# INTEGRATED OPERATIONS

**Rubén David Monje, Technology Services Consultant, KBC – A Yokogawa Company,** discusses how integrated operations can optimise scheduling, production accounting and energy cost, and manage emissions on LNG sites.

At the core of every successful LNG site, whether it is engaged in liquefaction or regasification operations, lies a trio of indispensable activities: optimal scheduling, production accounting, and expert management of energy costs and greenhouse gas (GHG) emissions.

Effective operations must be scheduled to ensure feasible and cost-efficient operations, including the ability to simulate scenarios for viable assessment under possible operational disruptions such as LNG tanker delays.

Production accounting is a mature technology that helps close the daily production mass balance and address data reconciliation issues.[1] Managing energy costs and GHG emissions requires a strategic approach that involves the calculation of emissions and energy metrics, optimisation, and real-time reporting within a given timeframe, as per the site's local regulations.[2,3,4]

All these activities can only be effectively performed under a digital environment. The advanced technology solutions use mathematical tools for optimisation, integrate first principle-based models, and enable data gathering from different sources while evaluating simulated scenarios and case studies. Additionally, the software offers the capability to calculate and report custom key performance indicators (KPIs) and present results to end users via a user-friendly interface.

This article provides references and examples that highlight how these advanced technologies produce tangible benefits to LNG operators.

## Production accounting and data reconciliation

The LNG industry holds significant value potential via its existing real-time data availability. However, it suffers significant financial losses attributed to the challenge of managing, tracking, integrating, and sustaining material and energy balances data in a synchronised manner across the entire business. The inherent complexity of processes, poorly integrated workflows, misinformation, and the associated costs for maintenance all contribute to diminishing the perceived value of production accounting systems (PAS). Some companies even marginalise this activity to 'only an administrative task.'

By adopting accounting best practices and incorporating engineering knowledge beyond the yield accounting methodologies, companies can extract maximum value from the reconciled mass balance data. This strategic shift expedites

tasks while enhancing the relevance and accuracy of the information generated.

A PAS was implemented in a European LNG facility. The main objective was to capture all necessary information for calculating inventories and material movements within a specific timeframe. The PAS excelled in data reconciliation, specifically detecting losses, custody transfer discrepancies, and data input errors.

The solution provided the following characteristics:

- Modelling of 11 pipelines for feed gas input.
- Integration with accounting and production scheduling.
- Integration with commercial gas system.
- Integration with upstream systems (well operation).
- Integration with plant historian for flow meters and composition data reading.

Production accounting models, inventories, material movements, and other business operations within the hydrocarbon industry were used to generate a mathematical data reconciliation model, as illustrated in Figure 1.

The entire LNG site and individual process units relied on the PAS, which played a pivotal role of calculating a comprehensive end-to-end mass balance that encompassed both bulk and individual component assessments. This functionality enabled the LNG facilities to closely track inventories and properties of the stored and exchanged materials, including energy received and/or dispatched, mix density, molecular weight, Wobbe index, and more.

