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Optimization-driven design for a sustainable process plant

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AVEVA

About ESTECO S.p.A.

ESTECO is an **independent** software company, highly specialized in **numerical optimization** and **simulation process** and **data management**.

Our technology brings modularity, ease of use, standardization, and innovation to the engineering design process.

Our customers and industries

Embraer
Leonardo
Lockheed Martin
Raytheon
Bombardier
Stellantis
Ford
Honda
Toyota
Volvo Cars Corporation

Mahindra
Takenaka
Bouygues Construction
ABB
Bajaj
BASF
Cummins
FAW
Whirlpool
Sony

Our products

modeFRONTIER

The leading software solution for simulation process automation and design optimization

VOLTA

The innovative enterprise platform for Simulation Process and Data Management (SPDM) and design optimization

How to design a sustainable process plant

Challenge

- Governments have started to impose regulations on greenhouse gas emissions in addition to the existing regulations on water, and toxic pollution. Manufacturing companies are looking to make their operations greener.

Solution

- An interface between the AVEVA Process Simulation and modeFRONTIER has been created in order to optimize the process parameters with the aim of reducing the Chemical Oxygen Demand (COD) in the wastewater and the cost.

Benefits

- We could reduce Chemical Oxygen Demand (COD) by ~70% and the Cost of 16% with respect to the rough baseline design in just a few days.

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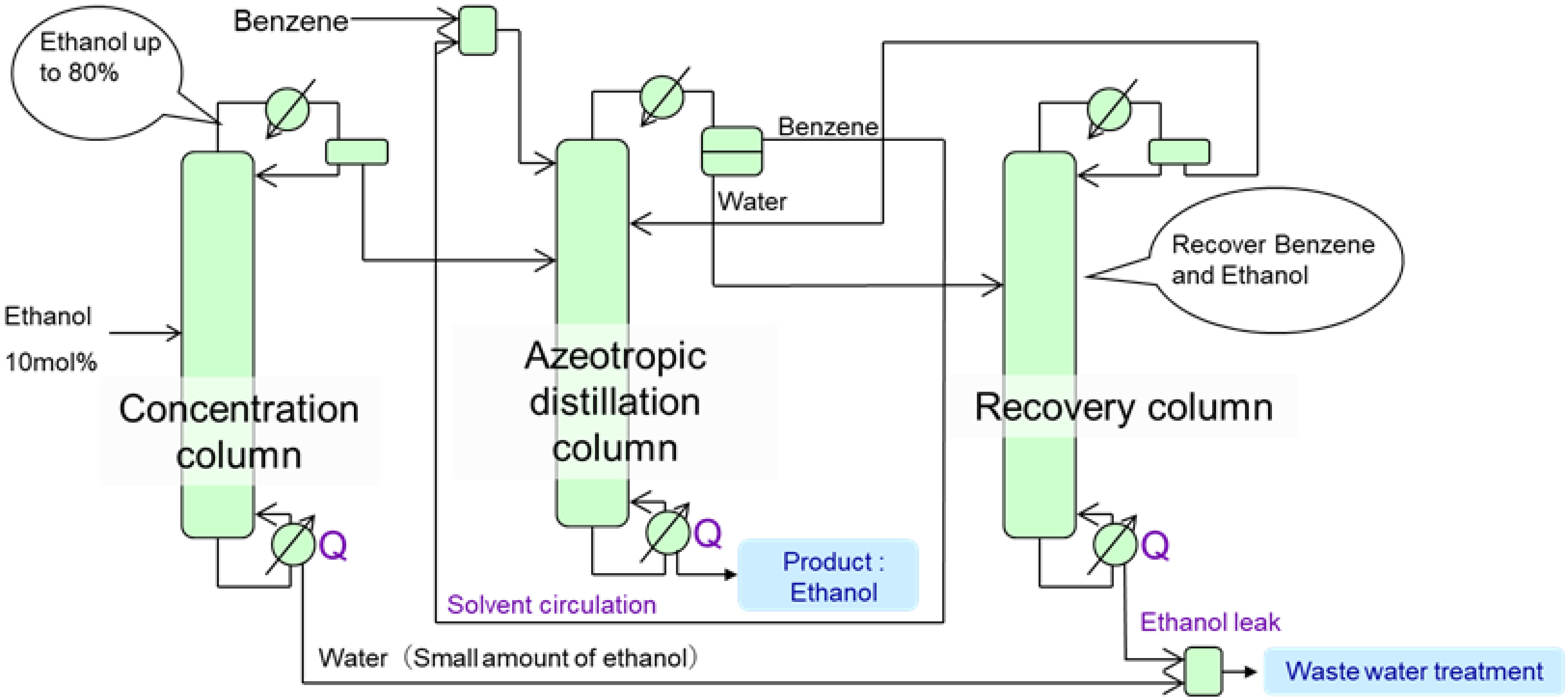
Challenges designing a Ethanol distillation process plant

1. The separation of ethanol and water is complex because ethanol/water mixture forms an azeotrope; several distillation sequences are described in the book Separation Process Principles (J.D. Seader)[1].
2. Need to find cost effective distillation sequences, operational and design conditions while reducing the environmental load



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AVEVA Process Simulation

How to develop a next generation program to enable true digital transformation?

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Digital Transformation

Designed from the ground up, delivering the process digital twin, to the next generation of engineers

Designed from the Ground Up

- Role-based user interface
- Continuously saved
- Open model writing
- Multi Core Solution

Delivering the Process Digital Twin

- Design, Rating, and Dynamics
- Industry Asset Libraries
- Design Digital Twin
- Operating Digital Twin

To the Next Generation of Process Engineers

- Groundbreaking Ease of Use
- Instantaneous results
- Python scripting enabled

- **Replaces single purpose solutions**
- **Reduction in Simulation Effort across the lifecycle**
- **Collaboration internally and externally**
- **Addresses Sustainable Process Design**
- **For True digital Transformation**

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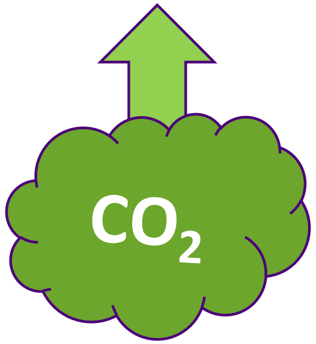
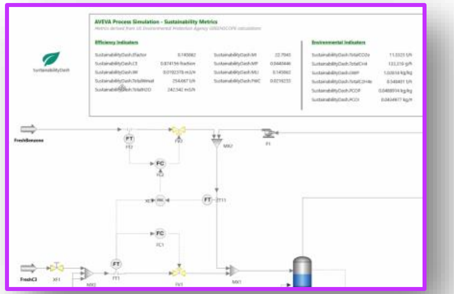
Trends in Sustainability

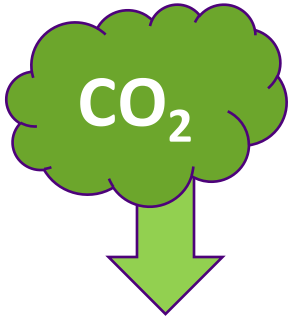
AVEVA Process Simulation focused on Four Areas of Sustainability



Greenhouse Gas Emissions

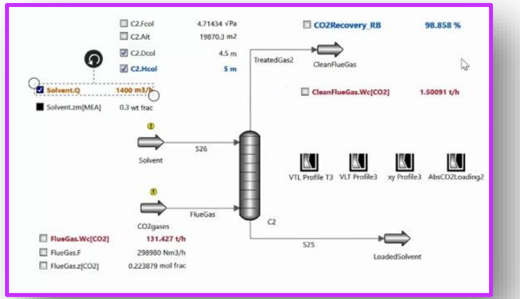
Use simulation to predict the amount of GHG emissions so that you can improve process design.





