



Norwegian University of
Science and Technology

Digitalization, virtual measurements and digital twins in gas processing

Outline

- Gas Technology (TEP4185)
- The gas value chain
- Digital tools in teaching and for problem solving
- NeqSim – an open source process simulation tool developed at NTNU
- From a live process simulator to a process digital twin
- Future gas value chains

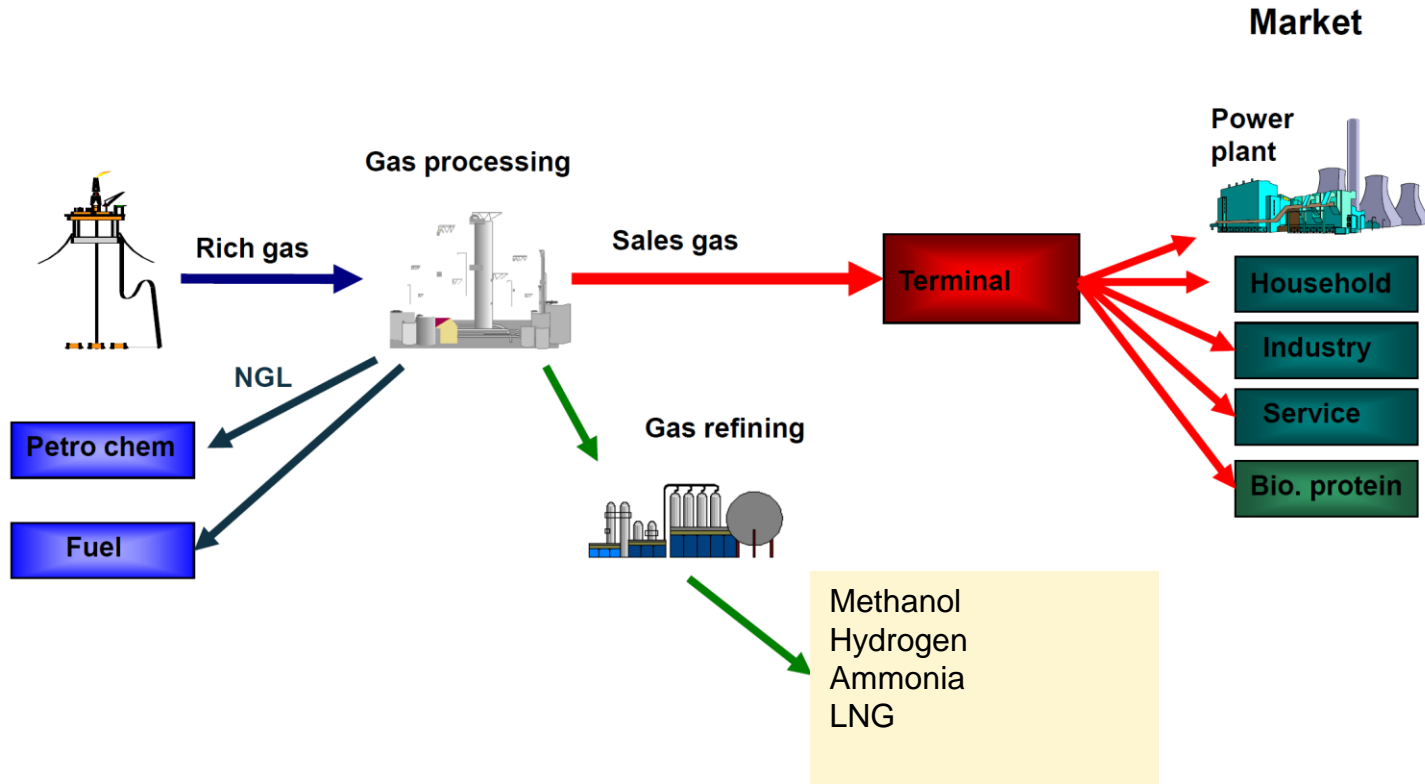
Gas Technology (TEP4185)

- Thermodynamics
- Process simulation
- Gas value chain
- Gas processing
- Power generation
- Hydrogen production
- CO₂ capture
- Cryogenic gas processing