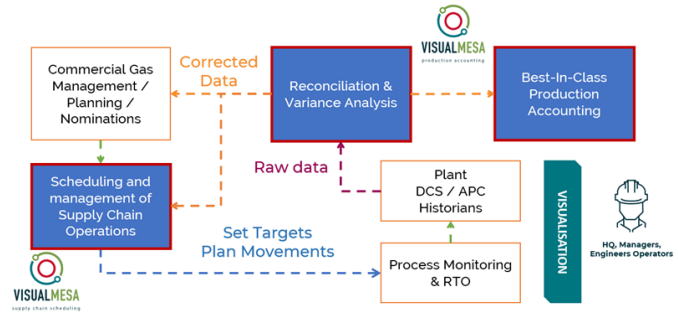


**Figure 1.** PAS as part of the intergrated production model for LNG supply chain management.

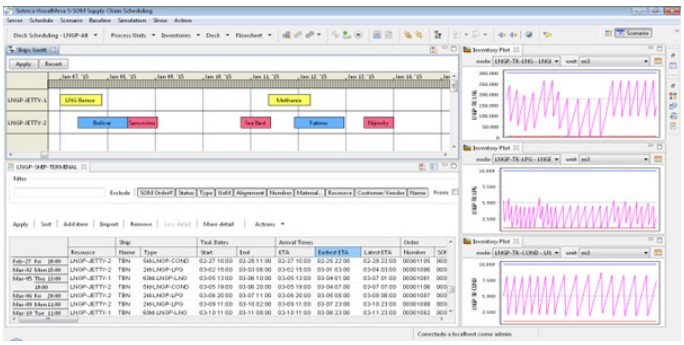

**Figure 2.** Supply chain and scheduling system, Gantt charts and inventory projections visualisation.

Once the mass balance is solved, and all the mixture compositions are calculated, the PAS becomes an indispensable tool to create KPIs. These KPIs serve as valuable metrics to help operations and management monitor and optimise their LNG workflows. For example, calculating and reporting KPIs included monitoring the amount of boil-off gas resulting from loading and unloading operations, comparing planned with actual monthly operations, tracking composition variations, and evaluating evaporative losses.

In this case study, the operator was able to generate KPIs from the reconciled mass balance and composition data. Additionally, the gross error detection engine identified potentially faulty meters that needed to be recalibrated.

To enhance operations, operators used the PAS results. More than 45 different reports were generated for the European LNG site, covering operations, inventories, tank movements, process unit reports, fuel consumption reports, balance reports, site losses, unit loss balance issues, balance audit reports, and more. By the end of the project, the PAS had integrated seamlessly with all business processes throughout the LNG supply chain, ensuring operational efficiency and data-driven decision-making.

## Scheduling and operations optimisation

For the European LNG processing facility, a scheduling system was developed via the simulation of an integrated model. With this powerful decision-support system, the LNG facility was able to gain visibility into both its logistic and process unit operations via a hybrid continuous and discrete event simulation approach. Flow rates, inventories, and material properties were continuously changing control variables in the continuous simulator, which enabled the integration of differential equations. Meanwhile, the discrete event simulator reproduced the behaviour of discrete operations such as alignments, tank movements, receptions, and shipments, as shown in Figure 2.

Furthermore, this scheduling system allowed multiple users and/or schedulers the ability to access the same scheduling scenario simultaneously to facilitate collaboration and enhance decision-making. The business processes inherent in the LNG value chain were also accommodated on a short, medium, and long-term scheduling basis. In turn, this flexibility enabled the conversion of annual delivery programmes into a feasible day-to-day operating schedule for the entire supply chain – from gas wells, gas plants, and liquefaction plants to vessels and LNG regasification terminals – balancing supply and demand while aligning commercial needs with operational capability.

Finally, this LNG processing facility was able to monitor the progress of current operations and environment status to capture potentially disruptive events such as the late arrival of an LNG tanker, highlighting potential future risks by simulating consequences of possible disturbances in the supply chain. With the model, a schedule of vessel arrivals, jetty allocations, and loading operations was developed and maintained, and terminal facilities were managed to coordinate lifting of products with the production plan.

The material properties of LNG tanks inventory could be inspected in a dedicated report to analyse the prediction of quality properties and compositions for final products and to assess the impact of incoming gas compositions and production capacity decisions on final product specifications.

The solutions were displayed in a graphical user interface (GUI) where the user could study and modify them. From the same interface, operations reports were generated in PDF, HTML, or XLS format, ensuring an easy sharing process.

Upon completing the implementation project, the scheduling system allowed for constant verification of the schedule, checking the feasibility of the operations, and assessing the schedule quality based on performance indicators. This was possible through the use of updated projections of inventories and material properties that could be automatically updated when the operations plan or plant data were modified.

## Tracking and reporting metrics

In the case of the energy management system (EMS),[6,7] it was applied at an Asian LNG regasification plant to calculate emissions and energy metrics that needed to be reported to the local authorities. Due to this capability of paramount importance, the site was able to qualify for ISO 50001 certification.

An online model of the process energy and emissions was developed to provide a graphic representation of how the different systems (process, utilities) interact for the regasification process. It was possible to calculate and historise energy and GHG emissions related metrics in real time by using a validated plant model fed with live data.

Data integration was crucial for the calculations to succeed. Thus, the EMS included specific libraries to communicate natively with the most commonly used historians in the industry and connect with real-time data bases through OLE for Process Control (OPC) or other protocols. At this Asian facility, the module for communicating with relational databases was also useful for retrieving data using SQL queries.

