# UNVEILING IMPACT

## How Industrial Software Advances Net-Zero Ambitions

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# Foreword

> *Our objective is to lay the foundation for a new sustainability impact assessment methodology, aimed at facilitating the quantification potential for digital solutions to unlock combined sustainability and economic KPI gains.*

## Lisa Wee
## Global Head of Sustainability, AVEVA

The pathway to achieving net-zero emissions by 2050 is narrow: it requires unprecedented transformation of the industrial sector, which currently accounts for more than 25%[1] of emissions worldwide. As a global software pioneer, AVEVA is determined to lead by example to combat climate change. We are proud to have been amongst the first 50 global companies to have our net-zero commitment validated by the Science-based Targets Initiative (SBTi). In parallel to working towards ambitious interim targets, which include halving our Scope 3 emissions by 2030, we strive to help our industrial customers deliver their own sustainability commitments.

AVEVA software is uniquely positioned at the nexus of the digital transformation and the energy transition. The combination of recent tensions in the energy market, post-Covid shortages in supply, and an increasing focus on sustainable production have created a challenging environment for many industries. Business continuity and commercial agility both demand the rapid identification of efficiency and sustainability measures, plus the widespread implementation of associated plans across all operational assets. Such an approach enables companies to meet their short-term needs while progressing towards long-term net-zero goals. AVEVA's software can support and help accelerate these achievements.

In an effort to build a quantitative understanding of the impact of industrial software and how it empowers our customers, AVEVA has partnered with Capgemini Invent to engage selected companies across three key industrial sectors. Our objective is to lay the foundation for a new sustainability impact assessment methodology. Aimed at facilitating the quantification potential for digital solutions to unlock combined sustainability and economic KPI gains, we expect to continue to refine this new model over time. We are excited to work with the customers who have already joined us on this journey and whose stories are detailed in this paper. We hope that you will find their success stories of interest and welcome opportunities for further dialogue and collaboration on this topic. Together, we are committed to helping accelerate the overall positive impact of digitalization for industries worldwide.

# Executive summary

> *Industrial software can help companies optimize operations and boost efficiency, reducing their environmental impact and driving enterprise sustainability goals.*

## Nicolas Clinckx
## Head of Manufacturing, Capgemini Invent, France

At a moment defined as a "polycrisis" with accelerating energy costs, geopolitical disruption, and systemic climate change, industries are facing a dilemma: they must drive commercial agility while moving towards net zero. Meeting these twin requirements is far from easy – ensuring growth while radically accelerating the decarbonization of facilities in line with a 1.5°C future scenario can appear to be a conflict. Achieving ambitious emission reduction goals is even more challenging when faced with tightening economic margins and energy insecurity.

In this complex environment, industry leaders are looking for win-win solutions that unlock both environmental and performance benefits. By optimizing operational efficiency, many industries have identified ways to improve their environmental performance.

Efficient and reliable facilities, traceable, high-quality production; and optimized processes lead to lower energy consumption, less waste, and more efficient supply chains and materials use. Together, such operational efficiency also means lower greenhouse gas (GHG) emissions, more responsible use of natural resources, and financial savings on top.

Industrial software can help companies optimize operations and boost efficiency, reducing their environmental impact and driving enterprise sustainability goals. By unifying data from across an enterprise or value chain, and combining it with sector-specific AI, industrial software can track, analyze, and model operations. Subject matter experts can then build more accurate models, indicators, and targets, and make more accurate decisions in real time.

In some sectors, this AI-enhanced, data-centric approach is also facilitating the development of new circularity models and driving efficiency throughout global supply chains.

Despite numerous individual examples, there is no agreed benchmark for measuring carbon reductions associated with industrial software across industries. In part, this is because while industrial software is key to enabling sustainability strategies, it is part of the overall solution, which encompasses new working practices, different processes, and often new hardware. Despite this systemic network, the aim of this paper is to make a start on calculating and providing a benchmark or yardstick to measure software's sustainability impact.

# Industries Leading the Way to a Sustainable Future

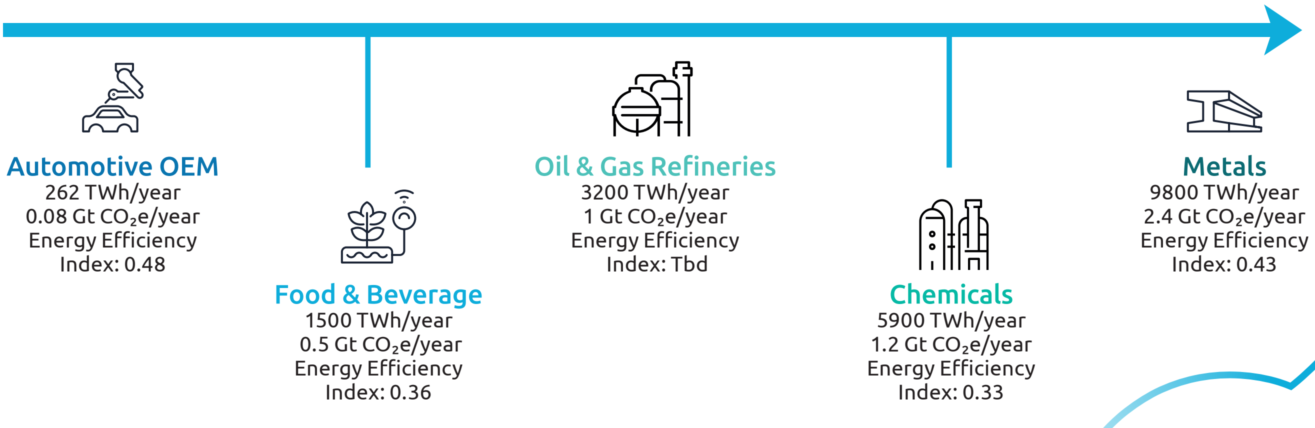



*Figure 1: Energy efficiency and emission levels by sector* [2]

To help organizations better understand the potential of industrial software to advance their sustainability KPIs, AVEVA partnered with Capgemini Invent to build an innovative modeling methodology for impact analysis informed by use cases from three industries. The industries were selected based on the potential improvement in energy efficiency and decarbonization: Chemicals, Oil and Gas, and Manufacturing (including Food and Beverage and Life Sciences).
The work leverages standard industrial KPIs (e.g., Overall Equipment Effectiveness/OEE, failure rate and yield) and available greenhouse gas accounting guidelines. It is therefore adapted to the industrial software deployment context. More details on this methodology are available in the appendix of this paper and key findings from the three focus industries are summarized below:

- **Chemicals:**
  With the support of new processes, the chemicals industry is striving to evolve in a way that enables circularity. In this context, several companies are using process simulation and integrated plant data combined in digital twins, which are digital representations of a real-world scenario. The initial purpose of the digital twin is to enable engineers to evaluate different design options faster. Using the cloud-based simulation platform, process and control engineers can collaborate better and benefit from a complete view of operations and emissions. Together, they can model scenarios and evaluate the overall emissions impact, enabling them to select the design with the lowest carbon output. Using this approach, we found organizations have achieved reductions of between 19-30% in distillation column design, with 30% lower flaring.

  The benefits of this digital approach extend beyond the design phase. Process simulation insights can be used to troubleshoot operations and improve energy and material efficiencies while the plant is operating. Even small operational adjustments can lead to significant savings.
  A case study of the Dimethyl Ether process model (presented later in this paper) suggests that fine-tuning distillation reflux ratios can save up 14,000 tons of CO2 equivalent (tCO2e) per year and 56 GWh of energy consumption.

- **Manufacturing:**
  Leading manufacturing companies need to advance efficiency while delivering on sustainability promises to their customers and keeping costs low. Here, combining data across the production and supply chain in an AI-enhanced manufacturing execution system is proven to improve quality and product traceability while driving materials efficiency.
  Additionally, this approach can drive eco-efficiency, both in terms of energy used in the plant as part of production execution processes, and yield and resource allocation. By tracking products from raw materials to finished goods and optimizing equipment efficiency, teams have cut energy use by up to 20%. This is highlighted in a life sciences plant case study presented in this paper: it suggests savings of 10g CO2e per unit production.