TEP 4185 Gas Technology Updated 07.11.2022

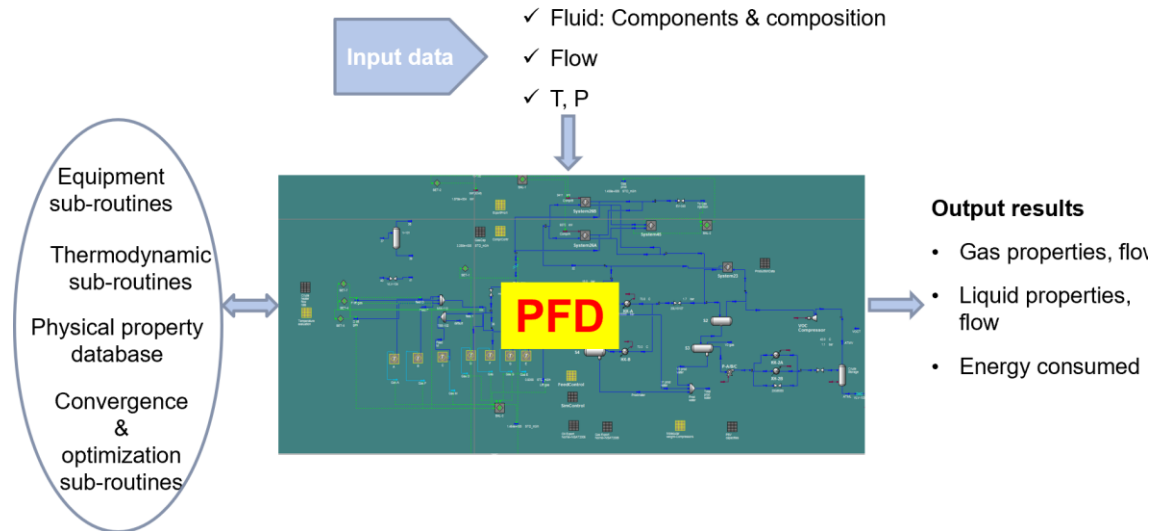
Date	Time	Type	Topic	Lecturer	Place
23.aug	10:15-12:00	Exercise	No exercise		R91
24.aug	13:15-16:00	Lecture	Information/outline/motivation Course outline and practical information	LN/ES/GM	EL1
26.aug	08:15-10:00	Digital exercise	No exercise		Blackboard
30.aug	10:15-12:00	Exercise	Python exercise P1	Vit.ass.	R91
31.aug	13:15-16:00	Lecture	Thermodynamics for gas technology Engineering thermodynamics important for gas technology	ES/LN	EL1
02.sep	08:15-10:00	Digital exercise	Python exercise P1	Vit.ass.	Blackboard
06.sep	10:15-12:00	Exercise	Computer Exercise CE1 - Getting started with HYSYS	Video, stud.ass.	R91
07.sep	13:15-16:00	Lecture	Process simulation primer Process modeling and simulation	LN/ES	EL1
09.sep	08:15-10:00	Digital exercise	Intro to exercise CE2 - Gas processing	ES	Blackboard
13.sep	10:15-12:00	Exercise	CE2 - Gas processing	Stud.ass.	R91
14.sep	13:15-16:00	Lecture	Gas Processing Gas value chain	ES	EL1
16.sep	08:15-10:00	Digital exercise	CE2 - Gas processing	Stud.ass.	Blackboard
20.sep	10:15-12:00	Exercise	CE2 - Gas processing	Stud.ass.	R91
21.sep	13:15-16:00	Lecture	Gas Processing Offshore processes	ES	EL1
23.sep	08:15-10:00	Digital exercise	CE2 - Gas processing	Stud.ass.	Blackboard
27.sep	10:15-12:00	Exercise	CE2 - Gas processing	Stud.ass.	R91
28.sep	13:15-16:00	Lecture	Gas Processing Onshore processes	ES	EL1
30.sep	08:15-10:00	Digital exercise	CE2 - Gas processing	Stud.ass.	Blackboard
04.okt	10:15-12:00	Exercise	CE2 - Gas processing	Stud.ass.	R91
05.okt	13:15-16:00	Lecture	Hydrogen production Overview and focus on reforming of natural gas	GM	EL1
07.okt	08:15-11:00	Exercise	CE2 - Gas processing	Stud.ass.	C201
11.okt	Group-wise	Presentation	CE2 - Presentation Gas processing	ES/Vit.ass.	C201
12.okt	13:15-16:00	Lecture	CO₂ capture Overview and focus on separation of CO ₂ with chemical absorption	GM	EL1
14.okt	08:15-10:00	Digital exercise	Intro to exercise CE3 - Power generation	Stud.ass.	Blackboard
18.okt	10:15-12:00	Exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	R91
19.okt	13:15-16:00	Lecture	Power generation Turbomachinery fundamentals	LN	EL1
21.okt	08:15-10:00	Digital exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	Blackboard
25.okt	10:15-12:00	Exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	R91
26.okt	13:15-16:00	Lecture	Power generation Gas turbine off-design operation. Gas turbine performance modeling.	LN	EL1
28.okt	08:15-10:00	Digital exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	Blackboard
01.nov	10:15-12:00	Exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	R91
02.nov	13:15-16:00	Lecture	Power generation Combined cycles	LN	EL1
04.nov	08:15-10:00	Digital exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	Blackboard
08.nov	10:15-12:00	Exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	R91
09.nov	08:15-11:00	Exercise	CE3 - Power generation	Stud.ass.	C201
09.nov	13:15-16:00	Lecture	Cryogenic gas processing	PN	EL1
11.nov	08:15-10:00	Digital exercise	Exercises P2, P3, CE3 - Power generation	Stud.ass.	Blackboard
15.nov	Group-wise	Presentation	CE3 - Presentation Power generation	LN/Vit.ass.	C201
16.nov	13:15-16:00	Lecture	Spare lecture		EL1
18.nov	08:15-10:00	Digital exercise	No exercise		Blackboard
22.nov	10:15-12:00	Exercise	No exercise		R91
23.nov	13:15-16:00	Lecture	Summary and Q&A for exam	ES/LN	EL1
25.nov	08:15-10:00	Digital exercise	No exercise		Blackboard

