A MARATHON, NOT A SPRINT

The journey toward low-carbon competitiveness is a marathon of discipline, not a sprint of innovation. **Sanjay Bhargava and Michelle Wicmandy, KBC (A Yokogawa Company),** consider how refinery profit improvement programmes (PIPs) can substantially increase margins and sustain real-time performance.

Refining today sits at the crossroads of market volatility and structural transformation. Margins have slipped back to pre-pandemic levels, with refining earnings down by approximately 50% in 2024 compared with 2023 and roughly 60% lower than in 2022. Over the next decade, refining capacity is projected to decline by up to 30% depending on region.[1]

Beneath those numbers lies a deeper shift. Refiners are being asked to do more with less – to run cleaner, leaner, and smarter – without the luxury of large capital expansions. The challenge is not merely economic; it is structural, operational, and human, all at once.

Operators are now expected to maximise margins with minimum CAPEX while facing a web of operational constraints. These include increasingly complex feedstocks, lower energy intensity, stricter emission obligations, and shifting product-demand patterns tied to mobility, biofuels, and the circular-economy. One empirical study found that refinery complexity, specific-energy consumption, and distillate yield positively correlated with gross refining margin, while fuel and loss factors had negative impacts.[2]

For decades, the default response was to build bigger. Today, expansion alone is no longer the answer. Leadership now hinges on disciplined operational excellence – the art of extracting more value from the same assets. Increasingly, refiners are turning to structured improvement frameworks, known as profit improvement programmes (PIPs). These programmes systematically identify, quantify, and implement operational, process, and refinery-wide improvements to generate value with minimal incremental capital.

PIPs focus on enhancing yield, reducing energy use and emissions, minimising crude costs, strengthening reliability, optimising turnarounds, and building human-performance capability. They emphasise a phased, cross-functional approach: baseline definition, opportunity discovery, modelling and prioritisation, rapid implementation of quick wins, and a comprehensive sustainment programme.

Running parallel to this methodological rigour is a wave of digital transformation to sustain implemented opportunities and transform a PIP into a continuous improvement programme. Advances in digital-twin modelling, high-fidelity simulation, and advanced analytics are transforming operations. Model-based AI-driven hybrid optimisation ensures real-time performance by tightening the link between operations, planning, and maintenance. Recent research in refining operations with digital twins reports average return on investment timelines of 12 - 36 months, efficiency gains of 15 - 42%, and maintenance cost reductions of 25 - 55%.[3]

What began as a series of isolated improvement projects has evolved into a strategic performance-management discipline – one that connects margin recovery, operational resilience, and decarbonisation readiness into a unified agenda.

Closing the gap: converting variability into value

Refining margins have always been a balancing act between efficiency and volatility, but the fulcrum has grown narrower. Industry benchmarking suggests that incremental inefficiencies in energy use, yield, and reliability may quietly erode a few percent of total operating expenditure – equivalent to millions of dollars of lost value annually. While market crack spreads largely dictate external margin swings, operational inefficiencies within the refinery often represent the most addressable source of lost value.[4] Closing that gap through systematic improvement has become essential.

Across the industry, benchmarking shows that structured improvement programmes can reverse this silent leakage. Typical implementations yield between US$30 and US$60 million in annual benefits, with payback achieved in under 12 months and internal rates of return often exceed 100%. The outcomes are tangible: 5 - 15% reductions in specific energy consumption, 2 - 5% higher availability, and measurable improvements in crude costs, process yields, reliability, and emissions intensity. These results suggest that the next competitive advantage will not come from scale, but from acting on the big-impact-creating prioritised quick-win projects that collectively define refinery performance.

From projects to performance systems

The traditional PIP has evolved from a one-time operational review into a continuous, digitally enabled performance-management system. At the heart of this transition is the ability to merge engineering models, plant data, and human decision-making into a unified improvement framework. The digital AI/ML layer enables refiners to quantify, implement, and sustain performance gains across yield, energy, reliability, and emissions metrics more effectively than ever before.

Digital profit improvement programmes (D-PIPs) typically follow a five-stage methodology – define, discover, develop, deliver, and sustain – linking opportunity identification with execution and continuous improvement, as shown in Figure 1. This agile, sprint-based approach accelerates benefit realisation while embedding digital capability across the organisation.

The shift is not purely technological. PIPs are increasingly designed to deliver dual dividends: economic performance and environmental progress. Many refiners track carbon reduction directly alongside margin improvement, with potential benefits ranging from US¢35 - 70/bbl in margin uplift and US¢5 - 15/bbl in energy and emissions reduction. This dual-focus approach aligns profitability with sustainability, a defining characteristic of the sector's new performance model.