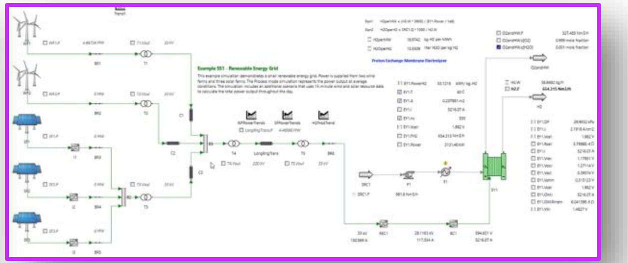
Carbon Capture

All process industries must reduce the amount of equivalent CO2 they release



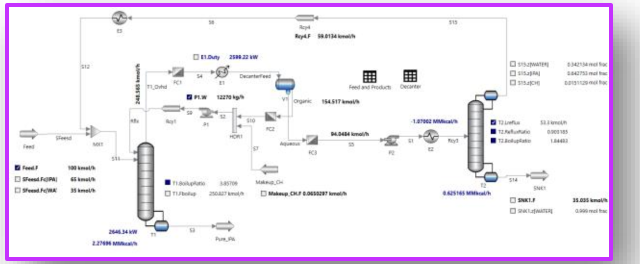
Energy Transition

Transition from “Oil & Gas” to “Energy” using renewable power and hydrogen



Circular Economy

Chemical companies must reinvent portfolio of products with sustainability in mind



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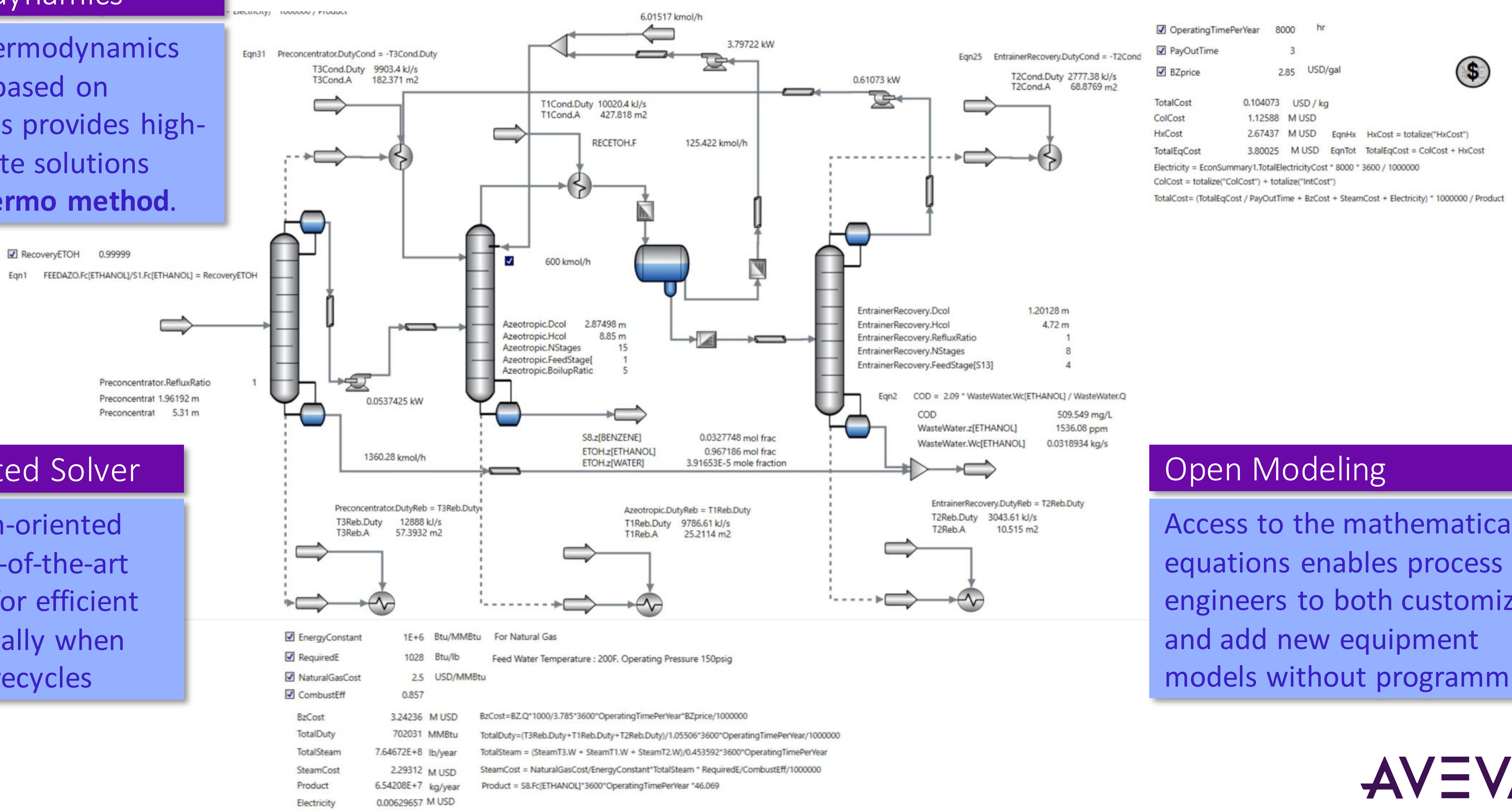
Simulation model with AVEVA Process Simulation

SimSci Thermodynamics

Proven SimSci thermodynamics and data import based on industry standards provides high-speed and accurate solutions with all major **thermo method**.



Equation-Oriented Solver

A robust equation-oriented solver using state-of-the-art numerics allows for efficient calculation especially when there are lots of recycles

Open Modeling

Access to the mathematical equations enables process engineers to both customize and add new equipment models without programming

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Model equations with AVEVA Process Simulation

- **Operation Cost**
  - Steam: \5222/10^6 kcal (Next Page)
  - Benzene : \2.85 USD/gal (2015 ICIS)
  - Operation time: \8000hr/year
- **Equipment Cost**
  - Pay out time : 3year
  - Column (Efficiency is assumed as 50%)
    - Material: SS
    - Column: $\$ = (957.904)\left(\frac{M\&S}{280}\right) H^{0.802} D^{1.066}\left(2.18 + F_m F_p\right)$
    - Internals: $\$ = (97.243)\left(\frac{M\&S}{280}\right) H^{1} D^{1.55}(F_s + F_t + F_m)$
  - Heat Exchanger
    - $\$ = (474.67)\left(\frac{M\&S}{280}\right) A^{0.65}(2.29 + (F_d + F_p)F_m)$

The **Total Annualized Cost (TAC)** is calculated as function of an annualized form of total capital cost and the total operating cost.