The Gas Value Chain



Use of digital tools in teaching and for problem solving

- Lectures are recorded via Panopto and available via course homepage in Blackboard ([23.11.2022](#))
- Exercise introduction are done online via Blackboard Collaborate
- Students learn to establish and run process simulations in HYSYS
- Python exercises ([P1](#)/[CE2](#))



NeqSim



NeqSim is a library for estimation of behaviour and properties of fluids. NeqSim is available for free use and distributed as open source under the Apache-2.0 licence.

News:

15/04/2022: Version 2.3.3 released

Contact project via [email](#)

[View the Project on GitHub](#)
[equinor/neqsimhome](#)

NeqSim - an open source process simulation software

NeqSim is a library for calculation of fluid behavior, phase equilibrium and process simulation. NeqSim can be used as a stand-alone tool via Excel or a web interface. It is integrated in computer programs via available interfaces in Java, Python, .NET, Matlab or in process simulators via the Cape Open interface. The basis for NeqSim is fundamental mathematical models related to unit operations, phase behaviour and physical properties of fluids. NeqSim is used for fluids such as oil and gas, carbon dioxide, refrigerants, hydrogen, ammonia, water and chemicals.

The original NeqSim web page is hosted at [NTNU](#)

NeqSim project in GitHub

The NeqSim library is written in the Java programming language. The source code and libraries are hosted in GitHub

- [NeqSim Java](#)