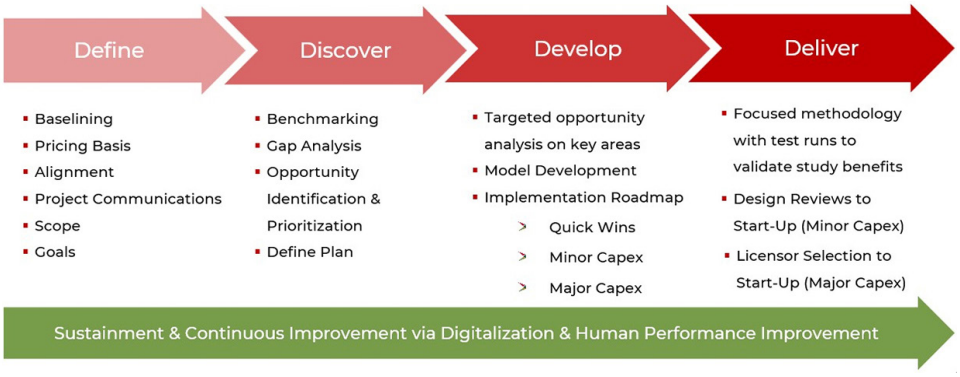

Figure 1. Five stage methodology.

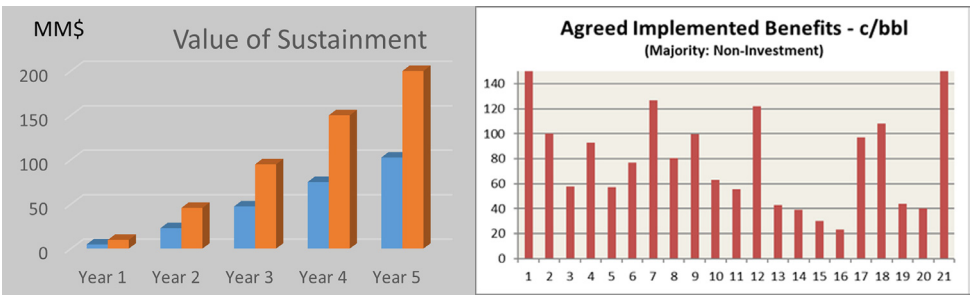

Figure 2. Value-creation distribution across process, energy, reliability, and supply-chain domains (left). Value-sustainment curve illustrating retention of implemented benefits over time (right).

Embedding resilience through digital discipline

By combining advanced analytics with empowered teams, refiners can move from reactive troubleshooting to proactive optimisation. Across implemented programmes, typical results show 40 - 80% of total benefits from yield improvements, 5 - 40% of total benefits from yield improvements from capacity utilisation gains, and 5 - 8% of total benefits from energy cost reduction (up to 15% with capital enhancements). Supply-chain alignment

commonly delivers a further 5 - 20% improvement in value realisation.

The result is not only sustained profitability but also improved reliability, energy performance, and emissions management – key metrics for competitiveness in a decarbonising market. The evolution toward digital PIPs positions refiners to achieve higher margins while building the operational resilience required for a low-carbon economy.

Industry-wide benchmarking shows typical improvement distribution and value-sustainment behaviour across domains, as shown in Figure 2.

Lessons from a legacy site

A large refinery embarked on a modernisation initiative that combined structured performance improvement with digital transformation. The approach, which is now becoming common across the industry, aimed to enhance profitability, reliability, and energy performance while advancing low-carbon operations. This example demonstrates how a structured improvement framework, supported by digital tools, can deliver parallel gains in financial and sustainability outcomes.

The site launched a full-scale transformation that brought together digital tools, operational-excellence practices, and sustainability. The initiative integrated advanced process-simulation, control, and optimisation technologies to enable higher profitability and energy efficiency while reducing emissions.

With its digital backbone in place, leadership advanced toward data-driven, semi-autonomous decision-making. The refiner combined first-principles simulation software, upgraded advanced process control (APC) systems, and real-time optimisation dashboards to shift from reactive responses to predictive operations, as shown in Figure 3.

A multi-period utility-plant optimiser reduced energy use while increasing profits, and automating a compressor-control strategy eliminated chronic hydrogen flaring, closing a gap in both emissions and margin.

Operational planning also evolved. Linear programming models were overhauled and backcasting introduced to bridge the gap between planned and actual performance. Improved crude selection increased profits by US$30 million/yr in additional profit.

Through more than 25 targeted process improvements, the team enhanced yields and reliability while lowering energy intensity. Focused upgrades in crude separation, catalyst use, and stream routing lifted middle-distillate yields by 6.5 vol%. Refined catalyst and constraint management reduced lower-value fuel-oil production in favour of higher-value distillates, generating US$100 million in incremental profit.

Energy as a margin multiplier

Energy efficiency became a defining metric of progress. Early benchmarking revealed substantial opportunity and, within months, overall energy performance improved by about 10% through low- or no-CAPEX measures. Continued optimisation – pinch analysis, energy real-time optimisation, heat-exchanger monitoring, and multi-period optimisation – pushed performance into sustained double-digit improvements.