A variety of KPIs were calculated and historised, including but not limited to specific energy consumptions for different envelopes in the process (booster pumps, regasification, overall), pump efficiency, deviations in pumping power from designs, lost opportunity costs linked to deviations from operating parameters, heat exchanger overall heat transfer coefficient for fouling monitoring and GHG emissions as demonstrated in Figure 3.

When a given KPI surpassed a limit value, the system generated an alarm. Besides being displayed in the web GUI, as illustrated in Figure 4, these alarms also could fire email messages to notify plant staff about deviations from operational ranges. As a result of the integrated drill-down feature of the GUI, users could pinpoint and contextualise the deviations, enabling them to identify the root cause of the alarm. This was especially useful not only to improve operations within targets but also to detect a list of possible malfunctioning metering devices that could explain the deviation in the KPIs expected values.

The web interface provided access to calculation results, allowing for monitoring, analysis, and optimisation of the digital twin.

After project commissioning, this EMS implementation allowed the customer to automatically prepare reports that were sent to local authorities containing the calculated KPIs.

## Conclusion

This paper discussed how LNG operations can improve their site's efficiency, reduce costs, and comply with environmental regulations by integrating a scheduling and production accounting system with an EMS. These advanced technology solutions offer the firm an advantage by streamlining complex processes, optimising resource utilisation, and providing real-time insights for decision-making.

First, a European LNG facility proved that a PAS was more than just an administrative task. By implementing best practices and seamlessly integrating the application with various systems, production accounting ensured accurate data reconciliation and generated valuable KPIs. Now, operators can monitor and optimise LNG operations by identifying potential issues such as faulty meters based on these KPIs, derived from mass balance and composition information.

Additionally, the case study discussed how the European LNG processing facility used scheduling systems to offer powerful decision-support tools. By using a hybrid simulation approach, these applications provide visibility into both logistics and process unit operations. This enables efficient scheduling across the whole supply chain, aligning commercial needs with operational capacity, and mitigating risks by simulating potential disruptions.

Second, the Asian LNG regasification plant's EMS goes beyond tracking emissions. By integrating real-time data into a plant model, the EMS calculates and historises energy and GHG emissions metrics. This not only helped the plant achieve ISO 50001 certification but also allowed for continuous monitoring, analysis, and optimisation of energy consumption.

In essence, the convergence of these advanced technology solutions in LNG operations creates a comprehensive framework for sustainability, operational excellence, and regulatory compliance. The tangible benefits witnessed in various projects underline the transformative potential of adopting these digital applications in the LNG industry. LNG

## References

Available on request.

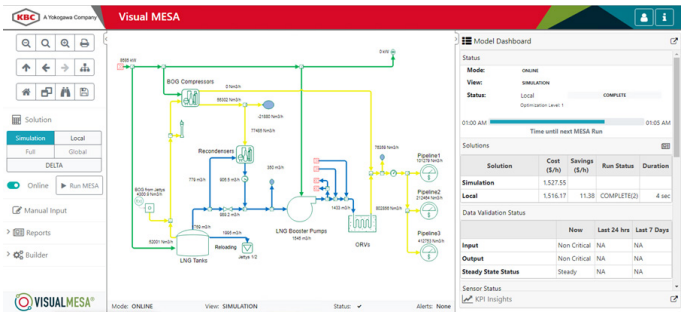


**Figure 3.** EMS web graphical user interface (GUI) for an LNG regasification process.

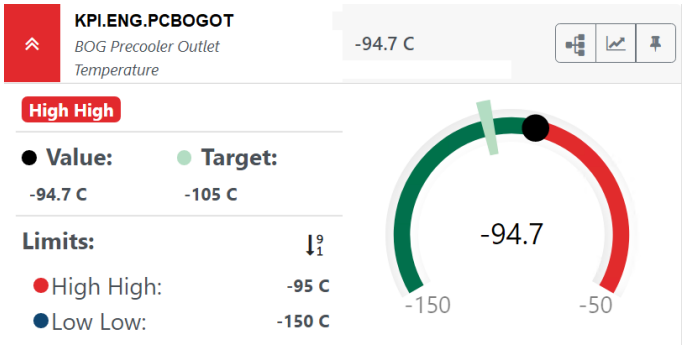


**Figure 4.** EMS KPIs are made abailable in a web GUI.