Cost escalation, interest, location factor is not considered here.

Baseline Results

- **COD:** 340.2 mg/L
- **TAC**: 0.14188 [USD/kg]
- **Product**: 6.5727e7 [kg/year]
- **Purity**: 0.99125 [molfrac]

Marshal and Swift Index [5] $(M\&S) = 1250 + 25(Year - 2005)$

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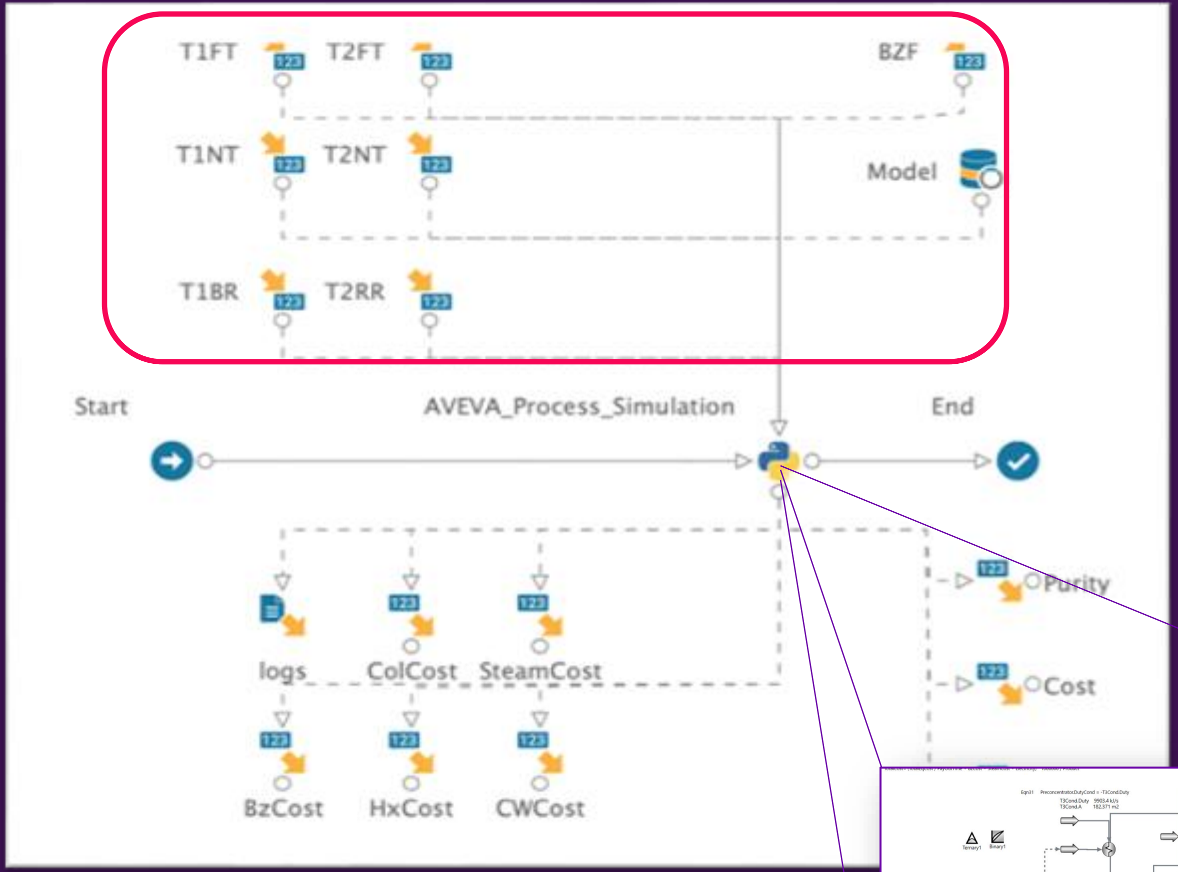
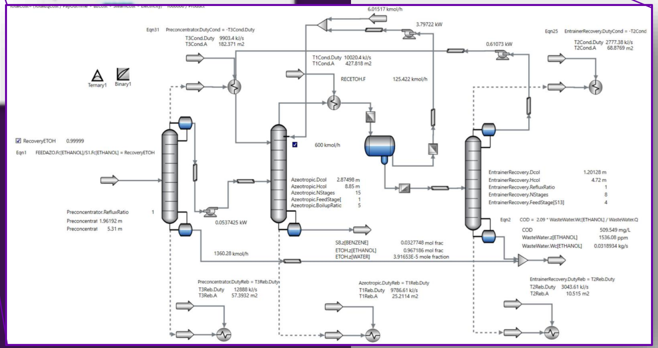
modeFRONTIER in a nutshell

The leading software solution for simulation process automation and design optimization.

