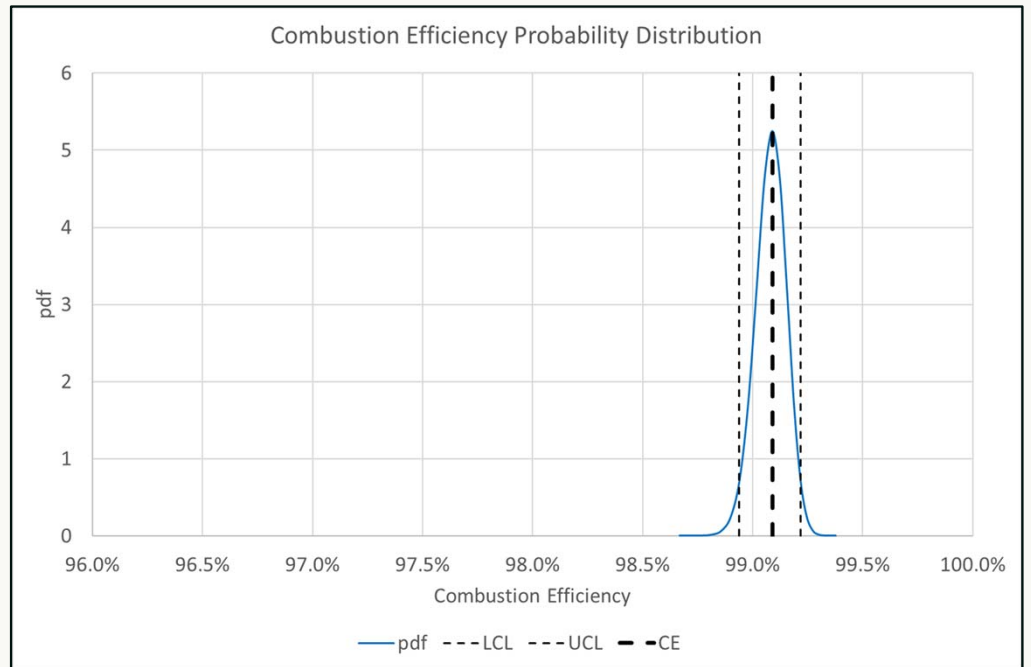
$$Unc_{CE} = \sqrt{\sum_i (C_i * Unc_{Xi})^2}$$

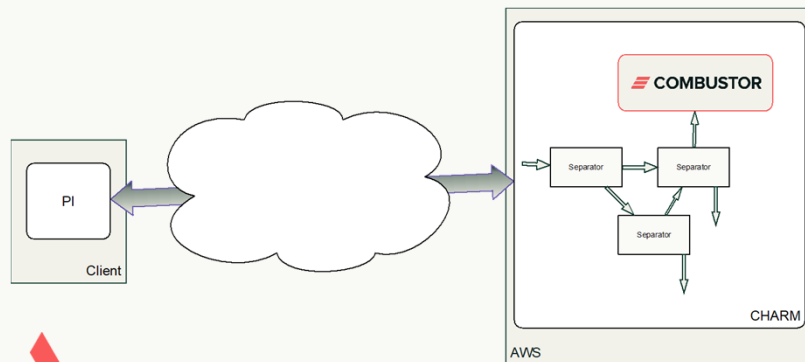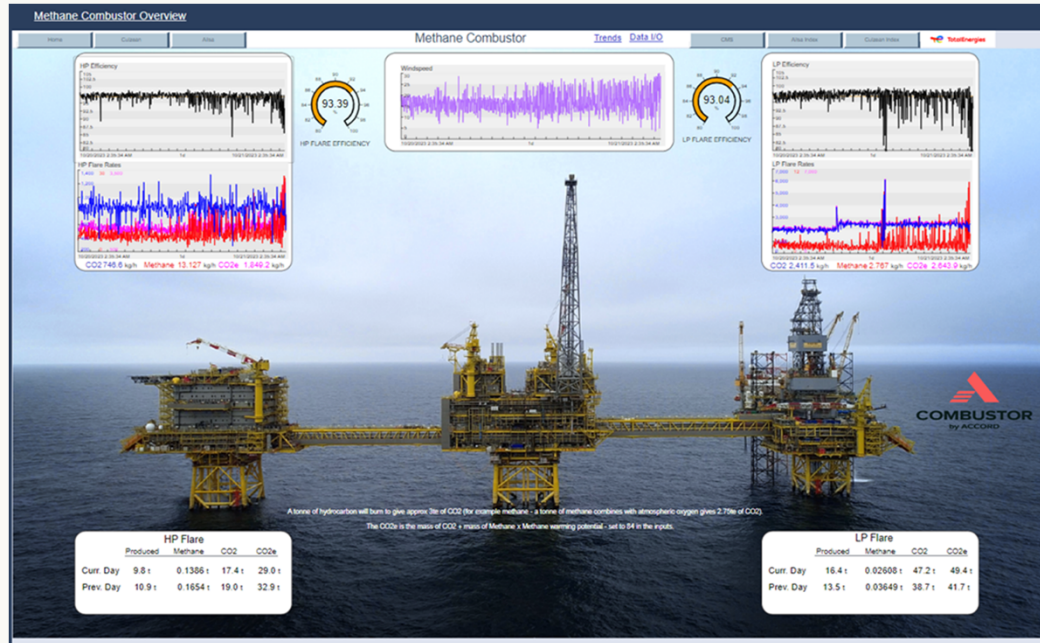Uses logarithmic formulation to reduce bias in results

Uncertainty

High Wind Speed 19 m/s

Average Wind Speed 10 m/s

TotalEnergies Culzean

➢ Integrated with the CHARM process modelling software
➢ Java implementation – portable and efficient – deployed on the cloud
➢ Secure and controlled software environment, additional calculations and extensions can be added
➢ Fast – typically 0.1 – 1s execution time depending on complexity of the process model
➢ Reliable and Reproducible – you always get the same answer

Summary

Some of the things we learned:-

➢   Modelling process is repeatable across assets
➢   Operator support is required to develop and verify simulation
➢   Timeline to finalise simulation model varied between 2 and 4 working weeks
➢   Software installation is relatively simple and quick
➢   LHV of flare gas and exit velocity needs to account for downstream N2 and/or flare gas purge
➢   Optimisation of CO2e may not be possible on all assets – design dependent
➢   Uncertainty calculations need to account for the exponential nature of the UoA algorithm

Some of the things we get from Combustor:

➢   Aligns with OGMP 2.0 and OEUK Methane Action Plan
➢   Minute by minute calculation of CO2, CH4, CO2e flow rates and cumulative totals
➢   Live uncertainty reporting for Combustion Efficiency
➢   Identify and optimise CO2e performance (where possible)
➢   Ability to post process data for mismeasurement events
➢   Can be updated to study, inform and incorporate future plant changes
➢   Pre and post combustion compositional information such as ISO6976 CVs, AGA8 Densities, etc.