

Yokogawa: Empowering Systems of Systems

Success as a Trusted Partner

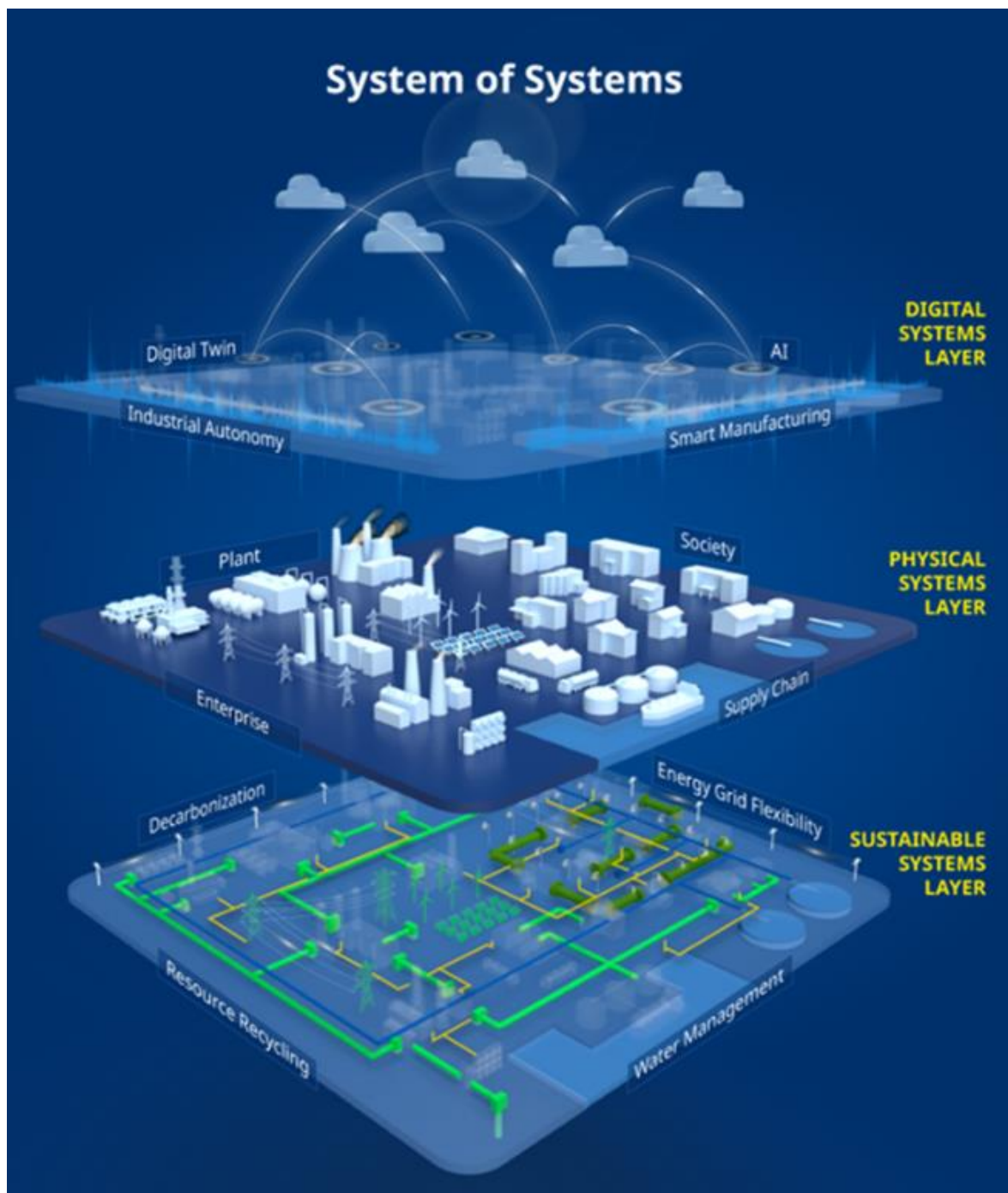


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Purpose of this internal brief

The intent of this brief is to define what internally what system of systems (SoS) are and why they are important for Yokogawa, our customers, and society. For a long time, Yokogawa has been integrating systems at the plant level. Over the past several years, there has been an emphasis on digital transformation which requires integrating more systems. Some of these systems extend to the enterprise level and even beyond to include partners, other companies, industry clusters and even societies.. Part of the objectives of an SoS is to achieve higher internal efficiencies as well as cooperate with other companies to address decarbonization and other issues. The urgency for transformative actions to mitigate climate change is a top priority. Every effort is being made for companies to reduce their dependency on fossil fuels and adopt low-carbon technologies, and energy efficient processes to decrease GHG emissions. Industry clusters are beginning to collaborate and share resources and this trend will accelerate over the next several decades to attain sustainable development goals (SDG). Yokogawa will play a key role in helping companies and society reach SDGs by leveraging its key strength in its ability to integrate and support SoS.