NeqSim toolboxes in GitHub

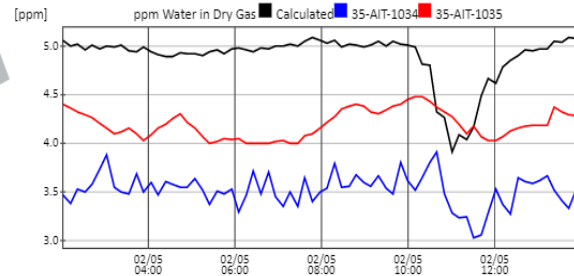
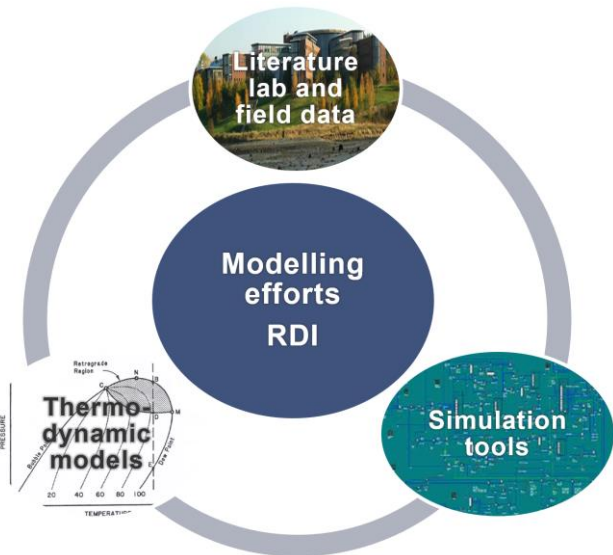
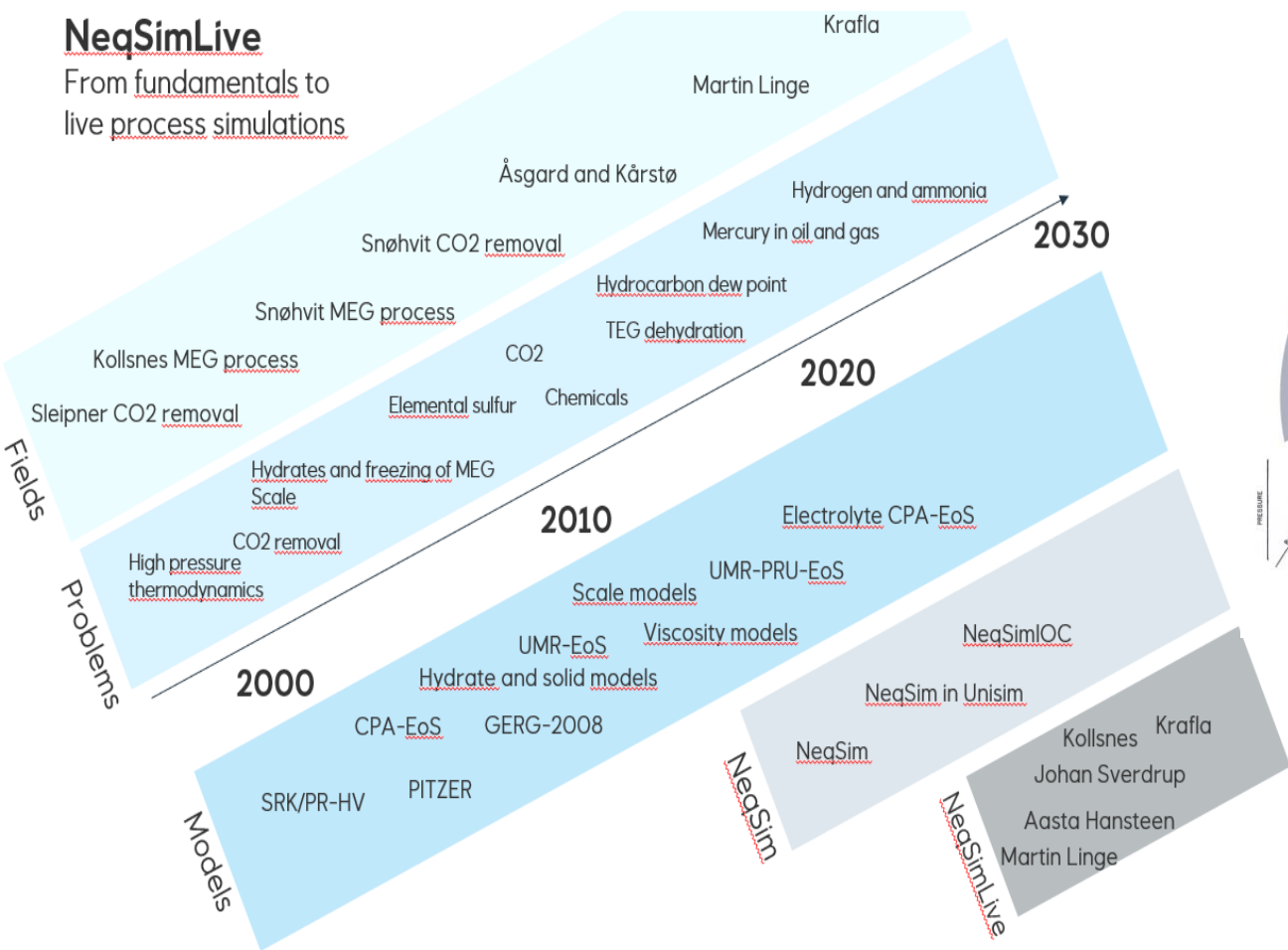
NeqSim toolboxes are available via GitHub for alternative programming languages.

- [NeqSim Matlab](#)
- [NeqSim Python](#)
- [NeqSim .NET](#)
- [NeqSim Excel/Cape-Open](#)

Code development and maintenance in GitHub

NeaSimLive

From fundamentals to live process simulations



Use of NeqSim as a process simulator in Python

Introduction to gas processing in Python

colab.research.google.com/github/EvenSol/NeqSim-Colab/blob/master/notebooks/examples_of_NeqSim_in_Colab.ipynb

examples of NeqSim in Colab.ipynb

File Edit View Insert Runtime Tools Help

+ Code + Text Copy to Drive

Introduction to Gas Processing using NeqSim in Colab

NeqSim (Non-Equilibrium Simulator) is a library for calculation of fluid properties and process simulation. Colaboratory (Colab) is a free Jupyter notebook environment that requires no setup and runs entirely in the cloud. In the notebooks listed in this page you will find examples of typical gas processing calculations using NeqSim in Colab, and will serve both as introduction to natural gas processing and to interactive use of NeqSim in a Python based notebook. The notebooks serves as a theoretical introduction and as a simulation tool for many processes found in the gas industry.

This module gives an interactive introduction to gas processing using NeqSim and Colaboratory. The notebooks use the NeqSim package in Python and calculations are run directly from the web browser (by selecting Runtime and Run all in the main menu). The user will need to log on using their google account. To learn more about Colab see the [Welcome To Colaboratory page](#).

Learn to use NeqSim in Colab and contribute with new material

Users are welcome to contribute with their own NeqSim Colab pages. [This template](#) can be used as a basis for a new notebook. An introduction to how to use Neqsim in Colab is given in [this page](#). A Python script as basis for a notebook can be seen and modified by right clicking a form and trigger show code. All Colab notebooks are stored in an open [GitHub repository](#).