- **Oil and Gas Refining:**
  For energy companies, decarbonization and energy security are pressing priorities that must be handled in tandem. Several use cases are presented in this paper that relate to overcoming this two-pronged challenge, each one with its own individual modeling approach. Firstly, rigorous optimization throughout the value chain can cut energy and water use, reduce emissions and ensure throughput. To ensure positive impact, the optimization model must be based on first-principles rigorous models and span across processes and utilities operations. Analysis performed in this study suggests 12 kilotons (Kt) of $CO_2e$ in annual savings could be achieved by optimizing the energy-intensive cracking and distillation units in a 120kbd refinery. Secondly, companies can use Machine Learning (ML) to better leverage asset performance data and develop agile predictive maintenance strategies that avoid failure of critical equipment. For oil and gas facilities, equipment failures can result in some of the most significant, negative energy and emissions impact scenarios. A case study with an Asian refinery suggests that avoided compressor failures could reduce emissions by as much as 199 $tCO_2e$ at equipment level.

## Final Thoughts

The findings in this report are exciting, yet they represent only a start to a deeper process of enquiry and analysis. Please contact sustainability@aveva.com if you are interested in participating in further sustainability impact analysis work or would like to share your own learnings in this area. We see ongoing research and collaboration in this domain as key to continuously enhancing the sustainability benefits of the industrial software ecosystem. Over time, we also expect more standards to be established to regulate related measurement, analysis, and reporting. A stronger dialogue between software providers and the industrial community on credible approaches to sustainability impact calculations will be key to staying ahead.

# 1.0. OPENING TWO DOORS WITH ONE KEY

# 1.1. Software as a Win-Win for Sustainable and Profitable Business

Efficiency is all about doing the same or more with less. For industrial companies, this means maintaining and even improving output with less raw materials, energy, and waste. Naturally, such optimized performance is inextricably linked with environmental benefits. This is what makes industrial software solutions so exciting for champions of sustainability. By optimizing performance, such software can profoundly improve an industry's relationship with the natural world. Efficient equipment, better production quality, and improved equipment reliability trigger lean methods to reduce waste, consume less energy, and use less raw materials.

### Software Needs No Hard Sell

Traditionally, critics of industrial practices have focused on the machinery. For a long time, this was a justifiable criticism. However, advances in hardware have furnished plants with next-generation equipment that is both more reliable and much less energy-intensive. Yet, there is still much to do to ensure industries maintain their trajectory for net zero.

This is where software comes in. It picks up where hardware leaves off, becoming a key lever to connect insights and augment decisions. As a result, companies can optimize operations and boost efficiency, thus reducing environmental impacts of industrial activities and driving enterprise sustainability goals.

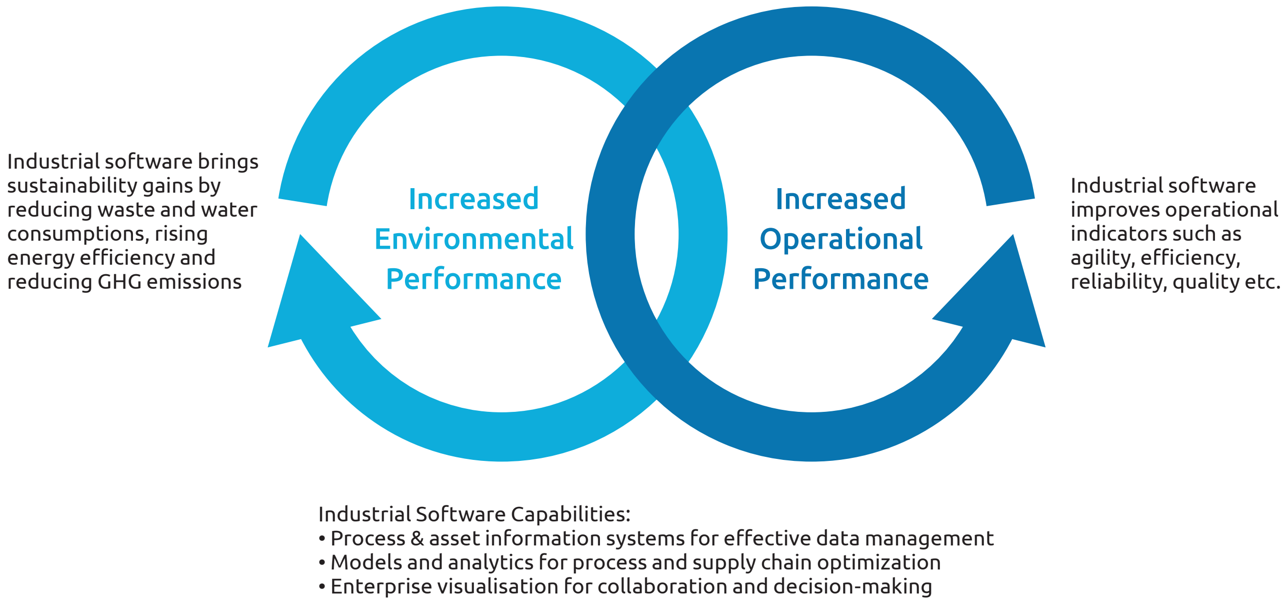



*Figure 2: Industrial Software capabilities and their interconnected effects on the environment and performance*

Industrial software can be leveraged to track, analyze, and act on emission intensity and resource utilization, which is a first step in the sustainability journey. A comprehensive view of operations facilitates indicator definition, standard setting, and target making. This three-step approach is pivotal to sustainable transformation. Only a data-driven holistic view can inform sound decision-making, empowering leaders to improve efficiency, optimize resource consumption, and reduce emissions and waste in real time. Moreover, new technologies are essential for the implementation of circular practices (e.g., product design and supply chain transformation).

# 1.2 Sustainability Use Cases for Industrial Software

## Reprogramming Operations with Ease

This report will estimate the impact industrial software has on efforts to unlock the benefits of sustainability, focusing on several use cases involving AVEVA software in the industrial context. Use cases have been selected according to their potential environmental impact, business criticality, and data accessibility. The focus is on how they are leveraged by users to improve sustainability performances in **Process Design, Operations Executions,** and **Asset Performance Prediction.**

According to recent business and IT energy efficiency projects, it is best practice to always start with a robust data infrastructure. From here, companies can systematically and continuously gather real-time data that reflects the pulse of their operations. Next, various applications and systems are aggregated to provide an overview of cross-functional value chain performance and outcomes.

This aggregation can be shown in a unified operations center, which is where enterprise visualization helps customers collaborate more effectively.

## Key use cases explored in this study:

- **Process Design**
  Process Simulation is used to build digital twins of processes for the industrial plant.
  This model can be used to facilitate design optimization. Moreover, it can be used online with a connection to real-time data, turning the design into a “living twin” and optimizing the operation.

- **Operations Execution**
  **Manufacturing industry**
  Operational excellence depends on the manufacturing system’s link to real-time data from the production lines. OEE is the most important KPI to drive improvement across availability, utilization, and quality.

  **Process Industry**
  Optimization based on rigorous first-principles models starts by reconciling the snap shots of real-time operational data.
  And then, it generates the optimum operating conditions, which augments operators’ decision with the best economic and environmental balance.

- **Asset Performance Prediction**
  Asset health is key to ensuring efficiency and reliability.
  Potential failures are identified way before they occur with historical data gathered and analyzed by advanced analytics. Through early notifications generated by predictive analytics, the maintenance team can take action in advance to avoid unplanned shutdowns and the respective impacts to the environment: additional emissions, rework and waste, plus potential accidents that could lead to higher damages.

