



# Sustainable Safety Instrumented Systems

The tangible benefits that end users can derive from implementing sustainable SIS are effective safety compliance, revenue maximisation and operational cost reductions.

# Executive Summary

In response to market volatility and disruptive operating environments, sustainability remains a core component of many corporate strategies. Sustainability is a concept that empowers key decision makers with opportunities to retake ownership and actively manage their operational safety performance. It is a means of future-proofing their plant's safety requirements while managing and optimising their operational and capital expenditures.

*Sustainable Safety Instrumented Systems (SIS)* is a natural evolution from conventional SIS which allows key decision makers to optimise their plant's safety performance without compromising productivity, revenue and cost.

Sustainable SIS incorporates a holistic assessment of operational safety to mitigate and manage risks throughout the lifetime of a plant. It empowers all stakeholders towards a common goal of protecting businesses from intolerable hazard-related downtime.

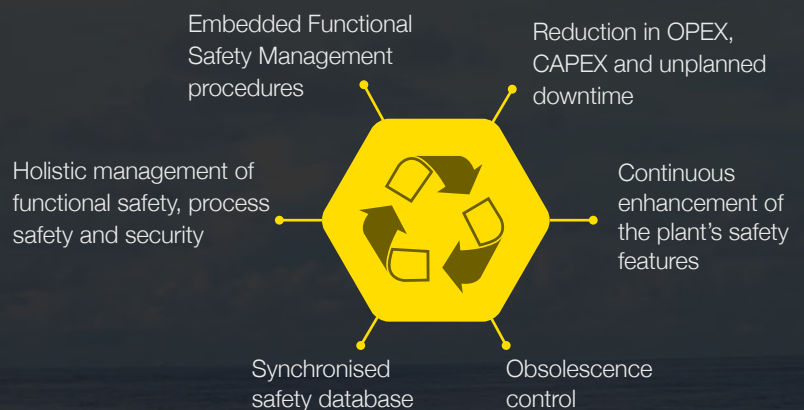
According to a multinational developer and operator of ultra-deepwater oil production platforms, a key operational benefit of sustainable SIS is the reduction of unplanned platform shutdowns.

From an operational standpoint, their SIS installation in Southern Africa was deemed a sound business decision due to it maximising productivity where each day equates to 160,000 barrels of oil.

Their sustainable SIS implementation also conveniently records and collates statistical data which is used to update their layer of protection analysis (LOPA) every 5 years. Generation of validated reports whenever any shutdown occurs means that period proof testing is reduced. Having a sustainable SIS implementation also presents a strong indication of the operator's corporate responsibility to its shareholders and stakeholders.

The benefits that end users can derive from adopting sustainable SIS are tangible in terms of safety compliance, revenue maximisation and operational cost reductions.

## Benefits of sustainable SIS



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# 1 Sustainable SIS Solutions

## 1.1. Overview

Future proofing a plant's operational safety performance involves understanding existing safety challenges and effectively identifying potential safety risks. Degradation of hardware, non-compliant legacy software and operator staff turnover are just a few of the predictable factors that will impact the lifecycle of a SIS. Being able to account for these factors can be a complex task. However, designing a SIS with a focus on sustainability can alleviate the risks of a safety system becoming obsolete and the plant can derive maximum operational benefits during its lifetime.

Sustainable SIS solutions can enhance a business through optimal management of safety risks, minimising plant downtime and establishing a reputable safety track record. An incident-free plant is a measure of the company's safety compliance culture and has a positive influence on stakeholders. Having an established safety track record helps retain high performing employees, obtain expansion permits and reinforce a longstanding relationship with safety regulators.

Table 1 summarises the enhancements offered by sustainable SIS solutions compared to conventional SIS. Each feature is described in greater detail in the subsequent sections of this whitepaper.