Comments and request for new content

Please use the [discussion forum](#) to comment and discuss the topics covered in this tool. Users can request new content or suggest improvements by [reporting an issue](#).

Table of Contents

Fundamentals of NeqSim

- [How to create a fluid in NeqSim](#)

Natural Gas Statistics

- [Natural gas and the World Energy Outlook](#)
- [Use of natural gas \(history, present and future\)](#)
- [Natural Gas in the Energy Transition \(2021-2050\)](#)

```
chokeValve = valve(wellFlowLine.getOutputStream())
chokeValve.setOutletPressure(inputdata['firstStagePressure'], 'bara')

feedToOffshoreProcess = stream(chokeValve.getOutputStream())
feedToOffshoreProcess.setName("feed to offshore")

firstStageSeparator = separator3phase(feedToOffshoreProcess)
firstStageSeparator.setName("1st stage separator")

oilHeaterFromFirstStage = heater(firstStageSeparator.getOilOutputStream())
oilHeaterFromFirstStage.setName("oil heater second stage")
oilHeaterFromFirstStage.setOutletTemperature(inputdata['temperatureOilHeater'],'C')

oilThrotValve = valve(oilHeaterFromFirstStage.getOutputStream())
oilThrotValve.setName("valve oil from first stage")
oilThrotValve.setOutletPressure(inputdata['secondStagePressure'])

secondStageSeparator = separator3phase(oilThrotValve.getOutputStream())
secondStageSeparator.setName("2nd stage separator")

oilThrotValve2 = valve(secondStageSeparator.getOilOutputStream())
oilThrotValve2.setName("valve oil from second stage")
```

Figure: Example of a NeqSim Process model in Python

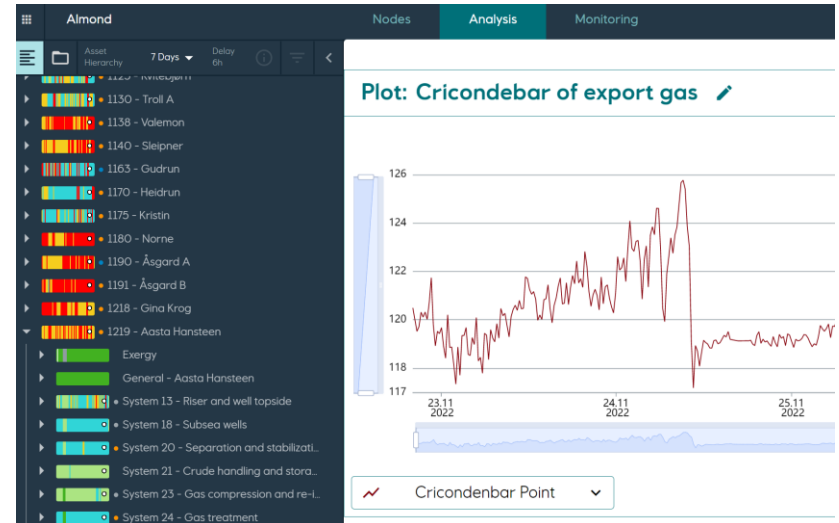
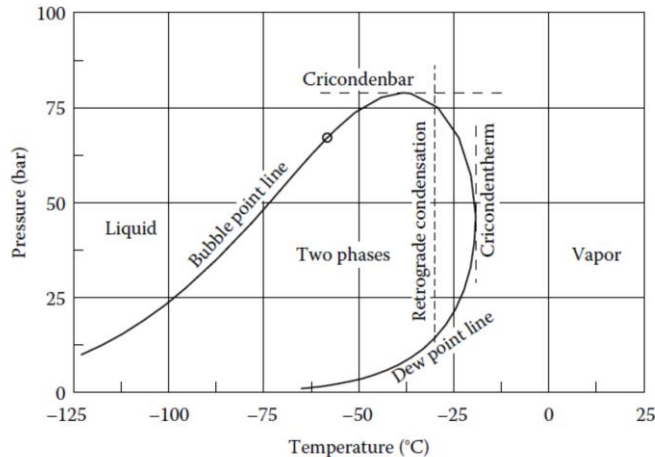


NTNU

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Science and Technology

Development of a Live Process Simulator

1. Validation of process simulation models
2. Tune process model to historic field data
3. Implement machine learning to improve the digital twin (hybrid models)
4. Company integrates model (API based) into its live monitoring tools



Applications of a live process simulator

- Basis for the process digital twin
- Virtual measurements
- Performance monitoring
- Live energy optimization
- Process maintenance planning
- Data validation and sensor reconciliation