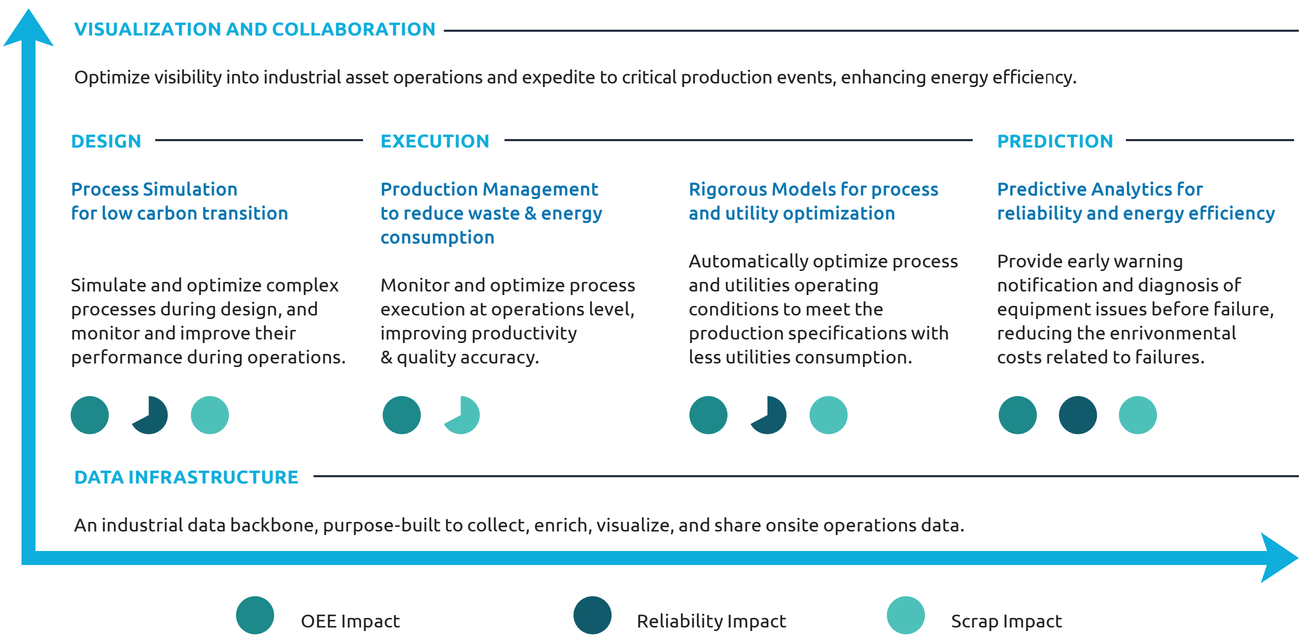



*Figure 3: Use cases selection.*

Detailed use cases are analyzed in the following sections with an illustration of impact analysis based on industrial context and actual customer reference or industrial expert experiences.

# EXAMINING THE INDUSTRIES

# 2.0. THE CHEMICAL INDUSTRY

## 2.1. The Acid Test for Sustainability

The chemical industry finds itself at the wrong end of the energy-efficiency scale, only slightly better positioned than the metals industry. If the industry is to align itself with more efficient sectors, such as food and beverage and automotive, it must first tackle three sizable challenges: **water consumption, air emissions** and **waste generation.** These are the three key sustainability metrics for the chemical industry.

The main challenge lies in optimizing the performance of energy-intensive equipment in basic chemical processes (e.g., in crackers and compressors). To overcome this challenge, chemical companies must begin designing for circular and more energy-efficient special processes.

Chemical production is energy-intensive and leads to significant emissions, mainly of CO2. The reason for this is that many chemical processes require high temperatures, which are currently achieved via fossil fuel combustion. Gas and electricity account for nearly two-thirds of total energy consumption. In 2017, the fuel and power consumption of the EU chemical industry, including life sciences, amounted to 52.7 million tons of oil equivalent.

To cut emissions, industrial chemical companies now implement two types of systems: *process-integrated techniques (such as water reuse, heat recovery, steam leakage controls, water savings, materials recycling, and pollution prevention)* and *end-of-pipe treatment*. Here, integration is the main challenge, since it generates more complexity and requires simulation and optimization tools. However, these tools empower stakeholders with the ability to make better operation and design decisions.[3]

### Key Facts

The chemical industry accounted for 5900 terawatts per hour (TWh) of energy consumption and for 1.2 Gigatons (Gt) CO2e globally in 2020.

From 1990 to 2009, energy consumption fell by nearly 27% in the chemicals industry.

Emissions are set to decrease by 9.1%, according to the Net Zero Emissions by 2050 Scenario (from 1.2 GtCO2e to 66 MtCO2e).

## 2.2. Modeling the Low-carbon Reality

The sustainability benefits of computer models and algorithms cannot be overstated. In the past, the real-world impact of a product or process could only be determined by creating that product or running the process. Of course, the manufacturers would learn a lot from this method, but that knowledge would come at the expense of the environment. The same is true of the efficiency of the process from a cost analysis perspective, which often fails to identify hidden costs. But today, manufacturers have an effective way to determine the viability of a product or process in advance: **Process Simulation.**

While process simulators are not new to the chemical industry, the latest advancements in this area allow Process Simulation to facilitate the creation of digital twins, which enable companies to envisage the physical impact of a product on the environment in a faster and more rigorous way. This is done by studying a representation of the real-word artefact with a large amount of variables (operational, economic and environmental) in a computer-generated environment designed to mimic reality. Engineers and operators can use digital twins to identify inefficiencies in their products and processes and make the necessary adjustments that result in reduced energy consumption and waste generation in both design and operations phases. This means manufacturers can pinpoint weaknesses and inefficiencies before they become damage and loss.

There are several key sustainability applications of Process Simulation, including:

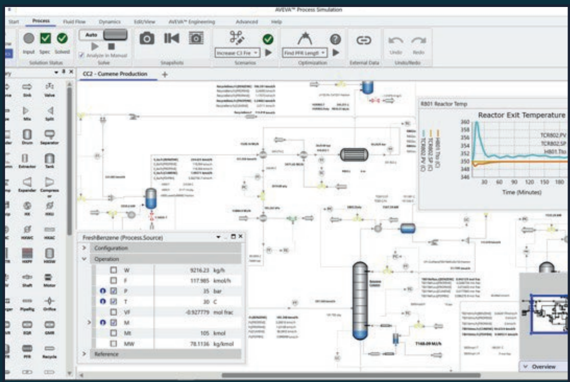
- The ability to track and calculate GHG emissions, making it possible to optimize $CO_2e$ against utilities cost and plant capital cost during design, and monitor emissions during operations using real-time data.
- The development of carbon-capture technology and the prediction of how well it performs, using new amines and other solvents that can strip $CO_2$ from flue gas streams or directly out of the atmosphere.
- The ability to model new processes that can scale up renewables and green hydrogen production by integrating steady-state and dynamic models with weather predictions.
- Enough data to design new processes for the circular economy that use biomass or recycled plastics to be carbon neutral.

Modern Process Simulation technology makes it possible to concentrate all the required models for the project cycle in a single simulation platform. This leads to design innovation at an unprecedented rate. Working designs are brought to market sooner with lower risks and even under budget, thanks to the integration of these models with engineering tools in a digital environment.

# CASE STUDY

## A Theoretical Case Study of a Dimethyl Ether (DME) Production Process.

The process simulation model is set up with embedded modules to calculate overall utility consumption and equivalent emission. An optimizer is configured to tune the model parameters, such as distillation column reflux ratio. This is done to minimize overall utilities consumption and reach the desired specifications. In this example, up to 14 ktCO2e and 56 GWh of energy consumption were reduced yearly using Process Simulation combined with the optimization features.