Features	Conventional SIS	Sustainable SIS
 System complexities	<ul style="list-style-type: none"><li>• Difficult to interpret, configure and operate SIS solutions</li><li>• Requires specialised skill from extensive training and experience</li></ul>	<ul style="list-style-type: none"><li>• Better visualisation of process behaviour during plant start-up or process upsets</li><li>• Intuitive user interface of safety applications</li></ul>
 Safety integrity reports	<ul style="list-style-type: none"><li>• Report format is not user-friendly or ready for interpretation</li><li>• Data gathering and analysis are time-consuming</li></ul>	<ul style="list-style-type: none"><li>• Raw data is automatically converted into comprehensible formats</li><li>• Automated and real-time documentation of the plant's safety status</li></ul>
 Management of change	<ul style="list-style-type: none"><li>• Changes are sometimes manually documented</li><li>• Difficult to trace and compile modifications chronologically</li></ul>	<ul style="list-style-type: none"><li>• Automated change management process</li><li>• Easy access to historical records for auditing purposes</li></ul>
 Capital and operational expenditures	<ul style="list-style-type: none"><li>• Safety operators and managers may maximise safety parameters irrespective of cost</li></ul>	<ul style="list-style-type: none"><li>• CAPEX reduction through optimal safety performance</li><li>• OPEX reduction through integrated automated management of change</li></ul>



## 1.2. Enhancing a Conventional SIS into Sustainable SIS



Instigating automated management of change as a means of OPEX reduction.

Embedding functional safety requirements into a SIS solution database.

Software tools to manage historical and operational safety data.

Effective safety lifecycle support infrastructure.

These relational enhancements are a holistic approach for SIS managers to retake ownership of their safety systems in a manageable and sustainable manner. Devices of any kind are susceptible to the effects of wear and tear or degradation. In view of operational integrity, vigilant ownership and regular maintenance schedules will constrain the operational risks within predictable levels throughout the plant's lifetime.

Sustainable SIS is regarded as the next evolutionary step for plant safety systems and it aims to provide key decision makers with the following benefits:

**The ability to robustly configure their safety processes on an ad hoc basis while maintaining regulatory compliance.**

Sustainable SIS solutions are likely to have more accessible and user friendly interfaces that can be understood and configured by a wider group of personnel instead of just maintenance engineers.

Essentially, this provides better visualisation of the process behaviour in the event of a fault as well as their associated trip analysis and risk mitigation actions. Moreover, offline simulations prior to deployment are a feature that will allow SIS operators to verify their designs and assess the consequences arising from overriding Safety Instrumented Functions (SIFs).

**Managing the transfer of knowledge from the project team (realisation phase) to the maintenance team (operation & maintenance phase).**

The workforce structure in conventional SIS categorises all the subject matter experts as part of the project team, which includes SIS vendors, EPC (engineering, procurement, and construction) firms and end users. Documenting and conveying the knowledge from one phase to the next helps maintain globally consistent implementations.

**Embedded Functional Safety Management (FSM) procedures that are compliant with IEC 61508 and IEC 61511 standards to ensure that the implementation is fail-safe and deployed using recognised best practices.**

A completely digitised database management system encourages consistent documentation and synchronisation of updates across the database. Fundamentally, this form of automated management of change helps to uphold the overall consistency of safety system information and allows smooth project execution. Furthermore, easy access to historical safety records simplifies the regulatory auditing process. Being able to track, identify and remove unauthorised changes on the SIS is an important benefit to mitigate cyber-security threats.

**Obsolescence control of legacy SIS implementations is a crucial factor to consider due to the rapid and frequent advancements in process and safety platform technology.**

It is important for SIS vendors to design technology migration features in their safety systems to assist existing SIS operators in upgrading their incumbent legacy systems.

**Continuous enhancement of the plant's safety features by dynamically adapting the SIFs.**

The differences between the expected and measured safety key performance indicators (KPIs) will be used to improve the SIFs, as illustrated in Figure 1.