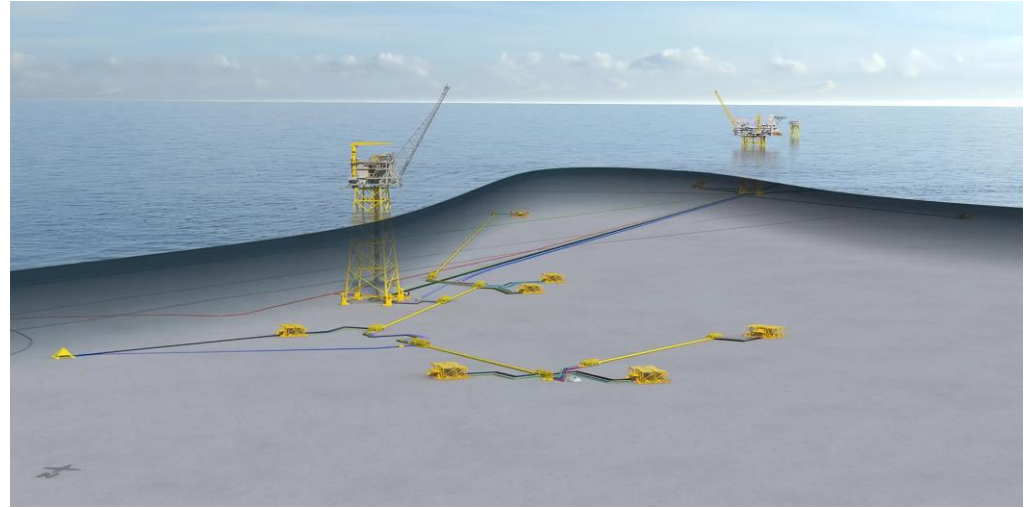
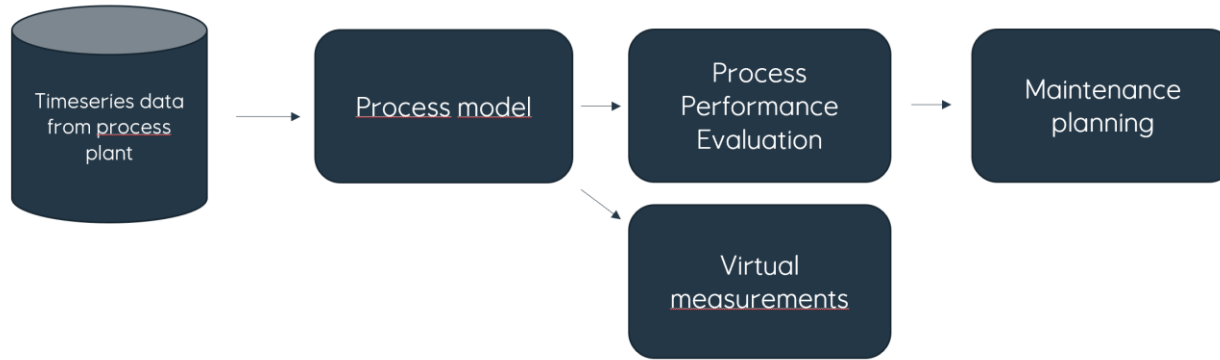
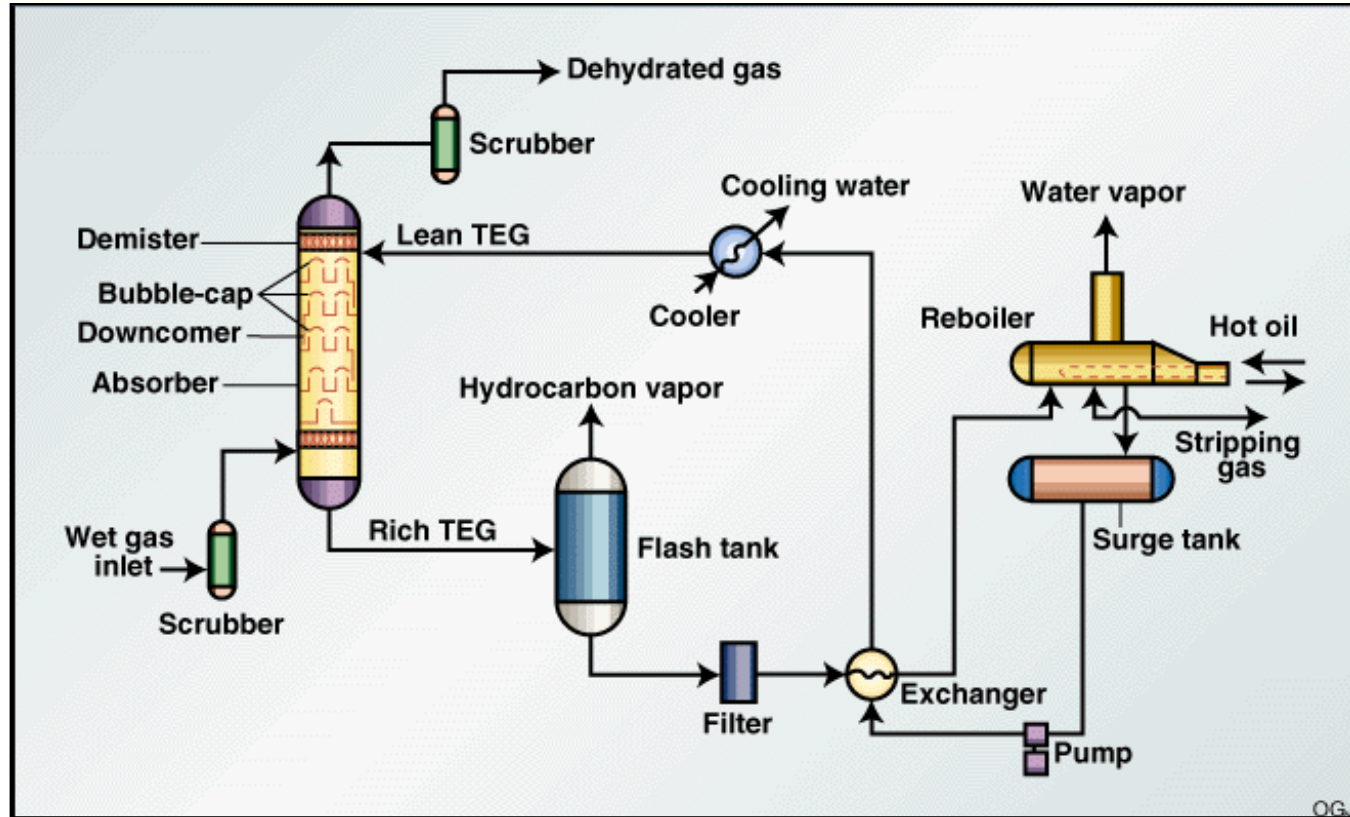