Process Automation

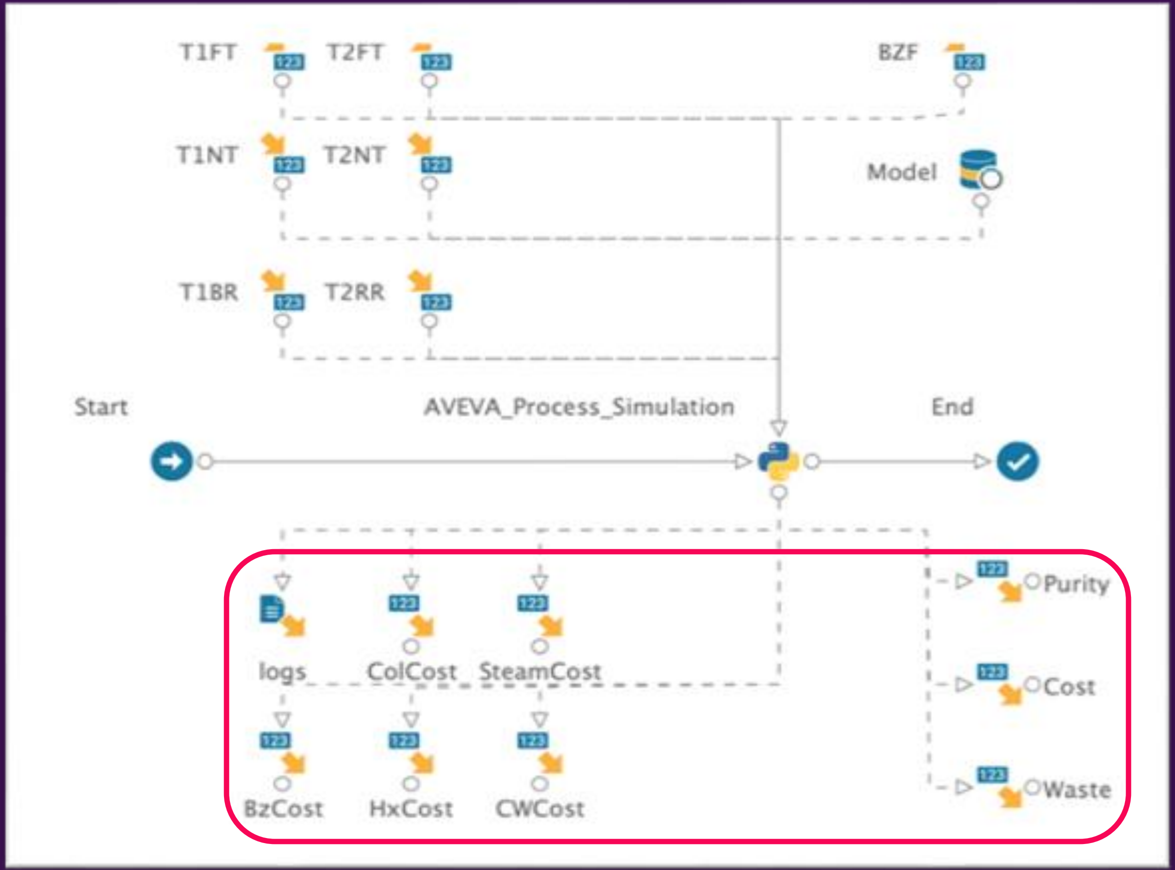




Design Variables

Name	Type	Value	Min	Max	STEP	Description
T1FT	V	3				Azeotropic column feed stage of recycle steam
T1NT	V	9	1	26	1	Azeotropic column total number of tray
T1BR	V	8	1	15		Azeotropic column boil-up ratio
T2NT	V	9	6	16	1	EntrainerRecovery column feed stage
T2FT	V	4	3	12	1	EntrainerRecovery column total number of tray
T2RR	V	1	1	8		EntrainerRecovery column reflux ratio
BZF	V	0.5	0.01	2		Entrainer flow rate [Kmol/hr]

Process Automation

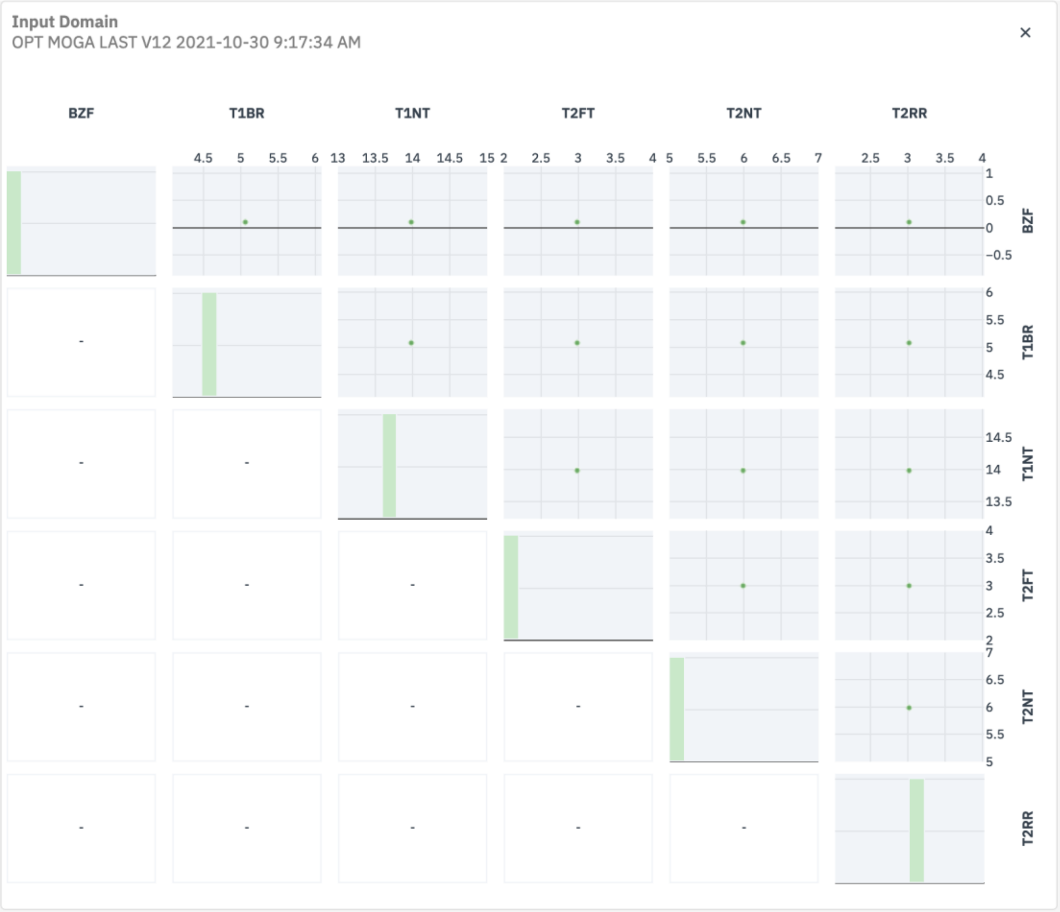


Design Conditions

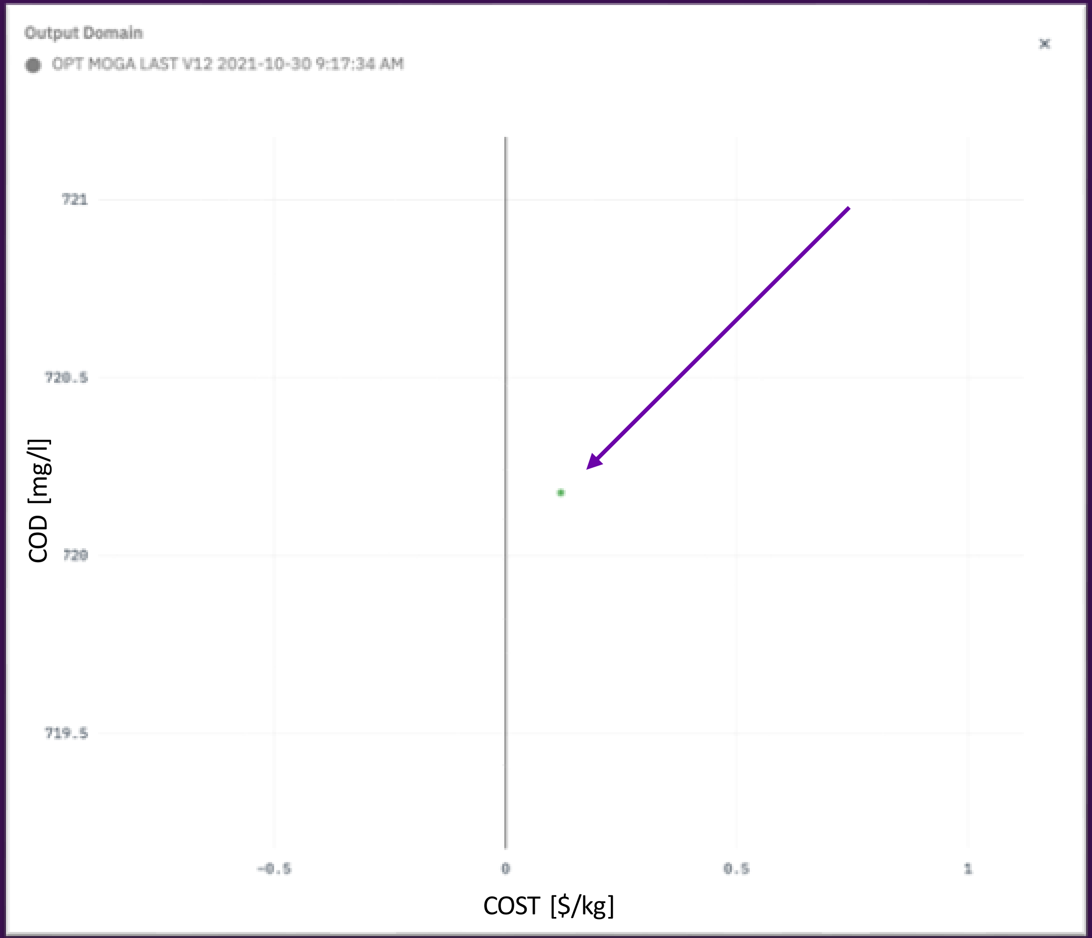
- **Constraint Condition**
  - Solved
  - Product Ethanol Concentration > 99 wt%
- **Objective Function**
  - TAC (Total annual cost))
  - Environmental Load (Ethanol concentration in the waste water)
- **Algorithm**
  - pilOPT -> 500 designs