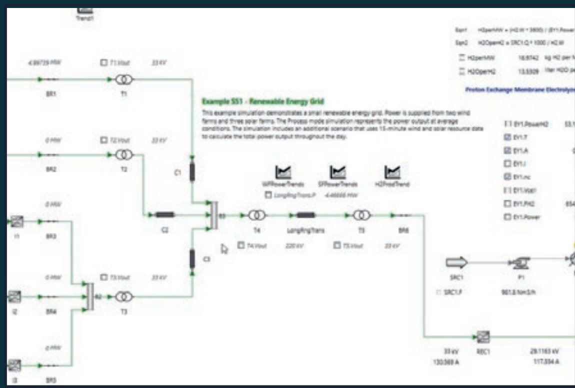




*Figure 4: Extract from AVEVA Process Simulation*

## What Clients Say

> *Today, our Process Simulation is already an important tool to improve our energy efficiency and thereby our sustainability KPIs for our brownfield plants in Germany. We will definitely expand the software deployment in the future, not only for Germany, but also worldwide, as we see the benefits of Process Simulation.*
>
> Covestro

> *Hyundai uses AVEVA Process Simulation to evaluate the energy intensity and inefficiency of a direct sequence distillation column and a divided-wall column. For a kerosene pre-fractionation column, a dividing-wall column provides energy savings of 19% over a conventional column; 30% for a de-ethanizer/ de-propanizer.*
>
> Hyundai Engineering

# 3.0. THE MANUFACTURING INDUSTRY

## 3.1. Manufacturing a Sustainable World

The sustainability of the manufacturing industry is paramount to achieving a 1.5°C future. There is much to consider, each aspect is a critical component of global net-zero targets. For instance, food waste is the direct loss of valuable resources, which contributes to greenhouse gas emissions and climate change. The United Nations Food and Agriculture Organization estimates that approximately one third of all food produced for human consumption is wasted every year, which amounts to 1.3 billion tons.[4] This waste not only generates significant emissions, but it is also a profound waste of water, energy, and other natural resources.

Another example is the life sciences sector. As is the case for other manufacturing sectors, energy consumption is becoming a major concern to ensure minimal emissions and compliance with regulations. The life sciences sector is actively working on sustainable energy management solutions. This includes the implementation of energy-efficient technologies and the adoption of renewable energy sources. Technological advancements and cleaner energy sources can help the industry to reach its net-zero objectives. When twinned with sustainable waste and energy management practices, the life sciences industry can minimize its impact on the environment and contribute to a more sustainable future.

With this in mind, it is imperative that the industry takes steps to reduce waste through better supply chain management and sustainable practices. Perhaps one of the best places to start is water usage. Many sectors in the manufacturing industry are energy- and water-intensive: the less water the industry uses, the less energy it needs to heat or cool the water it does use. Conservation here would be instantly effective. For example, two thirds of energy use in the EU is consumed as heat, and the last third is used for electricity. This electricity is mainly used for industrial cooling. But decarbonizing heat that is consumed via the production of high temperatures is a challenge. The food, drink, and milk sectors account for approximately 10% of the final industrial energy consumption in the EU-28, with 20% of the fresh extracted water of the food production sector being used for the production and processing industries.[5]

### Key Facts

Food and beverage accounts for 37% of GHG global emissions

Food and beverage manufacturing emissions are estimated at 94 Metric tons (Mt) $CO_2e$/year in the EU (equal to the total emissions of Belgium).

In the 1.5°C scenario, the European food and beverage sector could reduce GHG emissions by 92% compared to 1990 levels.

The pharmaceuticals industry is responsible for 4.4% of global emissions, and the $CO_2$ emissions are set to triple by 2050. In 2019, the pharmaceutical sector produced 48.55 $tCO_2e$ for every $1m it generated – or 55% more than the automotive industry, which emitted 31.4 tons per $1m generated in the same year. [6]

## 3.2. Production Management to Reduce Waste and Energy Consumption

Among the biggest challenges for manufacturing companies with multi-site operations is enforcing standards for data collection and best practices. However, it is the key to unlocking value, enabling manufacturers to track both energy consumption and the types and quantities of waste generated.
A digital production management footprint relies on a high-quality operational information management system, planning and scheduling capabilities, followed by a robust manufacture execution system (MES). This digital approach can help manufacturers to identify potential waste-to-energy opportunities and track the progress of waste-to-energy projects.
When done effectively, it enables manufacturers to align people and processes with advanced manufacturing execution systems. This marriage provides manufacturers with consistent and cost-effective operational excellence, compliance, transparency, and agility.

By connecting multiple plants to one digital backbone, it is easier and cheaper to implement the same standards at every plant.
This technology contextualizes data, optimizes the schedule for minimum waste, and then monitors and drives operations execution at the operations level. It facilitates the digital management of business rules, information capture for all operational activities, and real-time data of plant events. By capturing information for all operational activities, this digital approach can help increase availability, usability, and quality.

As previously mentioned, the volumes of water and the energy consumed by machinery are a major barrier to plant sustainability. Digital production management technology boosts productivity by increasing the labor and machine efficiency by ~10%. This in turn optimizes the energy and water consumption of the equipment per unit produced.

Meanwhile, the described technology enables improvements of scrap rate (up to 20% improvement), directly reducing waste and indirectly water and energy consumptions. The knock-on effect of this improvement is that it contributes to the reduction of quality deviations, thus cutting waste generation.

Circularity is a vital part of the overall net-zero mission, especially for the manufacturing industry. It is imperative for manufacturers to reduce waste generation and divert materials from landfills.
This technology can also help improve the rework and recycling rate, thereby improving material consumption.

Lastly, as previously outlined, the start-stop phenomenon is an ongoing challenge on the manufacturing industry. The energy and resources consumed whenever machinery needs to be brought back online is a significant hurdle for companies worldwide. Production management technology helps to improve the reliability rate in these facilities (up to 15% to 20% improvements), optimizing maintenance quality and frequency, which leads to additional material and energy savings.[7]

# CASE STUDY

**Use of the AVEVA PI System enabled a multinational life sciences company to reduce electricity, natural gas, hot water, and water consumption per unit of production between 2019 and 2022.**

Since the 2018 implementation of a data infrastructure platform to collect data in the Czech Republic site, the company experienced a continuous drop in electricity, heat, and water consumptions per unit of production for its production site. The platform created data-driven insights to help plant staff manage their production lines while enhancing required electricity, natural gas, heat, and water utilization, managing in an efficient way HVAC, boilers, compressors, chillers or process equipment for blending, granulation or tablet press and coating.

The data infrastructure platform contributed to the environmental performance along with several other external factors, such as people awareness, process reengineering, quality initiatives. It has yielded up to a 2.6% drop in electricity consumption per unit of production, from 0.169 kWh to 0.156 kWh; a 1.8% reduction in heat from natural gas combustion and external heat supply, from 0.163 kWh to 0.155 kWh per unit of production; and a 5% cut in water consumption, from 0.907L to 0.778L per unit of production. This corresponds to a reduction of 10g of $CO_2e$ per unit of production.

## What Clients Say

> *MES performance coupled with our company's continuous improvement strategy has increased our packaging line efficiency by 30%, saving us more than $400,000 annually in previously planned labour expenditures. OEE increased from 45% to 65% in just over 2 years.*
>
> A North American Brewing Company

> *Since the implementation of Energy Monitoring System (EMS) at one of our plants, we were able to detect water overconsumptions in milk sterilizers and other equipment, which led to over 630m3 of water savings per week.*
>
> *On the other hand, by monitoring our energy consumptions, we were able to take decisions to change the process to reduce energy consumption, leading to energy cost savings of ~€50000 per year for 3 different plants.*
>
> *We are on our way to rolling out this solution in 10 other sites in 2023.*
>
> A European Dairy Product Company

# 4.0. THE OIL AND GAS REFINING INDUSTRY

## 4.1. Purifying Processes with Optimization

Refineries are intensive consumers of energy and water. They generate huge emissions that escape into the air. Refineries also generate water and potentially soil pollution, mainly through the refining and storage processes. Discharged refinery water can contain pollutants, such as heavy metals, oil, and chemicals. Leaks, spills, or waste disposal make soil unsuitable for agriculture, harm aquatic life, and make water unsafe for human consumption. In short, it can erode healthy ecosystems.

Other processes, such as boiling, heating, and catalytic cracking produce even greater volumes of emissions. Levels of carbon dioxide are of particular concern since this gas has been proven to significantly contribute to rising sea levels and extreme weather events.

The industry occupies the median level of energy efficiency over all sectors. However, there is still much that can be done to align the industry with the more efficient sectors.