Yokogawa has been promoting the term “System of Systems” since the release of AG2023 in May 2021. This brief document summarizes the established messaging, market research, and internal business feedback on the SoS concept. Also, this document introduces new concepts, content and positioning

that builds upon what has been used by Yokogawa to describe and position System of Systems in the past. The content contained in this document should be used across businesses in Yokogawa to promote the Systems of Systems concept and to present to the marketplace as well as show Yokogawa's unique competencies to serve the System of Systems market.

1. Introduction and establishment of a System of Systems

Introduction of System of Systems

“System of Systems” (SoS) is a term that has been used since the 1950s to describe systems that are composed of independent constituent systems, which act jointly towards a common goal producing synergy between them. SoS arise in many areas, such as energy technology, transportation, production, and the military.

In understanding the difference between a hierarchical complex system and a System of Systems, as an example, consider an airplane flying and an airport operating. The airplane, while flying, is an example of many complex systems that operate various parts of the plane, but the plane flies when all its systems work in tandem and does not fly if the systems work independently of each other.

An airport in operation is another complex system; however, airport operations involve many things, such as aircraft, support trucks, baggage-handling equipment, and many other systems that can and do operate independently of each other. For the airport to function, it needs to have the right mix of these independent systems, and these systems need to cooperate with each other. The airport in its operation can be considered a System of Systems as this is an integration of many independent, self-contained constituent systems (also called sub-systems) to satisfy an overall need.

According to the International Council on Systems Engineering ([INCOSE](#)), traditional systems engineering is challenged by Systems of Systems because of the independence, heterogeneity, evolution, and emergence properties.

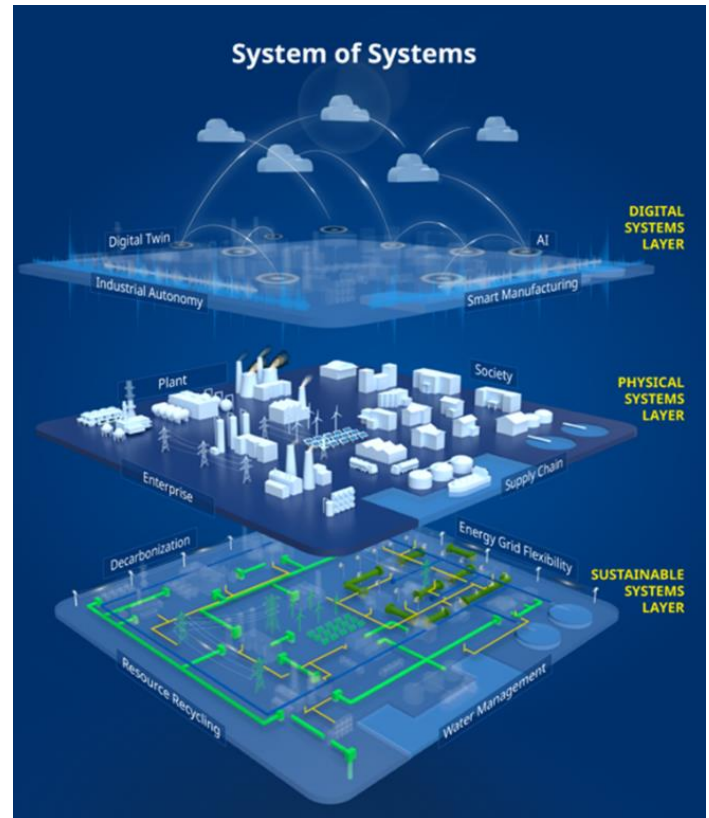
Today, many participants within companies, supply chains, and society overall face an increasingly interconnected and complex environment in which normal applications and practices around systems are not adequate, and SoS principles and best practices need to be applied to ensure positive outcomes.