Domain Investigation

Input Domain

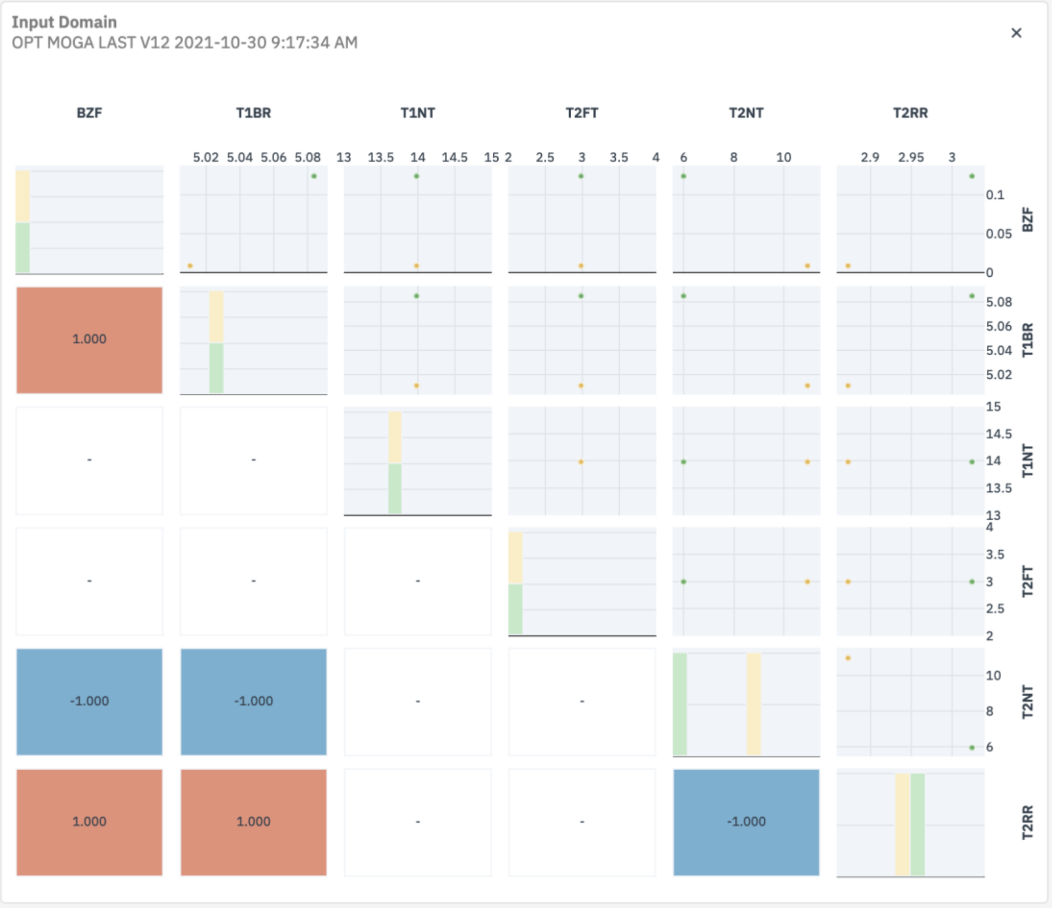


Output Domain

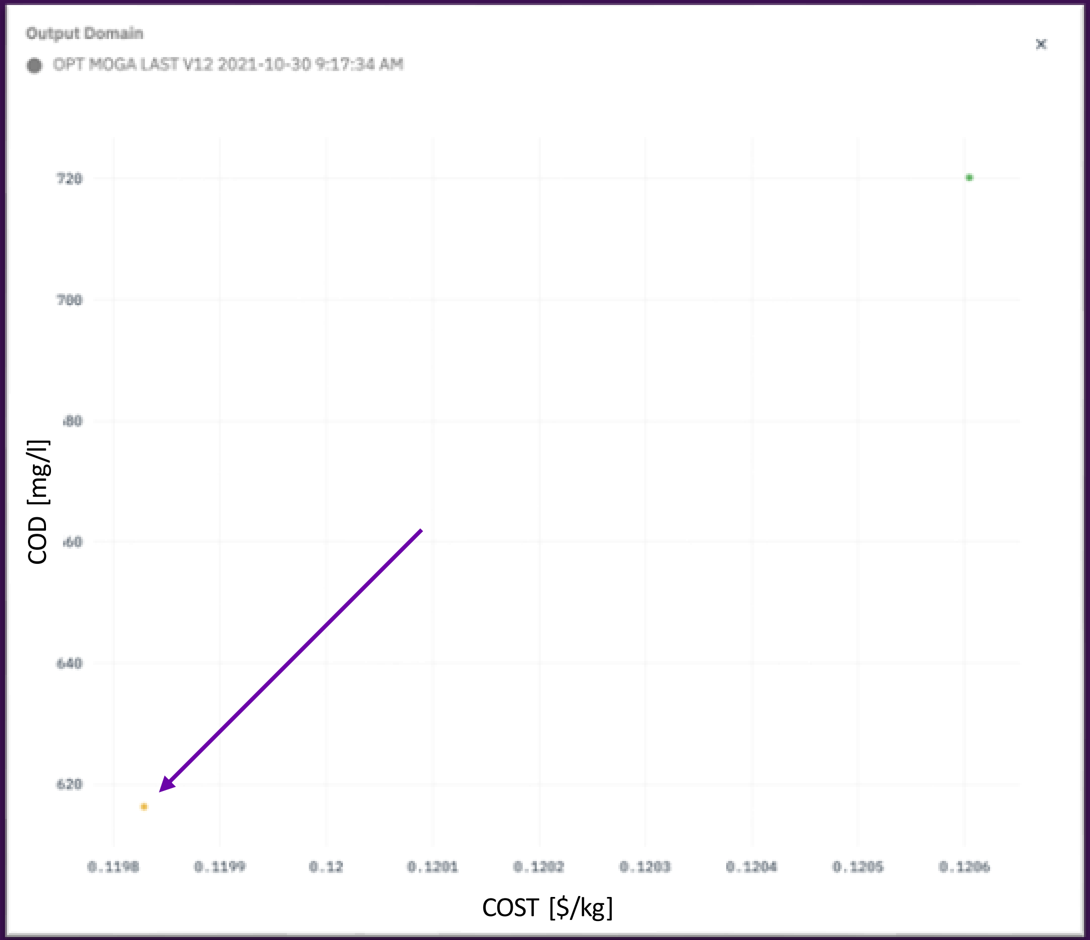


Domain Investigation

Input Domain