As a mature industry, pollution abatement programs are well established in many refineries, though to different extents in each. As a result, the emissions generated by refineries have declined per ton of crude processed. For instance, emissions from US refineries declined by 9.7% from 2011 to 2020. This trend is expected to continue with such policies as the US 45Q credit tax, which provides incentives for Carbon Capture, Utilization, and Storage (CCUS) projects. Refiners are also increasingly using vegetable oils to produce biofuels and thereby minimize their footprint.

Operational efficiency improvement is key to minimizing the total footprint and consequently maximizing the total emission abatement effort.[8]

### Key Facts

Oil refining emissions stood for 1 GtCO2e globally, 147 MtCO2e across the European Union in 2019 and 160.9 MtCO2e in the US in 2020.

-3% of potential reduction of GHG emissions across the US through decarbonization of refineries, mainly from reduction of on-site heat generation and refining processes.

# 4.2. Rigorous Models for Process and Utility Optimization

Rigorous optimization technology uses process and economic real-time data to improve the performance of industrial operations. When utilities and process optimizations are integrated, sustainability and operational KPIs can be more effectively combined. This results in the ability to minimize utilities consumption while ensuring product specifications. Rigorous optimization technology can also improve margins and throughput. Occasionally, the utilities variables are not directly added to the model, but other process variables lead to sustainability improvements as well.

### Process Optimization

In refineries, process optimization is mainly used to optimize energy-intensive complex processes, such as Crude Oil Distillation Unit/Vacuum Distillation Unit (CDU/VDU) and Fluid Catalytic Cracking (FCC). This is done by adjusting operations control parameters, according to process conditions, which include a large amount of variables, such as temperatures, pressures, and operations costs. When variables related to the utilities systems are incorporated (directly or indirectly) in the optimization model, process optimization enables sustainability improvements.

Refiners need support as they strive to meet production specifications with less energy consumption. Process optimization facilitates this by, among other activities, optimizing utilities consumption, such as steam. The result is decreased water consumption and wastewater. Of course, this reduction in steam consumption can also reduce the refiner's energy requirement. This is particularly noteworthy, since any reduction in the consumption of fuel gas will mitigate GHG emissions produced by combustion (scope 1).

For instance, for a 120kbd refinery, up to 8 GWh of energy and 7,200 m3 of water can be saved per year using AVEVA Process Optimization in both FCC and CDU/VDU units. This corresponds to a reduction of 12 ktCO2e per year.

To help industry actors meet sustainability goals, it is necessary to integrate both CO2 and economic data to improve both the operational and environmental performance of oil and gas refiners.[9]

# CASE STUDY

## Anonymous refinery optimizing both FCC and CDU/VDU unit.

**Savings for anonymous AVEVA customer per year (best case scenario).**

**12 kt $CO_2$e (-0.3%)**
of emission savings per year through reduction in fuel gas consumption

**7,200 m³ (-0.01%)**
of water consumption avoided per year through reduction in steam consumption

**8 GWh (-0.5%)**
of energy savings per year through reduction in fuel gas consumption

**2,552k€**
of yearly cost savings through savings in fuel gas and carbon permit purchase

In this example, the FCC unit is using AVEVA Process Optimization to manage certain products (fuel gas, ethylene, propylene, propane, C4 BB, light cycle oil, and coke) while reducing others (gasoline, benzene, and decant oil). There is a calculated reduction in fuel gas consumption (-2.3%) and in steam consumption (-0.5%) in the core process. It is estimated that reducing steam consumption leads to an additional reduction in fuel gas consumption (-0.8%), which in turn leads to less air pollution and water consumption. As a result, GHG emissions can be reduced by 11 kt CO2e (-0.4%), energy consumption by 3.8 GWh (-0.6%), and water consumption by 2700 m³.

In the CDU/VDU unit example, steam consumption can be reduced by 3%, thus reducing fuel gas consumption in the boilers (-4%). This has a direct effect on GHG emissions, which can be reduced by 1 kt CO2e (-0.05%) Additionally, energy consumption declined by 4.2 GWh (-0.5%) and water consumption by 4500 m3.

The calculations rely on the assumption that steam reduction is due to lower steam generation in boilers. Steam is usually lost to wastewater and to the atmosphere. Several techniques can be implemented for optimizing the use of steam, including reducing the amount of steam stripping, managing demand over boiler capacity, optimizing yield for boilers, optimizing such process parameters as temperature, pressure, and quality of water; recovering heat and condensate, and **minimizing losses** on the steam network. AVEVA Process Optimization can help customers achieve this complex goal.

### What Clients Say

*Monitoring heat exchanger performance is crucial to profitability and sustainability as the inefficiencies introduced by fouling may result in increased energy consumption, GHG emissions, and/or production loss. Amongst other parameters, process duty, overall heat transfer coefficient, or fouling resistance can be used to monitor fouling in heat exchangers. AVEVA Process Optimization is being used to continually collect raw field data and transform the obtained raw data to abovementioned engineering metrics. Calculated values are then historicised and used for further analysis to determine the optimum cleaning time.*

A North American Oil and Gas Company

# CASE STUDY

## A European refinery optimizing fuel gas and water consumption with open-loop utility optimization.

**Savings for anonymous AVEVA customer per year.**

**8.7 kt $CO_2e$ (-0.4%)**
of emission savings per year through reduction in fuel gas consumption

**18,200 m³ (-1.1%)**
of water consumption avioded per year

**37 GWh (-2%)**
of energy savings per year through

**7,525 k€**
of yearly cost savings through savings in fuel gas and carbon permit purchase

In this example, the refinery is using utility optimization to reduce overall energy and water consumption. The implementation of this technology has been an unmitigated success. It was responsible for 20% of all annual CO2 emission reductions in the refinery.

In this specific example, utility optimization facilitated better use of steam production from process units, improved the use of propane/butane over natural gas as marginal fuel, and achieved optimum processing of hydrogen consumption feeds. The technology is responsible for the following results:

- A decrease in direct emissions, from 656k tons of CO2e to 648k tons of CO2e (-1.1%), mainly due to reduced emissions in the internal hydrogen plant, and the optimization of propane and natural gas combustion.
- Indirect emissions fell by 0.08%, largely due to the decrease in fuel gas imports. Fuel gas consumption decreased by 2%, from 1592 GWh to 1555 GWh.
- Water consumption declined by 1%, due to lower boiler feed water consumption.

Utility optimization provided indirect benefits:

- The Utilities Shift Manager learned about beneficial operations never before considered.
- Different operational strategies for energy, utilities, and emissions were evaluated.
- It became possible to re-evaluate utility contracts.

## Utility Optimization

In the US, refining activities account for 28% of the energy consumed by industry, mainly in combustion systems and process units. Water and steam are used for various processes, including distillation, cleaning, steam generation as a feedstock to boilers, and in cooling systems.

Utility optimization technology automatically optimizes utilities systems to produce reliable guidance for optimal operation. Refiners often use this technology to optimize energy, water, and steam consumption.

For instance, a European refinery used AVEVA's solutions for utility optimization for their whole refinery. The results speak for themselves. The refinery achieved annual savings of 37 GWh of energy, primarily from fuel gas, and 18,200 m3 of water, which corresponds to a nullified 8,700 tCO2e per year.

In this example, fuel gas consumption decreased by 2%. This is a direct result of having used propane instead of natural gas as a marginal fuel. Moreover, water consumption decreased by 1%, due boilers consuming less. The net result was lower GHG emissions.

With the uncertainties in energy supply during the current energy crisis, it is even more critical for customers to optimize their energy consumption.[10]

## 4.3. Predictive Analytics for Reliability and Energy Efficiency

Predictive analytics technology provides early warning notification and diagnosis of equipment issues before failure. This reduces equipment unplanned downtime, increases reliability, and improves performance while reducing operations and maintenance expenditures.

In oil and gas facilities, predictive analytics is used mainly in critical assets, both process and utilities equipment, such as compressors, turbines, boilers, heat exchangers, pumps, expanders, etc. With this technology, facilities can prevent moderate, catastrophic, and total loss of performance. This markedly decreases the following environmental costs:

1. The energy cost of an incident consists of the energy required for shutting down and restarting the equipment/plant, as well as the energy required for response logistics (labor and equipment shifts).