System of Systems in Manufacturing

SoS in manufacturing is not new and can be applied at many distinct levels from unit operations on the plant floor, the enterprise to across supply chains. Today, with new societal pressures and technological advances SoS activities in manufacturing are driven by:

1. **Technological advances of AI and digitalization-**

- The introduction of advanced digital technologies gives additional incentive for businesses to consider collaboration with other firms through:
- Digital interconnectedness- As data accumulation and analysis continue to advance, it becomes easier to share data and analysis across systems.
 - Virtuous cycle behavior - As constituent systems advance in autonomous operations and digital connectedness, the incentive to interconnect with other systems becomes compelling, and distinct advantages occur.
 - Advances in digital twin technology – As more systems are modeled and optimized by using digital twin technology, it becomes easier to connect and model the proposed System of Systems connections to predict synergistic and emergent value.
- ### 2. **The constant business pressure to become more efficient**
- There has been a long-term drive for businesses to cluster and collaborate for mutual benefit to improve efficiency and increase advantage over competitors. Since the establishment of the first Industrial cluster ([Verbund](#)) sites in Europe, this trend has continued to grow.
- ### 3. **Sustainability**
- With the increasing governmental and societal pressure to increase sustainability, firms are responding with additional efforts to collaborate across established systems to improve sustainability performance such as Environmental, Social, & Governance (ESG) goals and other efficiencies to minimize waste and emissions.



2. Definitions and concepts of SoS adapted by Yokogawa.

Background- Concepts brought to Yokogawa, Investor relations messaging, and AG2023.

In May 2021, Yokogawa published the mid-term business plan AG2023 with a significant focus on sustainability. In outlining future market presence and the value proposition to customers in 2030 introduced the concept of a System of Systems. Among several presentations and other content published on AG2023, the most in-depth content found was the “Accelerated Growth

2023” booklet which contained the following aspirational statement on page 11 discussing value provision to customers.

“In the world today, everything is increasingly interconnected in complex ways, and it is becoming ever more important to capitalize on that interconnectedness by engaging in co-creation. To provide value, we will focus on the System of Systems concept, we will pursue our IA2IA and Smart manufacturing initiatives.”

Additionally, AG2023 defined an SoS as a “System of independently operated and managed systems that work together to achieve a purpose that cannot be achieved by any one system”.

Beyond AG2023 – New definitions and concepts

As Yokogawa has pursued the goals of AG2023 and has expanded and refined the internal knowledge of Systems of Systems, it continues to build the messaging of the concept and defined the definitions to align with stakeholders. Because the concept of Systems of Systems is used across many human endeavors, there are many definitions of the concept, many crafted to focus on the field of an author’s and readers interest and perspective. It was decided that Yokogawa should support two definitions on for a general audience and another for stakeholders of an SoS.

SoS definition - For general audience

For an overview definition, Yokogawa has adopted a definition created by the International Council on Systems Engineering (INCOSE). INCOSE is an industry organization that focuses on system engineering and has the most comprehensive body of knowledge of the System of system concept.

“A System of Systems (SoS) is a collection of independent systems, integrated into a larger system that delivers unique capabilities. The independent constituent systems collaborate to produce global behavior that they cannot produce alone.”

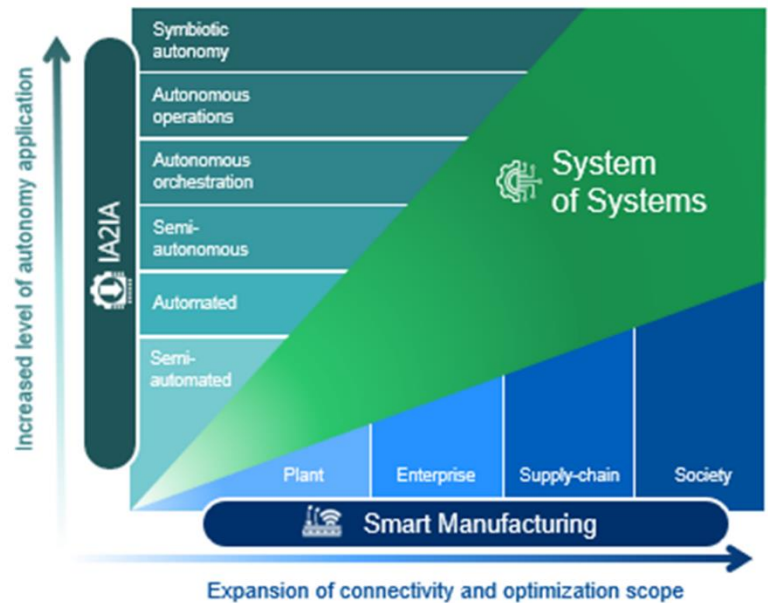
This definition is useful to Yokogawa in many cases such as introducing Yokogawa’s interest and concepts to the public and potential future stakeholders in the endeavors that Yokogawa is involved in.