**Figure 1:**  
Continuous  
improvement of  
plant safety  
performance



### 1.3. Role of SIS Vendors

SIS vendors are likely to play an increasingly important and expansive role throughout their customer's plant lifecycle. Sustainable SIS implementations will present new opportunities for vendors such as:

- Providing value-added services to address the operation and maintenance of their customer's SIS implementations. In taking the long term view of sustainability, SIS vendors have opportunities to extend their role as a main automation contractor (MAC) and continue to provide support services throughout the plant's lifecycle. The customer implements a sustainable SIS, while the vendor has a recurring service-driven revenue stream.
- Generation of rigorous Safety Requirements Specification (SRS) is a crucial process for any SIS solution as this defines the requirements that form the basis for the safety specifications and deliverables. Vendors have to ensure that they have the right technology to ensure accurate and complete representation of the customer's safety requirements at the design phase and for changes throughout the plant's lifecycle.
- Proper documentation of amendments and updates to the safety application reduce potential sources of errors that may accelerate degradation of the SIS. Vendors need to design suitable documentation protocols that will help maintenance engineers track and address questionable changes to the safety system. SIS operators often work under tight project schedules and in some cases, stressful environments, which can lead to safety shortcuts.

*"Having the SIS vendor support our hardware and software troubleshooting efforts is extremely important especially since our safety processes requires revalidation on a yearly basis."*

Senior Automation Engineer in a global chemicals manufacturer that is headquartered in Dallas, Texas. Operates the DCS and SIS implementations in chemical plants across Southeast Asia

### 1.4. Key Success Factors for Sustainable SIS

Integrating sustainable features into an established market such as SIS requires the cooperation of every stakeholder in the value chain. Key to the success of sustainable safety systems are:

- Implementation of a SIS that is easily maintained throughout the lifetime of the plant.
  - Incorporating a FSM structure that is understood by safety personnel from all levels of competency.
  - Automated change management processes that ensure the plant's safety integrity throughout its lifecycle.
  - Having a synchronised safety database that provides proper historical and real-time documentation of the safety status of the plant.
- Designing a sustainable SIS solution requires a holistic perspective of each stage of the safety lifecycle and their influence on the total lifecycle. This includes the safety hardware (sensors, logic solvers and final elements), application program, user interface and all related human factors of the safety system.
- By embedding sustainability into SIS solutions, vendors are allowing their customers to retake ownership of their safety operations. More importantly, safety management and compliance becomes a practicable task that can be understood and adapted according to the customer's changing requirements and increasing regulatory pressures.

## 2 Challenges in Using Conventional SIS

### 2.1. Complexity

Operation and configuration of SIS requires extensive knowledge and it is a niche skillset that is often limited to well-trained and experienced employees. Making SIS more transparent to a wider range of personnel would improve the understanding of the SIS' purpose and how to efficiently recover from incidents.

Senior Automation Engineer in a global chemicals manufacturer that is headquartered in Dallas, Texas. Operates the DCS and SIS implementations in chemical plants across Southeast Asia.

*"Understanding the operation of SIS requires specific technical expertise and we need more safety operators and engineers that are knowledgeable about SIS."*

Senior Instrumentation Control Engineer and Project Manager in a Malaysian petroleum conglomerate. Supervises the implementation of safety systems for oil & gas facilities in Southeast Asia.

*"The main challenge in operating and maintaining a SIS in my facility is software errors from the supplier and also on our side. The time spent interpreting them can be better utilised elsewhere."*



### 2.2. Effective Database Management

In many conventional SIS solutions, the FSM procedures are performed independently from the safety application program. On a global rollout, this can become cumbersome to synchronise and manage quality control. In some cases, the safety checks and documentation are distributed across several databases, which further complicate the management of functional safety. Documentation of changes to the FSM is often conducted manually and this increases the difficulty to trace and compile modifications chronologically.

Additionally, maintenance engineers sometimes find that conventional SIS solutions are not able to reflect the present SIS status due to improper documentation of changes or incomplete handover procedures between personnel. These situations can be prevented by having an effective database management system that maintains the consistency of safety system data with the current application.

For these reasons, manual implementations of FSM processes are not a sustainable means of managing such a complex and labour intensive feature of SIS.