2. The material cost is the quantity of raw materials used to replace or repair the equipment and the scrap related to the maintenance activity. The scrap could be reduced if the materials are recycled.

3. Water cost refers to flushing water used during maintenance. Pollution of water can also be considered as a critical environmental cost, particularly during a catastrophic incident.

4. Direct and indirect GHG emissions refer to emissions directly released during the incident (e.g., flared gas). In refineries, unplanned shutdowns could lead to an average of 10 ktCO2e per year.

Reducing the occurrence of incidents is crucial to prevent the consequent environmental and financial damage.

Predictive maintenance technology also enhances equipment efficiency (e.g., by indicating the perfect time to clean equipment outside the preventive cleaning cycle, optimizing efficiency and selecting the moment when the efficiency is so low that operating costs and emissions are higher than desired, i.e., an inefficient moment that does not represent a significant productivity loss) and helps predict possible leakages, (e.g., by monitoring a steam network).[11]

## CASE STUDY 1

### Early catches of compressor incidents at the Formosa Petrochemical Corporation (FPCC) Refinery led to 199 tons of CO2e savings per year.

Reciprocating compressors are used in refineries and chemical plants to increase system pressure to the level meeting the demand. As the compressors' outlet temperature increases, the outlet valve seal might fail. When this occurs, production is disturbed at the process unit level and the damaged compressor requires repairs.

By using AVEVA Predictive Analytics, since 2019, 14 anomalies were detected before any the compressor could be damaged, leading to better equipment performance and lower environmental costs.

More specifically smooth load shifting to the standby compressor made it was possible to avoid any disturbance to the process unit. The equipment was less damaged, which led to less material consumption used to repair the equipment (120 kg/yr of plastics saved). Each incident could have released 4 tons of hydrogen flaring directly into the atmosphere.

For this type of incident alone, predictive analytics contributed to annual savings of 199 tons of CO2e, and 120 kg of materials consumed at the refinery.

# CASE STUDY 2

**Early catches of pump incidents at the Formosa Petrochemical Corporation (FPCC) Refinery led to 13 tons of CO2e savings, 11 MWh of energy savings, and 10 tons of material savings per year.**

High pressure centrifugal pumps (280/12 segment) with a batch process (frequent start-up and shutdown) could easily result in high vibration and cause distortion at the rotor. The rotor needs to be replaced, which affects the normal operation of the unit. This incident is rare, but it could lead to environmental damage.

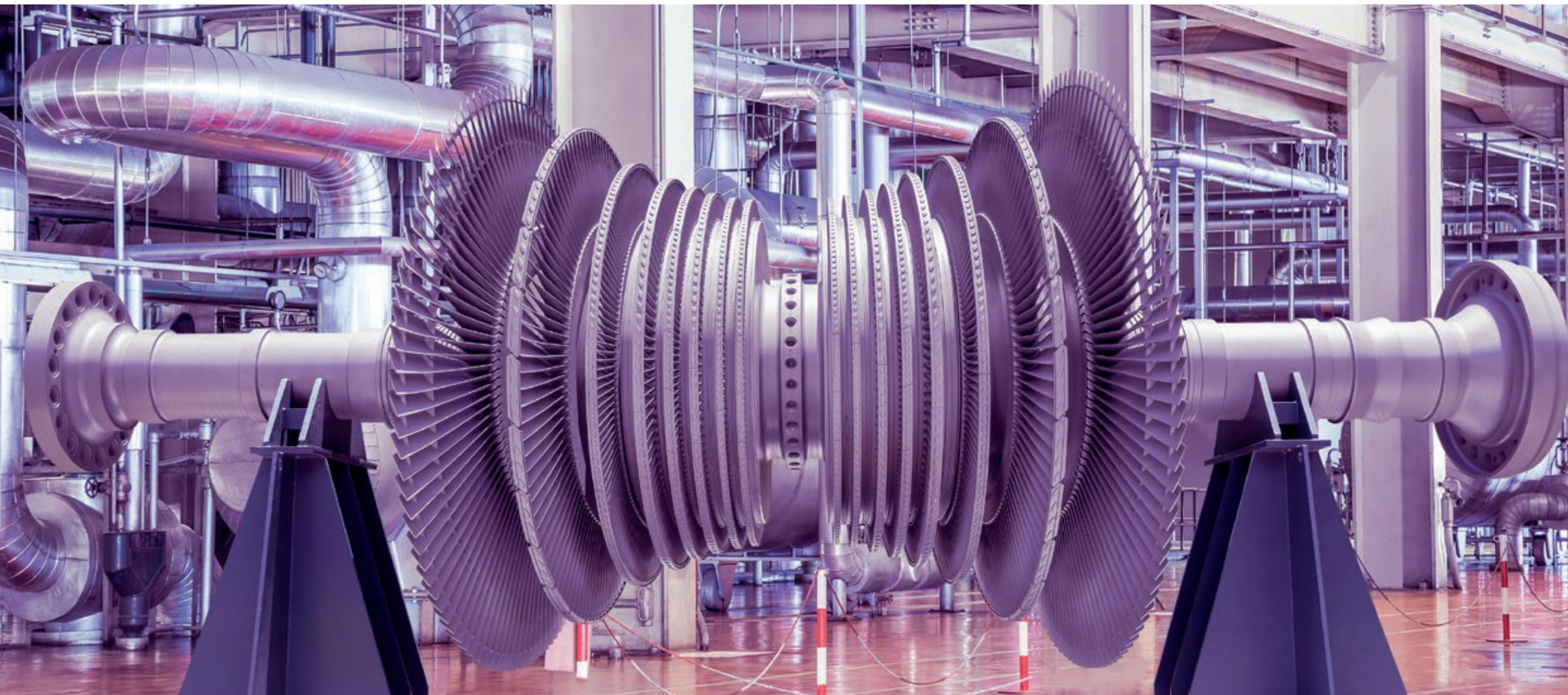
By using AVEVA Predictive Analytics, Formosa detected the anomaly before the incident occurred, avoiding the environmental cost related to this incident.

More specifically, the early catch made it possible to avoid shutting down the process unit, thus lowering the energy consumption needed to restart it (-1 MWh). The rotors were less damaged, meaning they could be repaired and reused instead of scrapped. This means less material is used to repair the equipment (-10 tons of stainless steel).

For this incident alone, predictive analytics contributed to annual savings of 13 tons of CO2e, 1 MWh of energy consumption and 10 tons of materials consumption.

## What Clients Say

> *AVEVA Predictive Analytics is leveraged as an online platform to monitor and optimize the operation. By catching a compressor anomaly early, maintenance teams discovered fuel overconsumption caused by compressed additional recycle gas that stood for hidden loss. This early catch also warned maintenance teams of a major failure that could have caused a major loss. It reduced energy overconsumption and the related additional GHG emissions (scope 1) and it prevented significant impact on air pollution.*
>
> An Asian Oil and Gas Company



# CONCLUSION

# Conclusion

Having analyzed the selected industries for this report, it is evident that industrial software can profoundly accelerate reductions in water use, energy consumption, and total emissions. This results in a significant twin benefit: expenditure optimization and environment preservation.
By driving efficiency and connecting people with trusted information yand insights, industrial software can help turn sustainability into a competitive advantage for forward-looking industries.

Completing this study has also reinforced a commonly held perception: one of the reasons there are no readily available standards for impact analysis of industrial software is that software is often part of an overall system of solutions and activities. This overall system includes external variables, such as hardware, people, environment, and process. Since software is so intricately linked with other factors, modeled sustainability benefits should continue to be framed as contributing to overall impacts, rather than as standalone achievements. Nonetheless, this paper has demonstrated that it is possible to collaborate with customers and industrial experts to develop and set parameters of impact for different types of solution and to start to model this impact based on industry-specific contexts.

High-quality data is critical for accurate quantification of impact. Among the final takeaways from this paper is not only that this high-quality data can only be generated by working closely with industrial companies but that this engagement process itself can unlock additional value from investments in digital solutions. Specifically, it can support industrial enterprises in finding further opportunities for economic and environmental impact reductions associated with industrial software in existing applications. The dialogue can also open the door to broader shared learnings, helping to drive collaboration on sustainability improvements that can holistically accelerate the evolution of industry.