Output Domain



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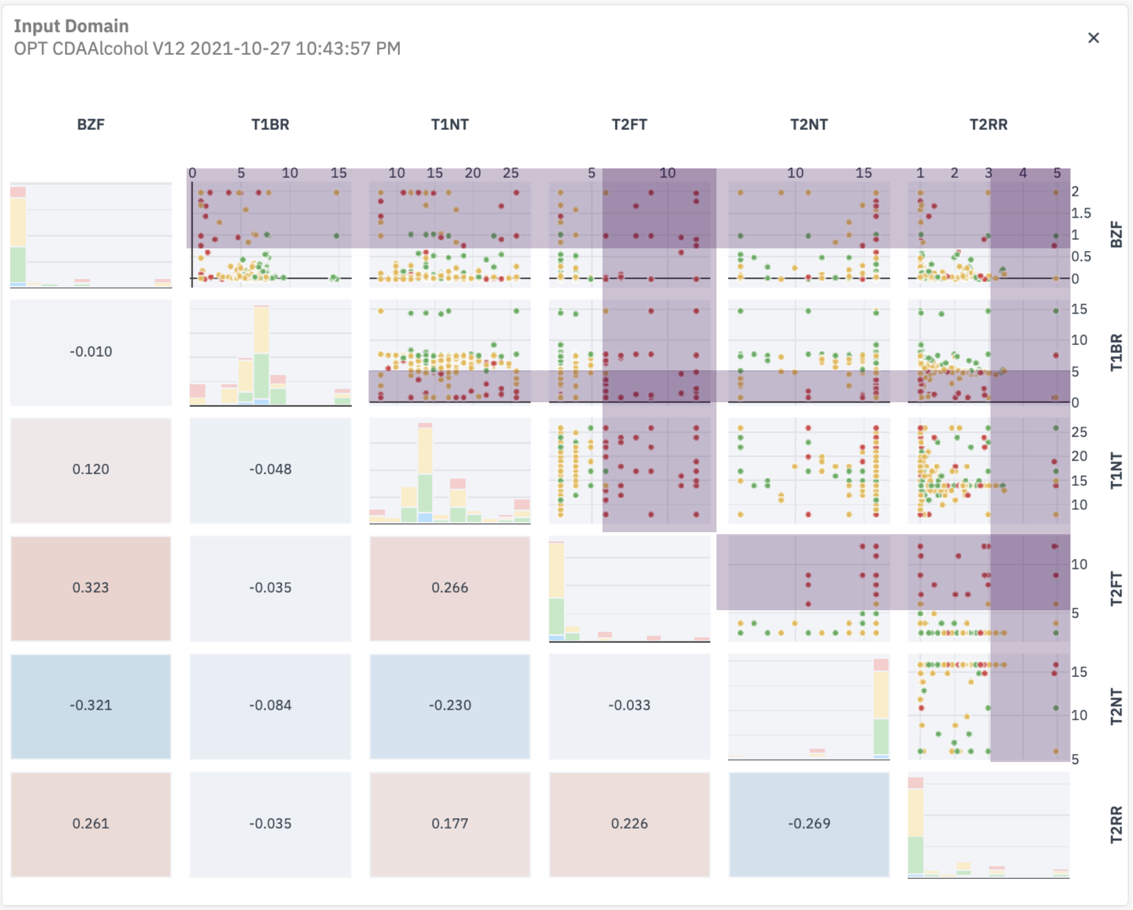
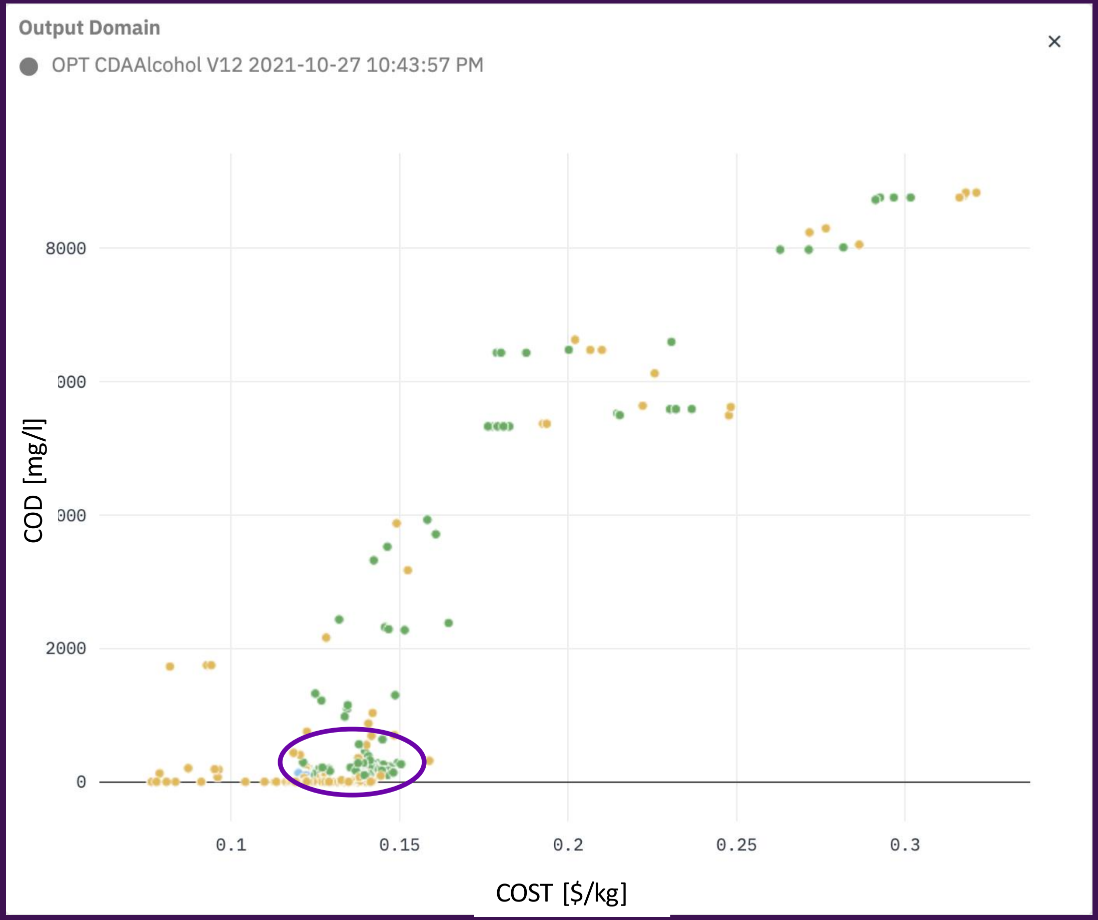
Domain Investigation