### 2.3. Tangible and Intangible Costs

Size of plant, number of input/output (I/O) modules and choice of vendor are several factors that are likely to affect the capital expenditure on a SIS solution. Apart from capital expenditure, the operating cost per SIS unit should also be taken into consideration. In the oil & gas industry, if the price of the commodity decreases, producers are less willing to invest to upgrade their SIS.

Operation of safety systems is a specialised skill that requires intensive knowledge and experience, therefore training costs cannot be neglected. Training SIS operators and managers may take months and in some cases up to 2 years, depending on their prior experiences and the competency level expected from them.

*“In the oil & gas industry, having 1,000 to 2,000 field instrumentation I/Os for a SIS is common and this could cost between US\$450,000 and US\$1.5 million.”*

SIS Engineer in an international oil & gas exploration and production company from Canada.  
Works on oil & gas exploration projects across Southeast Asia.

*“My budget for SIS ownership ranges from US\$250,000 to US\$750,000 and this depends on the complexity of the solution. This is for a turnkey solution that involves design, engineering and implementation.”*

Automation Supervisor of a midstream oil & gas service provider in Texas, US.  
Manages four natural gas processing plants with total production of 1.1 billion cubic feet per day.

*“For a floating production storage and offloading (FPSO) facility with daily production of 20,000–70,000 barrels, staff training may cost US\$200,000 to US\$300,000.”*

Chief Procurement Officer at a Fortune 500 oil & gas company.  
Manages the safety processes of an FPSO in West Africa.

### 2.4. Monitoring and Analysing SIS Performance

Safety status reports from conventional SIS typically record past events and alarms in a format that is not user friendly or formatted for easy interpretation. The raw data has to be segmented, grouped and analysed according to the relevant SIFs for it to be associated with parameters such as demand frequency, output response time and the duration that the SIFs are in operational mode, to name just a few.

For more complex SIS implementations, producing and interpreting safety status reports is a time consuming task as the conversion of raw safety data is still performed manually. The quantity of data to be analysed increases with time and in cases where the safety data has to be stored throughout the plant's lifecycle for auditing purposes, data management and storage becomes a major challenge.

*“Gathering information for the safety status report is a time consuming task that would benefit from simplification. In my plant, it may take at least an hour to query the SIS. This is conducted on a daily basis to identify alerts.”*

Automation Supervisor of a midstream oil & gas service provider in Texas, US.  
Manages four natural gas processing plants with total production of 1.1 billion cubic feet per day.

*“Open source software is gaining popularity as SIS customers prefer to use non-proprietary components and essentially having the freedom to mix and match safety components from different vendors. In this case, it would be more convenient to process the raw data using open source software and not be constrained by the vendor's software.”*

Former Chief Procurement Officer at a Fortune 500 oil & gas company.  
Manages the safety processes of an FPSO in West Africa.

# 3 Creating Sustainable Value

## 3.1. Finding a Balance Between Plant Safety and Cost

Industrial processes are becoming progressively complex with risks that are often inherently indeterminate, which makes quantifying the safety risks of an evolving process a challenging task. It is not possible to be justifiably certain of every possible outcome of real-world processes, therefore assessing the possibility of loss and acknowledging the existence of safety risks are important tools of safety systems. Identifying, understanding, quantifying and finally mitigating all possible safety hazards in a process plant will always remain an ongoing challenge. Even more so if the plant has to evolve and adapt to changing industry trends.

Key decision makers would have to establish a balance between safety compliance, costs and revenue. The latter is a factor that is correlated with plant downtime. Often, the simplest option is to maximise safety irrespective of cost but this is likely to result in an over-designed SIS. Contrastingly, under-designing a SIS results in intolerable levels of risk and a lack of safety

compliance. These two examples are sub-optimal implementations that could lead towards excessive proof tests, higher degradation rates or, in the case of safety alarms, unnecessary triggering in an over-designed SIS or a failure to trigger in under-designed systems. Essentially, a SIS would benefit from a holistic assessment of the hardware, software and human factors in a plant. This would also result in a more accurate representation of its safety KPIs.