Stakeholder definition of SoS

To pursue the markets that Yokogawa is concentrating on, it is also important to have a more focused definition of SoS to represent the value of understanding the concept from the perspective of Industry and society. This stakeholder definition also keeps the IA2IA/SoS/Smart manufacturing relationship which is summarized in the graphic to the right in context.

Yokogawa’s definition of SoS for stakeholders is:

“Yokogawa defines System of Systems (SoS) as a collection of independently operated and managed systems connected to form a larger system that delivers synergies and emergent value to all stakeholders in a plant, enterprise, supply chain, or society ecosystem.”



To break down the SoS definition into a detailed explanation of each of its components:

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| “Collection of independently operated and managed systems” - | This is the key statement in differentiation between a hierarchical complex system and a system of Systems. There must be some level of sub-system independence and it depends on the scale on which the SoS is defined. For example, at a plant level, it may be different unit operations that are managed by their own departments. |
| “Connected to form a larger system” | Connections can be a multiple of things such as energy, material, waste, and/or information connections. |
| “Delivers synergies” | Created when two or more entities(constituent systems) interact or collaborate to produce a combined effect that is greater than the sum of their individual effects. The value results from cooperation, collaboration, or interaction between the parts, leading to improved efficiency, innovation, or competitive advantage. |
| “Emergent value” | Arises from the interaction of entities within an SoS, where the overall value output cannot be exactly predicted beforehand. The value is observed when the relationships and interactions between entities lead to new properties or behaviors that were not present or apparent by the individual systems themselves. |
| “to all stakeholders” | All participants that commit resources to the SoS. |

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| “Plant, enterprise, supply chain, or society ecosystem” | This is the general boundaries of the SoS. These four “Ecosystems” stated are the areas that Yokogawa is currently involved or aspires to be involved in. |
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3. Yokogawa’s competencies in the context of SoS

Over the years, as industry has evolved through the distinct levels of industrial revolution from the basics of Industry 1.0 to the emerging digital era of Industry 4.0, Yokogawa as a participant in the market has built up many intangible qualities to serve customers and other stakeholders. These qualities over time market. As industrial enterprises supply chains, and industrial clusters have started to collaborate more, Yokogawa has been recognized across companies as a valued partner in collaboration within and across companies. This is best expressed as core competencies of SoS. These 25 identified competencies in the following chart are known across our customer base through our actions and deeds and not through marketing. The core competencies fall into four categories.



Please find below the details of the core competencies:

Cultural Foundation core competencies - Yokogawa’s culture of building trust and breaking down silos both with and between companies and taking advantage of data integration.

- **Strong Collaboration with customers to achieve new and innovative solutions.** Yokogawa strives to be at the forefront of transforming these complex challenges into valuable technology and services together with its partners. ‘By joining forces with partners within existing markets and entering partnerships in new areas, we make sustainable innovation in the industrial sector possible.-Through a smart approach that involves cooperation in essential areas or looking beyond the boundaries of the established domain, we work with customers to achieve results

that really matter in terms of people, the environment, and the economy. While co-innovation may sound like a recent buzzword, Yokogawa has been doing it for years. By always putting the right people in the right places and looking at each challenge from different angles, Yokogawa boosts the innovation success rate.