Reliability reimagined

Structured turnaround reviews and a dedicated gatekeeper avoided over US$8 million in unnecessary work. Reliability-centred maintenance (RCM) and root cause analysis (RCA) programmes reduced an estimated US$30 - 45 million in production losses, increasing mechanical availability and safety performance.

Modernisation also aligned with broader regional investments in renewable-fuel capacity, including hydrotreated vegetable oil (HVO) and sustainable aviation fuel (SAF) production, reinforcing the link between refinery optimisation and future clean-fuel infrastructure. The results were as follows:

- US$150 million in validated annualised benefits across process, energy, reliability, and supply-chain performance.
- 6.5 vol% increase in middle-distillate yield.
- >10% energy efficiency improvement driven by low-CAPEX solutions.
- Over US$30 million/yr in potential profits via PIMS LP upgrades.
- Downtime reduction through RCA and RCM, and lower maintenance costs via gatekeeper controls.

This case demonstrates that operational performance and decarbonisation are complementary forces.

Sustaining value through people and process discipline

Technology initiates change, but sustained value depends on a workforce able to interpret data, act, and adapt. Industry experience shows that up to 70% of potential value can be lost without proper sustainment and organisational alignment.

Human-performance improvement remains central to sustaining results. Continuous coaching, competency development, and structured problem-solving ensure that improvements achieved through digital tools are retained through disciplined execution. Leading operators embed structured work processes, digital dashboards, and capability-development programmes that reinforce accountability and knowledge transfer.

Digital tools such as model-based profit tracking systems now provide a live view of realised and sustained value, capturing every opportunity from identification through execution, as shown in Figure 4. They monitor progress, track benefit leakage, and maintain alignment between operational actions and financial outcomes.

Continuous-improvement mechanisms – supported by near-real-time performance tracking – help ensure that gains remain visible and measurable. Training programmes focused on operational awareness, problem-solving, and energy stewardship cultivate a performance culture that adapts to new digital tools

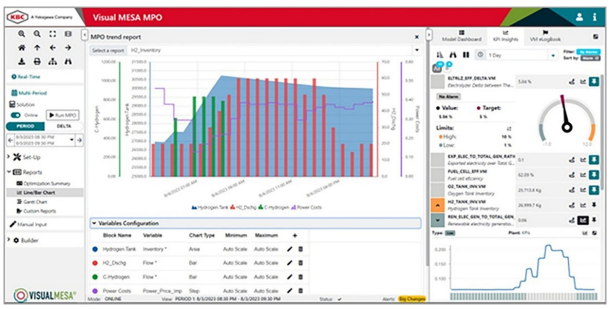

Figure 3. Real-time optimisation dashboard supports predictive operations and KPI tracking.

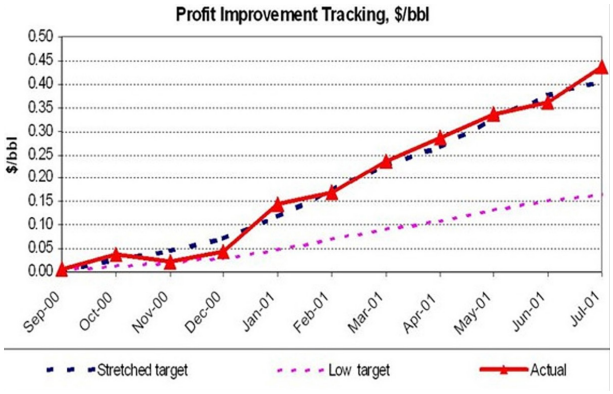

Figure 4. Profit-tracking dashboard showing how digital monitoring aligns operational actions with realised and sustained value.

rather than resists them. Over time, this integration of technology and human capability transforms short-term profit-improvement projects into ongoing strategic disciplines.

Field experience shows that properly executed PIPs can yield implemented profits of 5 - 10 times programme cost, generating internal rates of return exceeding 100%. Cumulative benefits of US$100 - 200 million are achievable in large, integrated sites when quick wins and minor investments are fully realised.

Conclusion: refining for a low-carbon era

As the refining sector adapts to a more complex and carbon-constrained environment, PIPs have become both a business necessity and a sustainability enabler. The same model-based data-driven frameworks that uncover process inefficiencies also identify opportunities to cut energy use and lower emissions. They improve asset utilisation while accelerating the speed to margin.

Digital technologies – ranging from process simulation and optimisation to AI-enabled analytics – extend the impact of these programmes by making improvement measurable, repeatable, and scalable. Coupled with strong organisational alignment and workforce capability, they transform short-term efficiency projects into a culture of continuous improvement and a bridge to sustainable competitiveness.

The journey toward low-carbon competitiveness is not a sprint of innovation but a marathon of discipline. Digital tools illuminate the path ahead, but it is human expertise – the judgement, creativity, and operational rigour of people – that keeps progress steady.

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