Figure: The Krafla field development

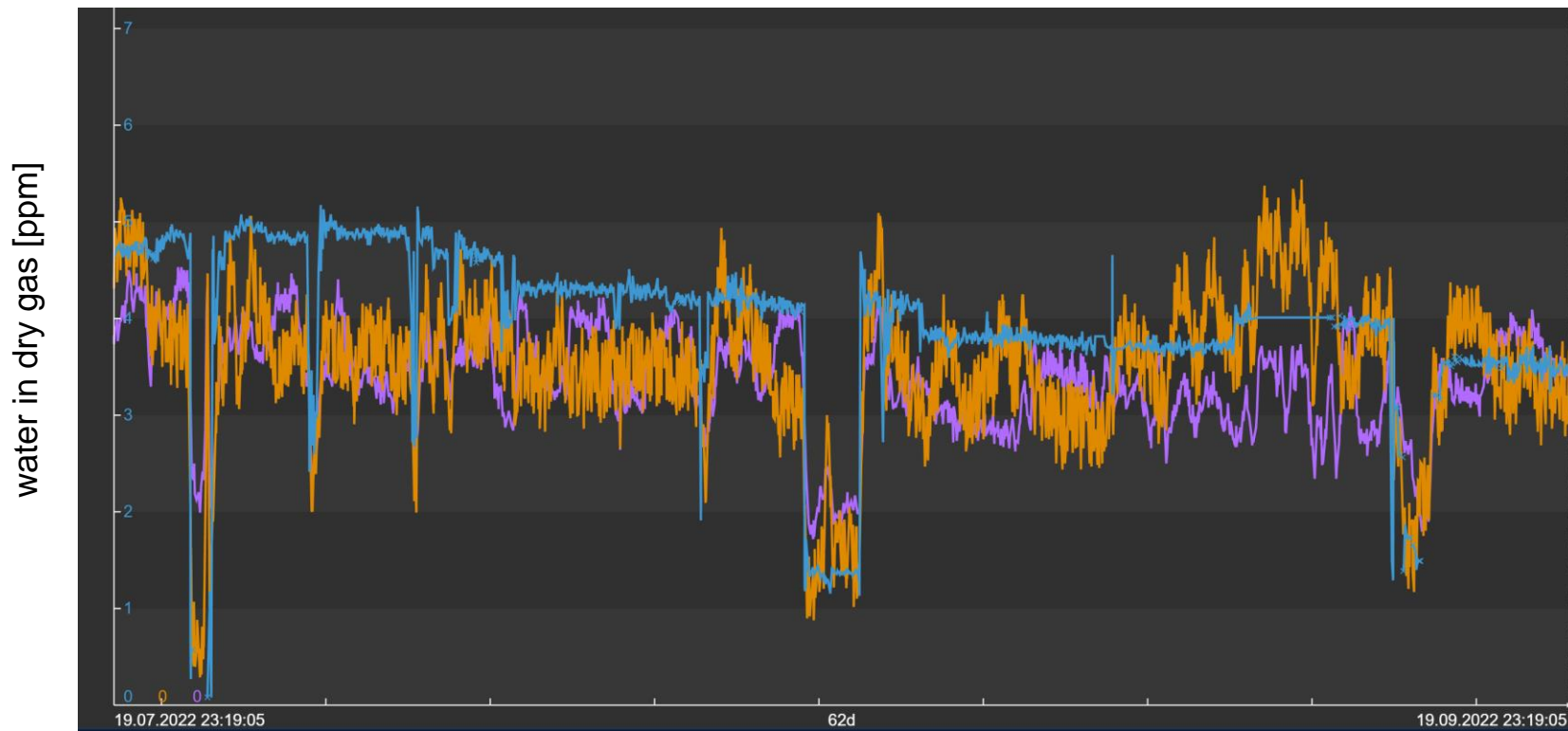
The NeqSim Digital Twin for Gas Processing