Given the pressing need to move faster on global decarbonization, AVEVA is committed to continuing these conversations and working together with our customers to ensure we achieve the pace of digital and sustainable transformation we need to make a more just, net-zero future a reality no later than 2050.

# Appendix and Methodology Note

This paper looked at saved emissions of industrial software compared to a reference situation. In that sense, the scope of this study should not be compared to software vendors' footprint (scope 1, 2, and 3 emissions).

This paper adopted a bottom-up approach and modeling methodology, which is inspired by the CO2e Project Accounting methodology developed by the French Agency for Ecological Transition (ADEME),[12] which is closely connected with the European LCA analysis standards (ISO 14040 – 14044).

## Key Guiding Principles

The CO2e Impact Methodology is applicable for all software offers.

1. The sustainability potential of AVEVA software is assumed to be correlated to the potential influence of AVEVA software on industrial KPIs (OEE/performance, reliability/failure rate, scrap rate/yield).
2. The impact of each operational KPI on sustainability KPIs is identified.
3. The sustainability impact is derived by evaluating the operational performance of industrial plants before and after solution integration. The data collection period is consistent with the standard operational period in which the plant operates at its nominal behavior, ideally for one year.

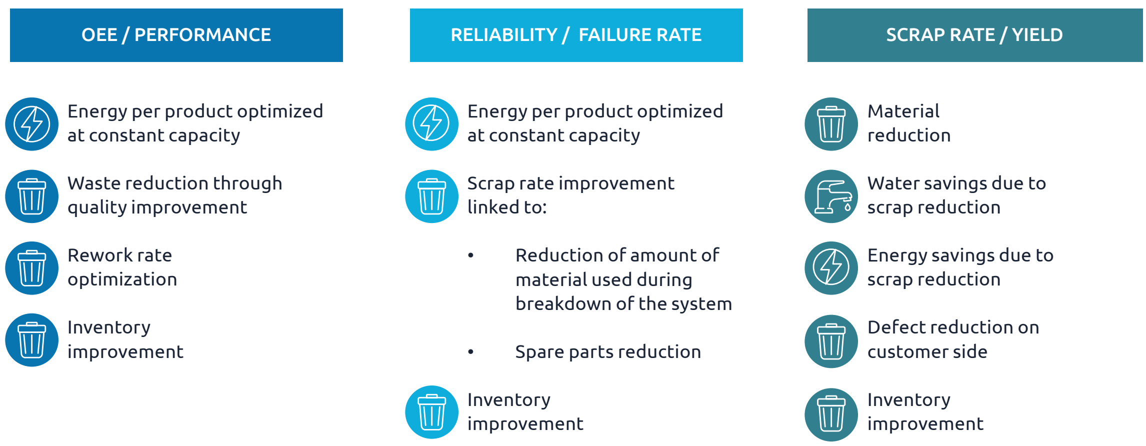



*Figure 5: Link between Industrial and Sustainability KPIs*

## Greenhouse Gases

According to the GHG Protocol Standard, results are reported in CO2 equivalent (CO2e). GHG emissions calculation covers scope 1 (direct emissions from industrial plants), scope 2 (energy consumption), and scope 3 upstream (feedstock supply). Scope 3 downstream will not be considered when industrial software has no impact on the use of its customers' finished products. In the case of asset reliability and maintenance, emissions calculations will cover scope 3 downstream emissions related to the treatment or disposal of scrap.

## Emission Factors

Emission factors are collected from public databases, such as ADEME and GHG Protocol. They are presented in metric tons of CO2 equivalent (MtCO2e) and must be frequently updated.

Electricity emission factors are location-based, meaning they correspond to the average country electricity emission factor, as referred to by ADEME.[13]
These emission factors originally come from a publication by the International Energy Agency (IEA). In this publication, the values take into account the electric and thermal kWh supplies. On the other hand, cross-border trade is not considered, as this concerns only direct emissions from power plants.

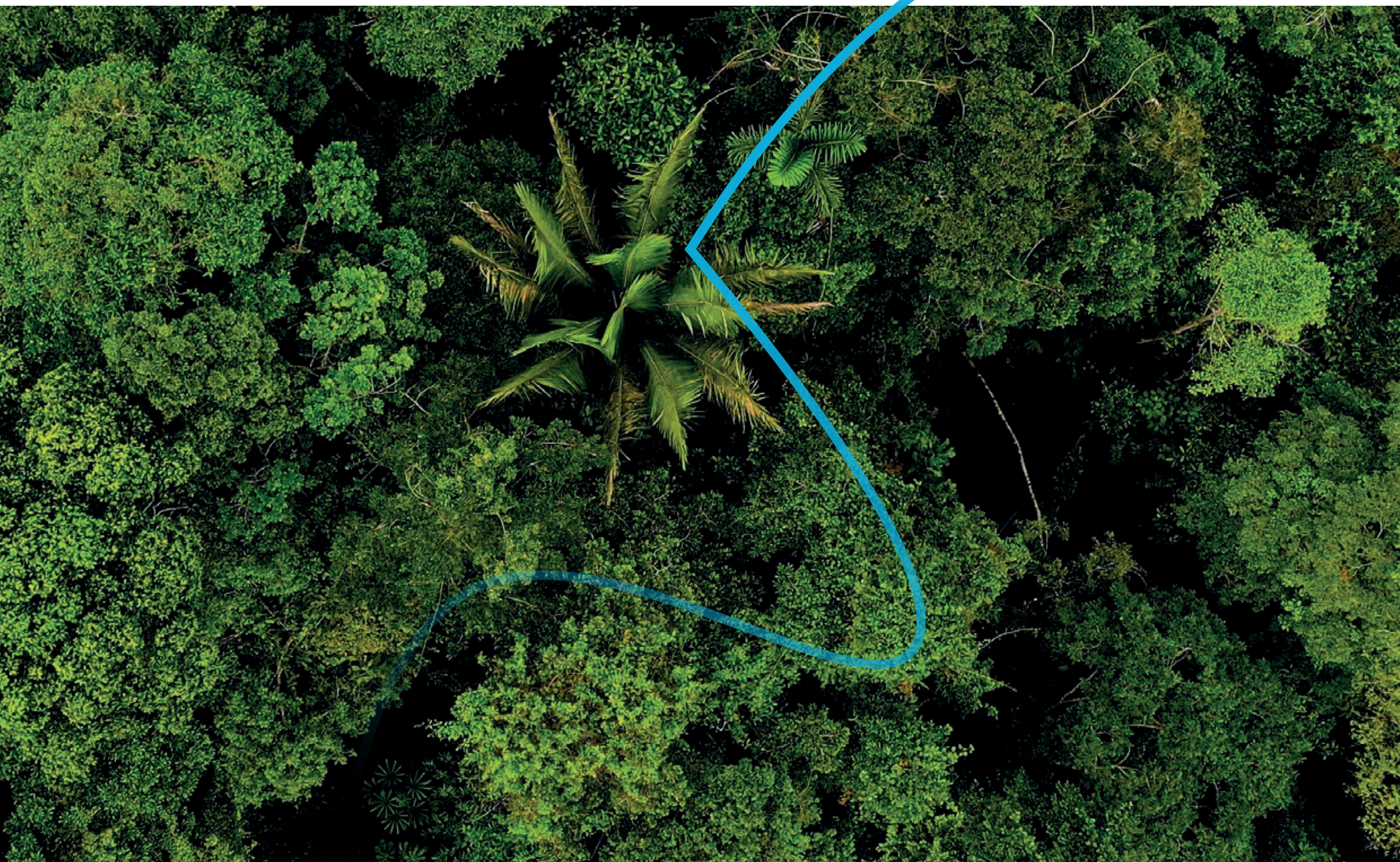
## Methodology Limitations

The results are conditioned by data availability and accessibility from organizations to address the following challenges:

- Data is an aggregate from multiple sources. A multi-function team is involved for data gathering.
- Data is not standard. Industry experts' intelligence is leveraged to scope, interpret, cleanse, and format.
- Data is often considered sensitive. Capgemini Invent worked closely with customers to provide accreditations and business justification to be shared outside operational teams.