For safety managers that oversee SIS at several locations, having a database that automatically manages and documents the changes across facilities is crucial. Collectively, these examples highlight the importance of incorporating sustainable design methods into SIS implementations. Sustainability is a concept that is gaining popularity as it affords key decision makers with an opportunity to retake ownership and actively manage their safety systems. It is a means of future proofing their plant's safety requirements and simultaneously managing their operational and capital expenditures.



### 3.2. Sustainable Work Environments

Historically, the concept of sustainability was strongly correlated with “going green”, in other words, pursuing and implementing policies that are environmentally friendly and responsible. Recent interpretations of sustainability are holistically inclined and focus on corporate strategy, product branding, engineering processes and meeting regulatory and statutory requirements amongst many others.

In 2015, the UN established seventeen Sustainable Development Goals that aim to eradicate poverty, protect the earth and ensure collective prosperity. The overarching aim is to create secure and safe working environments, to reinforce risk mitigation procedures and to ingrain disaster preparedness, especially in sectors such as chemical, petrochemical, oil & gas and power generation to name just a few.

Over the years, several safety-related organisations such as the International Electrotechnical Commission (IEC), Occupational Safety and Health Association (OSHA) in the US

and the Health and Safety Executive (HSE) in the UK were established to develop industry-specific standards and regulations. Regulatory compliance is a step towards disaster prevention and, to a larger extent, risk mitigation. Excruciating incidents such as the Unchahar boiler blast in India, the Piper Alpha gas explosion in the North Sea and the Deepwater Horizon oil and gas eruption in the Gulf of Mexico highlight the need for reliable safety systems and processes. For this reason, industrial processes are governed by the design and operation of SIS.

The ability to holistically account for the safety, security and risks in a process plant is a core component of operational sustainability. More importantly, it is an opportunity to retake ownership of plant safety and directly influence its design and FSM throughout the lifecycle of the plant.

Similar principals of sustainability are increasingly applied to SIS for the purposes of upholding the integrity and reliability of safety systems in a process plant.



### 3.3. Risk Factors and Challenges

A manufacturer's track record is highly dependent on the performance of its production plants, which in turn, depends on the safety and state of their facilities, working environment and processes. The onus is on the end user to ensure that they have identified the risks that would affect their production line and this is the challenge that most maintenance engineers face; quantifying real-world processes into an automated safety system that is capable of mitigating the inherent risks.

In an industrial setting, projects are often classified into greenfield or brownfield developments. The latter requires a review of their Functional Safety Management plan in accordance with new compliance specifications. OSHA, for example, recommends revalidation of existing processes every 5 years to ensure that the preceding safety analysis is still applicable. The challenges that SIS operators face are similar irrespective of greenfield or brownfield projects and these include:

- Effective cost management in terms of safety, revenue and costs (capital and operational expenditure).
- Identifying, quantifying and assigning the relevant safety functions for each safety protection layer.
- Accurately documenting the SRS.
- Shutting down the plant to perform maintenance and repair works on the SIS.
- Having competent and trained SIS operators throughout the lifecycle of the plant.
- Maintaining safety integrity throughout the plant lifecycle.

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### 3.4. Regulatory Standards: IEC 61508 and IEC 61511

The regulations surrounding SIS specifically addresses the concerns about functional safety, a concept that is defined by the IEC as:

*"Functional safety is the part of the overall safety that depends on a system or equipment operating correctly in response to its inputs. It is the detection of a potentially dangerous condition resulting in the activation of a protective or corrective device or mechanism to prevent hazardous events arising or providing mitigation to reduce the consequences of the hazardous event."*

Accordingly, SIS solutions are regulated by two international standards, the IEC 61508 and the IEC 61511. The former ensures that the safety system achieves the required Safety Integrity Level (SIL) whereas the latter governs the application of SIS for industrial processes, which is the focus of this paper. A key component of IEC 61511 is clause 16, which requires that the applicable SIL of each SIF be upheld during operation and maintenance. In addition, the SIS should be operated and maintained such that the functional safety is also maintained. The implications of IEC 61511 clause 16 on SIS operators and managers are that they must perform the following tasks:

- Conduct regular maintenance and proof testing of their SIS.
- Maintain adequate documentation of process data and certification of test and inspection procedures.
- Ensure that safety personnel are trained and assessed accordingly and regularly.