Input Domain



Output Domain



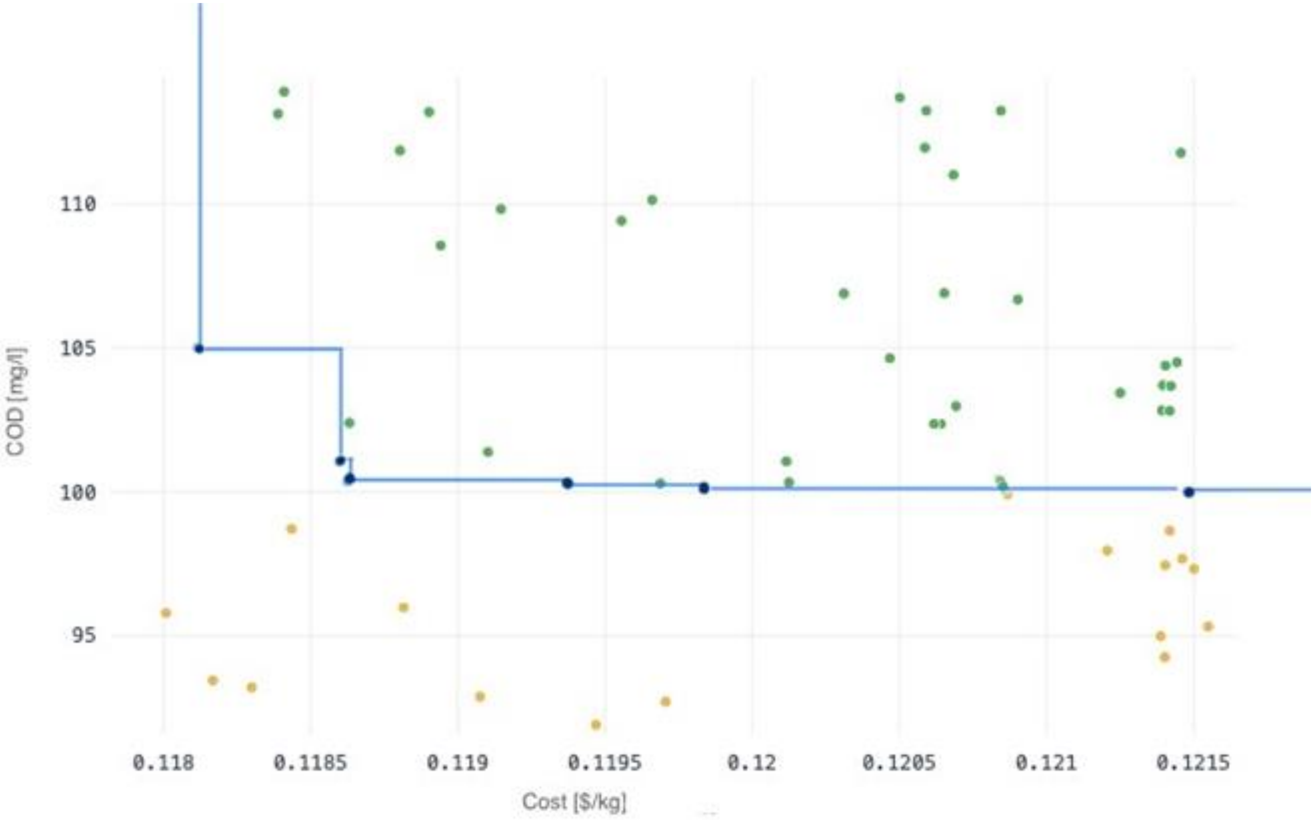
Genetic Algorithm

We used the MOGA-II algorithm to evaluate more 900 designs.

The Genetic Algorithm found 8 interesting designs on the Pareto Front.

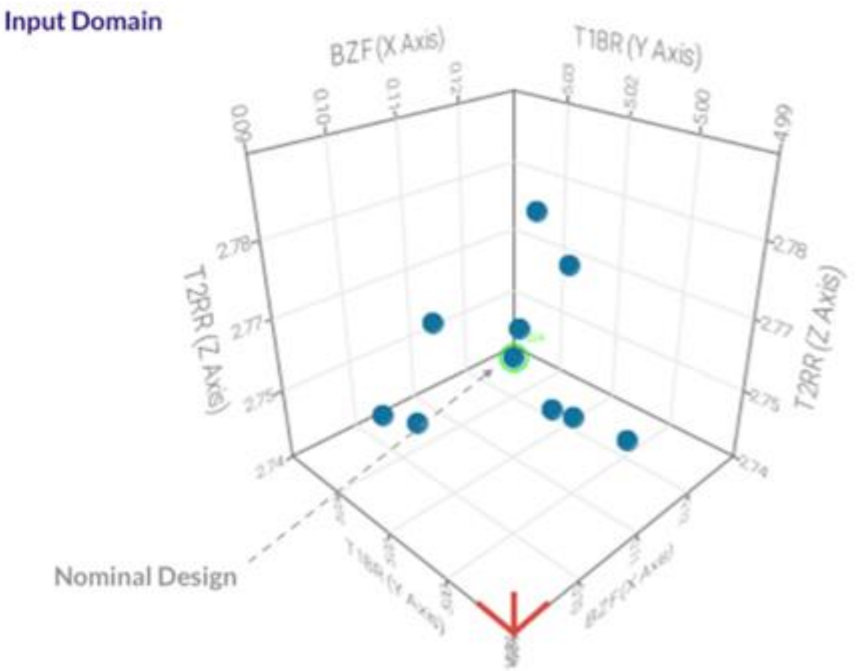
Plant performance is often determined by factors that are difficult to predict in the design stage. These factors, known as uncertainties, may include manufacturing errors, material property variation, or external conditions in which a given product is operated in real life.