Nevertheless, the challenges go against a growing need for transparency demanded by markets (investors in particular) and stakeholders. The methodology of sustainability impact calculation is disclosed in the analysis for each industrial use case. Uncertainties of results could be of the order of magnitude of +/-30%. Uncertainty is the result of a combination of factors:

- Data shared by organizations are estimated.
- Emission factors rely on IEA calculations from 2011.
- Rebound effects are not considered in the calculations.
- Financial estimations rely on European data.



| USE CASE | TYPE OF DATA COLLECTED |
|---|---|
| Process Simulation | To be assessed case by case to verify total impact on energy, water, and waste. |
| Production Management | • OEE/performance ratio<br>• Scrap rate/yield<br>• Reliability/failure rate<br>• Feedstock quantities<br>• Energy/water consumption |
| Process and Utility Optimization | Utilities consumption:<br>• Electricity<br>• Fuel gas<br>• Fuel oil<br>• Hydrogen<br>• Water (cooling water)<br>• Steam |
| Predictive Analytics | Data related to environmental cost per incident:<br>Energy cost<br>• Energy to restart the plant/process unit/equipment<br>• Energy required for maintenance team transportation<br>• Energy used for maintenance equipment (drone, crane, welding stations…)<br>Material cost<br>• Equipment scrap<br>• Process scrap<br>• Spare parts to replace/repair equipment<br>• Other resources consumption for maintenance usage<br>• Water cost (flushing water and other maintenance water)<br>GHG emissions<br>• Direct emissions occurring during an incident (e.g., flared gas) |

# References


1. IEA (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector. Available from: https://www.iea.org/reports/ net-zero-by-2050 [Accessed on the 28th of 2023]

2. Hypotheses: 1) The yearly results are global results. 2) Data on energy consumption and CO2e emissions come from global reports or from extrapolated results from selected key companies in the sector. 3) CO2 equivalent emissions cover scope 1 and scope 2 emissions, except process and CH4 emissions. 4) The higher the value of the Energy Efficiency Index (EEI), the greater the sector's improvement towards energy efficiency. Sources: Capgemini analysis; World Energy Outlook 2021, IEA, (2021; Best Available Techniques (BAT) Reference Document for the refining of Mineral Oil and Gas, European Commission, (2015); Best Available Techniques (BAT) Reference Document for the Production of Large Volume Organic Chemicals, European Commission, (2019); Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk industries, European Commission, (2019); Composite index for energy efficiency evaluation of industrial sector: sub-sectoral comparison, ScienceDirect, (2020)

3. Sources: 2020 Facts & Figures of the European chemical industry, CEFIC, (2020); Best Available Techniques (BAT) Reference Document for Common Wastewater and Waste Gas Treatment/Management Systems in the Chemical sector, European Commission, (2016); World Energy Outlook, IEA, (2021)

4. Food and Agriculture Organization of the United Nations (2011) Global Food Losses and Food Waste Extent: Causes and Prevention. Available from: https://www.fao.org/3/i2697e/i2697e.pdf [Accessed on the 20th of March 2023]

5. Sources: Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries, European Commission (2019); Climate Change and Land: an IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, IPCC, (2019); Decarbonization road map for the European food and drink manufacturing sector, Ricardo, (2021)

6. Iyer, J. K. (2022). 6 ways the pharmaceutical industry can reduce its climate impact. World Economic Forum (WEF). Available from: https://www.weforum.org/agenda/2022/11/pharmaceutical-industry-reduce-climate-impact/ [Accessed on the 15th of March 2023]

7. Sources: Capgemini internal benchmark; AVEVA brochure

8. Sources: Best Available Techniques (BAT) Reference Document for the refining of Mineral Oil and Gas, European Commission, (2015); Technological Pathways for Decarbonizing Petroleum Refining, World Resources Institute, (2021); World Energy Outlook, IEA, 2018

9. Sources: Capgemini calculations; AVEVA average values; Best Available Techniques (BAT) Reference Document for the refining of Mineral Oil and Gas, European Commission, (2015)

10. Sources: Capgemini calculations; AVEVA average values; Best Available Techniques (BAT) Reference Document for the refining of Mineral Oil and Gas, European Commission, (2015); BP Energy Outlook, BP (2022)

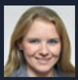
11. AVEVA brochure

12. ADEME (2021). Empreinte projet : évaluer l'empreinte environnementale d'un projet (Project footprint: assessing the environmental footprint of a project). Available from: https://librairie.ademe.fr/produire-autrement/5040-empreinte-projet-evaluer-l-empreinte-environnementale-d-un-projet.html#:~:text=La%20m%C3%A9thode%20Empreinte%20Projet%20est,de%20projets%20pour%20leur%20%C3%A9valuation [Accessed on the 15th of March 2023]

13. ADEME, Bilans Ges. (2023). Bienvenue sur Bilans GES. Available from: https://bilans-ges.ademe.fr/documentation/UPLOAD_DOC_FR/index.htm?moyenne_par_pays.htm [Accessed on the 15th of March 2023]

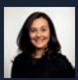
# Authors


## AVEVA



Lisa Wee
VP of Sustainability, AVEVA

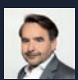
Wenting Zhu
Program Manager of Sustainability, AVEVA



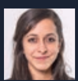
Fernanda Martins
Marketing Director for Energy and Sustainability, AVEVA

Catherine Edmunds
VP of Brand and Communications, AVEVA

## Capgemini



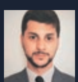
Nicolas Clinckx
Head of Manufacturing, Capgemini Invent France



Amira Tantaoui El Araki
Director of Intelligent Industry and Sustainability, Capgemini Invent

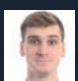
Hélène Chanel
Director, Energy Transition, Decarbonization, and Low-carbon Products and Services, Capgemini Invent

Alain Chardon
Director, New Sustainability Platforms, Capgemini



Amine Ghaffor
Director of Intelligent Industry, Capgemini Invent

Ibtihal Karfia
Senior Consultant, Energy and Utilities, Capgemini Invent



Louis Fesquet
Consultant, Strategy, Innovation, and Digital Transformation: Energy, Utilities, and Chemicals, Capgemini Invent


# Contributors


**AVEVA and Capgemini Invent would like to thank the following contributors:**

Jarrett Campbell
Robert Kambach
Vishal Mahna
Ilaria Michelizzi
Ryan Bradley
Luca Bruni
Ted Combs
Daniel Crisp
Cindy Crow
Boris Demarrez
Cal Depew
Satyendra Dubey
Gregor Fernholz
Caue Fontana
Freddy Garces
Michael Graves
Sree Hameed
Craig Harclerode
Joe Kovach
Joseph McMullen
Rainer Muhm
Jesus Francisco Palacin
Miguel Forneas
Stuart Parker
Erik Philipps
Christian-Marc Pouyez
Stephen Reynolds
Charles Rieb
Romuald Royer
Rishabh Singhal
Chloe Smith
Tolu Sodeinde
Tom Troy
James Wade
Byungsuck Lee
Sean Gregson
Michael Reed
Elaine Chou
Qiong Liu
Jason Tan
Rob McGreevy
Kim Custeau
Formosa Petrochemical Corporation

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AVEVA is a global leader in industrial software, sparking ingenuity to drive responsible use of the world's resources. The company's secure industrial cloud platform and applications enable businesses to harness the power of their information and improve collaboration with customers, suppliers and partners. Over 20,000 enterprises in over 100 countries rely on AVEVA to help them deliver life's essentials: safe and reliable energy, food, medicines, infrastructure and more. By connecting people with trusted information and AI-enriched insights, AVEVA enables teams to engineer efficiently and optimize operations, driving growth and sustainability.

Named as one of the world's most innovative companies, AVEVA supports customers with open solutions and the expertise of more than 6,400 employees, 5,000 partners and 5,700 certified developers. With operations around the globe, AVEVA is headquartered in Cambridge, UK.

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