Inherently, the fulfilment of IEC 61511 clause 16 requires principles of sustainability to be ingrained into the lifecycle of SIS solutions. In other words, planning ahead to account for preventative and reactive operation and maintenance of the SIS.





# 4 Evolution of SIS technologies

## 4.1. Data Management

As regulations and standards become stricter, SIS customers will benefit from automated data management and synchronisation to track safety KPIs. Examples of safety KPIs may include activation frequency of final elements, proof test scheduling and activation of SIFs amongst many others.

Such features can expedite the extraction and management of data for process audits and business intelligence purposes. Future SIS implementations will also need robust cyber-security measures to protect safety data and this has been accounted for in the latest updates to IEC 61508 and IEC 61511.

Senior Automation Engineer in a global chemicals manufacturer that is headquartered in Dallas, Texas. Operates the DCS and SIS implementations in chemical plants across Southeast Asia.

*"We are dependent on our SIS vendor to have replacement parts on hand because the hardware components suffer from degradation and in some cases, for upgrading purposes."*

## 4.2. Predictive Maintenance

Operators are looking at SIS with effective predictive maintenance capabilities to reduce inefficiencies and detect problems sooner. A SIS solution must come with statistical and analytical software that can analyse future possibilities of breakdowns before they happen. Ideally, a SIS solution that can simulate functionality and interaction of safety functions during operation and maintenance, without affecting or requiring process downtime, is preferable. This would help reduce maintenance costs by avoiding unplanned plant shutdowns.

## 4.3. Service-driven Business Models

SIS vendors are increasingly adopting holistic approaches to identifying and managing risks. The pervasiveness of Big Data and IIoT are key enablers for ad hoc data management and consequently, the development of service-driven business models. Under such circumstances, the customer would be able to engage their vendor to provide robust enterprise-level services that are correlated with monitoring and management of the plant's functional safety and by providing operational support when required.

Equally important is a total package solution from the SIS vendor that can incorporate all documentation of testing and operational changes that might otherwise be hidden or missed throughout the lifecycle of the SIS. The abundance and availability of safety KPIs is a key enabler for optimising safety levels without compromising on revenue, CAPEX and OPEX.



# Conclusions



The embodiment of sustainable SIS is when customers can focus on their core business with the sound knowledge that their operational safety will be rigorously upheld for the lifetime of the plant.

The complexity of conventional SIS implies that the majority of end users often treat it as a black box and sustainable SIS aims to address this by making many aspects of the system accessible to a wider group of personnel. In doing so, safety managers can optimise their safety requirements instead of maximising safety irrespective of cost. In other words, over and under-designing SIS solutions need to be a thing of the past, favouring optimal solutions that ensure safety compliance.

Finding a balance between safety compliance, productivity, revenue and cost is an overbearing issue that management teams often have to deal with; sometimes successfully, sometimes with dire outcomes. Sustainable SIS aims to address the limitations present in conventional safety systems by ensuring adaptability to probable changes in a plant during its lifetime.

Sustainability is an attainable goal with many long term benefits and it presents an opportunity for corporations to craft a legacy in their industry. Sustainable SIS aims to promote longevity for industrial processes and allow safety managers to better manage and oversee their plant's operational safety performance.


The challenges in creating a sustainable SIS are not insurmountable, rather the underlying constraints are commonly found in many sustainability initiatives. Cost, complexity, digitisation and being able to appreciate the foreseeable trends that could impact the industry are several challenges that could hinder widespread implementation of sustainable SIS. Nevertheless, without these challenges, the motivation to innovate and adapt to the changing safety requirements would have been minimal.

The future of SIS, like many industrial processes, is likely to have sustainability and automation at its core, giving key decision makers a peace of mind. Equally important, it allows companies to fulfil their responsibility to protect their employees from operational hazards through strict and consistent adherence to industrial safety regulations.

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