Process monitoring of a TEG dehydration process



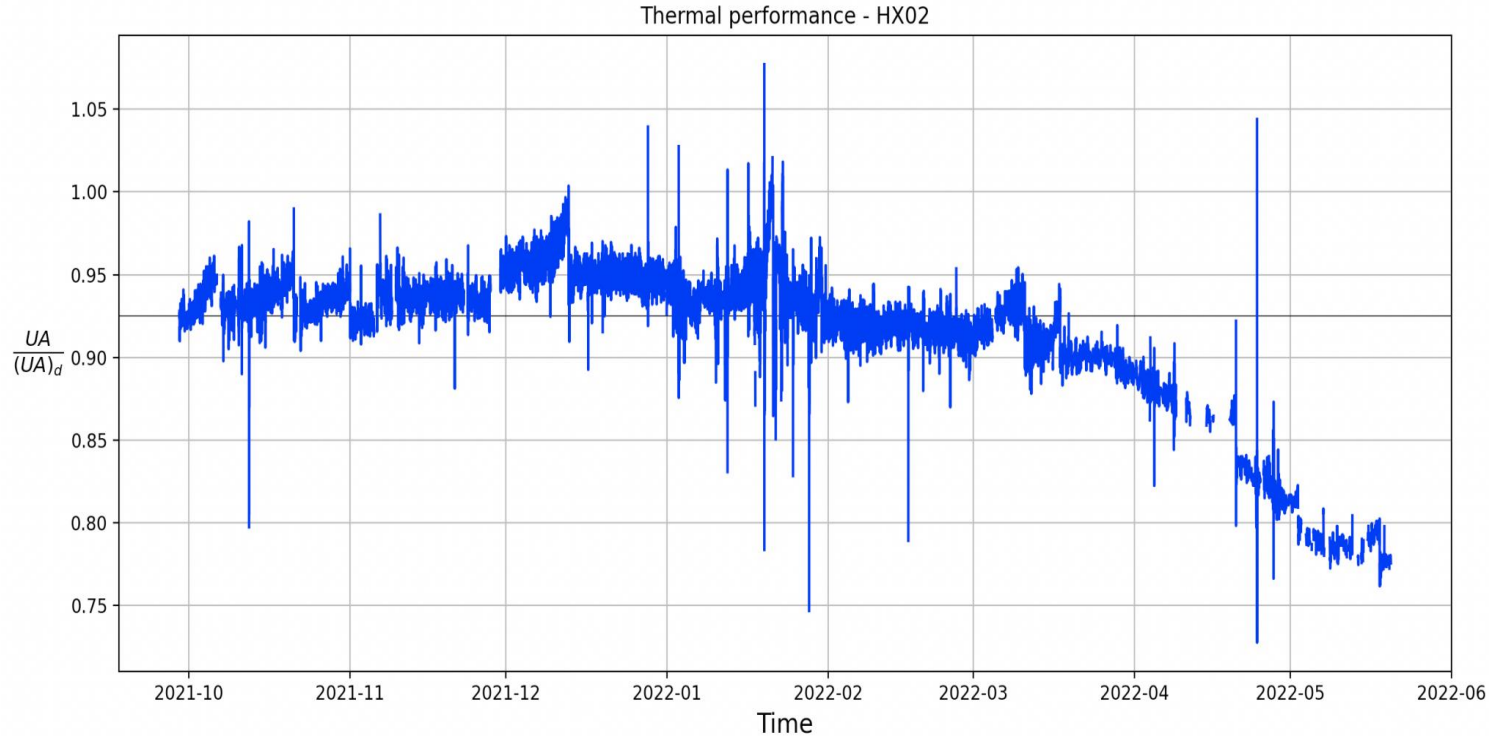
Virtual measurement of water in dry gas



Blue: process simulator

Orange and purple: instrument1/instrument2

Performance monitoring of heat exchangers



Y-axis: relative performance of heat exchanger

Future gas value chains