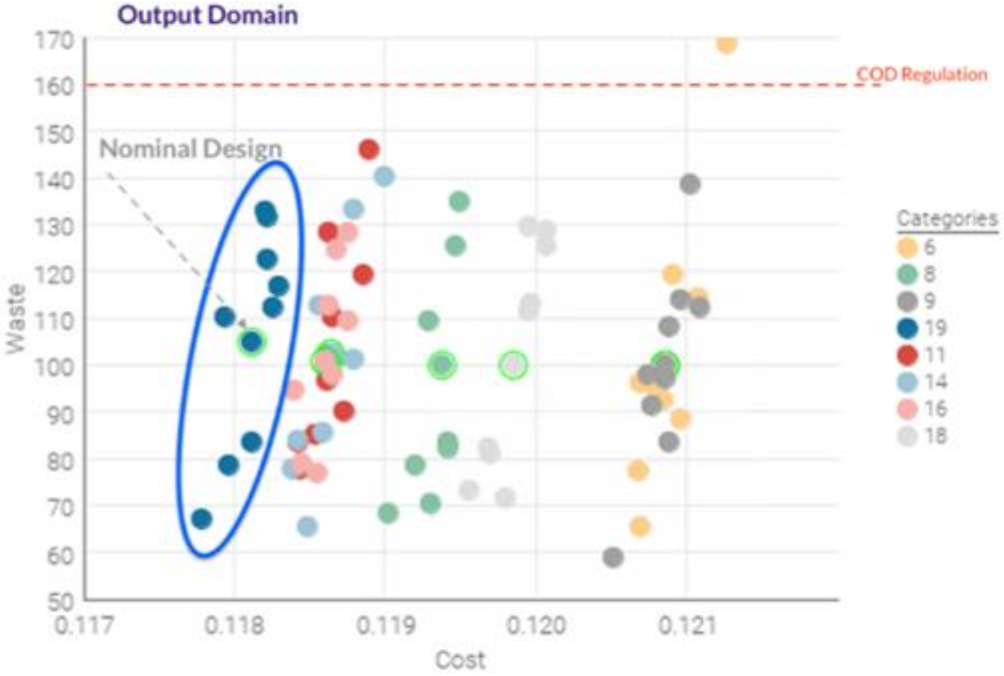
Robust analysis avoids opting for designs that perform well on paper but under-perform in real life conditions.



RID_CAT	BZF	T1BR	T1NT	T2FT	T2NT	T2RR	Cost	Purity	Waste
6	0.105301	5.01072	15.0000	3.00000	16.0000	2.85240	0.120857	0.997302	100.101
8	0.106813	5.01772	14.0000	3.00000	13.0000	2.76008	0.119377	0.991313	100.265
9	0.104266	5.01072	15.0000	3.00000	16.0000	2.85240	0.120849	0.997295	100.249
11	0.144902	5.01590	14.0000	3.00000	9.00000	2.77452	0.118632	0.992168	102.398
14	0.144902	5.01590	14.0000	3.00000	9.00000	2.77304	0.118624	0.992170	100.357
16	0.106813	5.01772	14.0000	3.00000	10.0000	2.76008	0.118597	0.991305	101.043
18	0.105321	5.01072	15.0000	3.00000	12.0000	2.85240	0.119840	0.997302	100.134
19	0.112385	5.01758	14.0000	3.00000	6.00000	2.75600	0.118116	0.991347	105.006

Robust Analysis





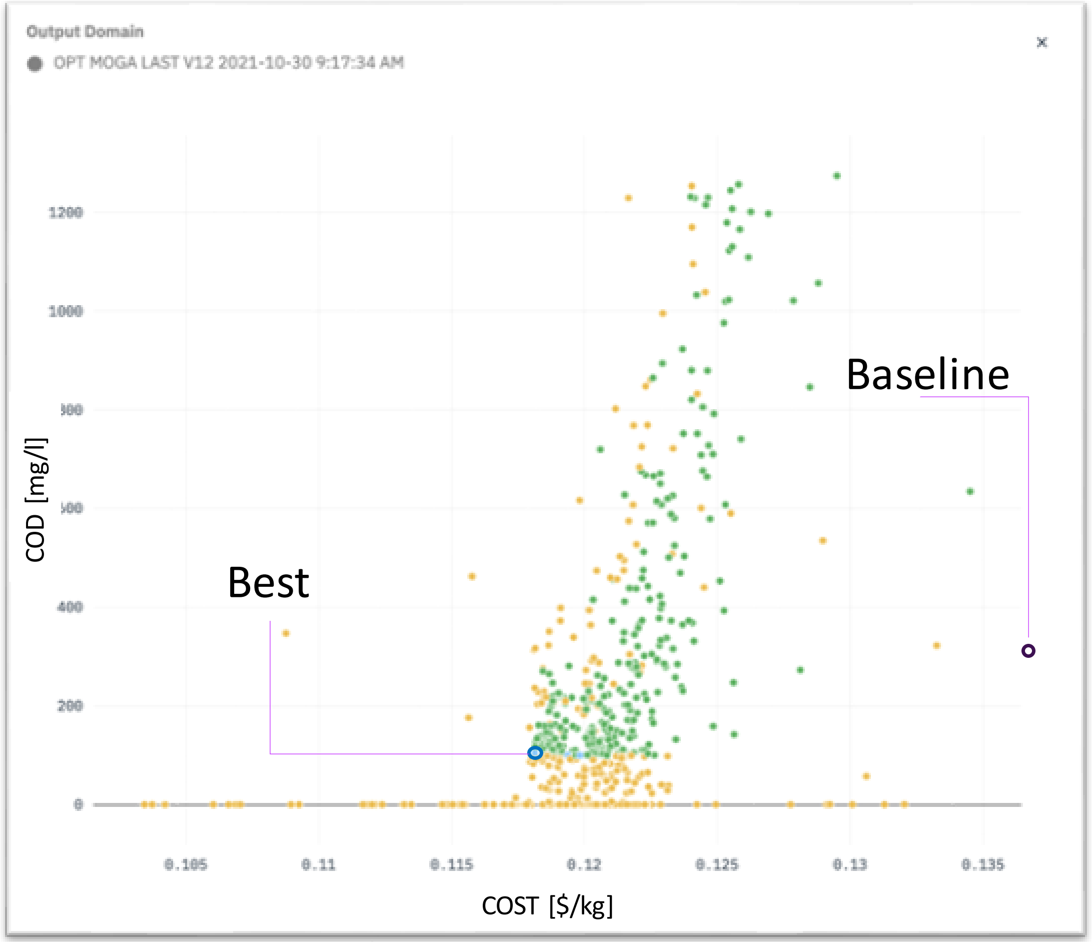
Normal Distribution

Cloud of points (fluctuations) generated with normal distribution around the nominal point.

Robust Design

The solution selected has the better Cost and not only the Nominal Point respects the COD regulation but also all the points that simulate fluctuations in the input.

Results



Comparison

Conclusions

- Using modeFRONTIER to analyze design simulations results from AVEVA Process Simulation gives some insights about the direction of the design and reduce the execution time of a parametric study thanks to its algorithms.

- modeFRONTIER® identified several good designs that satisfy constraints and reduce environmental impact and total annual cost (TAC)

- A probabilistic analysis helped to reject one of the eight designs present in the Pareto Front

- **Days of engineering work can be saved**

Questions?

Please wait for the microphone.

State your name and company.

Please remember to…

Navigate to this session in the mobile app to complete the survey.

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Thank you!

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Learn more at www.aveva.com

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