- **Deep roots in Operational Technology (OT)** Since the introduction of instrument and recording products in 1951, Yokogawa has been deeply involved in the manufacturing operational technology space supplying reliable solutions to a diverse group of customers globally.
- **Trusted long-term committed partner to many companies.** As a Japanese company, Yokogawa's major driver behind the emergence of their business philosophy is 'Sanpo Yoshi', meaning three-way-satisfaction. It is a way of doing business in Japan that emphasizes a win-win-win relationship for sellers, buyers, and society. This philosophy was primarily advocated by merchants in Shiga Prefecture over 200 years ago. It was then believed that when sellers and buyers reach mutually satisfactory terms, and when the local community is satisfied with the outcomes of the transaction, it makes for good business. It is said this belief is expressed by the term Sanpo-Yoshi.
- **Demonstrated track record of world-class safety standards and culture.** Yokogawa provides process safety services to assist clients to meet their obligations and comply with many global safety regulations. Yokogawa has specialized in the IEC 61511 Safety Lifecycle requirements, regardless of the lifecycle stages being examined. Whether it be from the preparation stage through to report finalization, we work closely with our clients to ensure that all gaps are bridged, and the activity is carried out as efficiently and smoothly as possible.
- **Established reputation of working well with other vendors.** As an experienced system integrator, Yokogawa has spent years working with other technology suppliers to bring together world-class solutions. Our clients are look for best-of-breed components, the process knowledge, and skills to blend these technologies together to achieve their desired outcomes and Yokogawa is always ready to work with the customer's preferred technology vendor for different components to build solutions that are optimal for their requirements.
- **High reliability – resilient and robust hardware and software systems.** Generation after generation Yokogawa control systems and project execution consistently deliver the industry's most reliable solutions. Since inventing the DCS in 1975, Yokogawa customers have achieved real world system availability of 99.99999% Seven nines means less than one minute of DCS related downtime in ten years. Delivering the most reliable DCS automation in the world. Over four decades and billions of hours of industrial production, only Yokogawa customers have enjoyed future-proof progressive compatibility where even the earliest systems work side by side with the latest and greatest technologies.

Integration-core competencies- Yokogawa's in-depth knowledge of integrating different systems across organizations.

- **Solutions Leverage cloud solutions technology and consulting services.** Yokogawa Cloud is a digital innovation platform that accelerates the development and deployment of industrial cloud applications. Yokogawa builds platform applications and solutions on behalf of customers through digital transformation consulting. The Cloud solution platform supports the ingestion, processing, and curation of data from various sources, provides industry-specific algorithms and models, and integrates across applications to support insightful decision-making and advanced levels of automation and autonomy.

- **Committed to open interoperable standards through participation, piloting, and adaptation .** Yokogawa actively participates, contributes, and adapts many OT and IT standards globally and emphasizes the benefits to customers. International standardization activities are one of Yokogawa's important R&D strategic elements of maintaining and expanding global business.
- **IT/OT integration, convergence, and harmonization experience.** In recent times, the digital revolution and technological innovations such as artificial intelligence, Internet of Things (IoT) applications, and the cloud have led to a crossover of IT and OT and a blurring of traditional boundaries.
- **Global experience in working with many stakeholders in plant, enterprise and supply chain environments.** Yokogawa supplies many Solutions that support optimization of all parts of an enterprise and supply chain, from raw material supply to product delivery, and help to ensure that business operations can respond quickly and efficiently to market changes and shifts in demand.
- **Experience in Intercompany integration.** As demonstrated with the support of the O-PAS standard and the extensive collaboration with ExxonMobil, Yokogawa has been developing, testing, and improving OPA technologies through the joint operation of an OPA test bed located near ExxonMobil's Houston, Texas campus. Yokogawa globally supports and collaborates with many partners to achieve the best solutions for customers.

Knowledge & Expertise Core competencies. Yokogawa's broad-based knowledge in business, technical, economics and social goals.

- **Expertise in data communication technologies and protocols** Yokogawa has been leading industry as one of the pioneers in field digital technologies represented by the Foundation fieldbus™ and Field Device Tool/Device Type Manager (FDT/DTM). Yokogawa has also participated from the early stages in standardization activities in the technical fields of industrial wireless sensor networks which will be a step toward the next evolution, and has contributed to a diverse range of industries.
- **Decades of experience in serving the industry requirements energy, consumer goods, and utilities.** From traditional industries in energy, manufacturing and consumer goods to new emerging sustainable industry technologies, Yokogawa has established itself as a trusted partner to many companies in many industries.
- **Efficient engineering and project efficiency delivery** - Yokogawa has Innovative, world-class project implementation capabilities, built on a strong track record of success all over the globe. Yokogawa delivers total IT/OT solutions that cover the entire project and facility lifecycle with long experience and proven engineering, technology, safety, and lifecycle support capabilities.
- **Understand the impact and deployment of autonomous technology** Yokogawa is preparing the way for a future in which industries will make the transition from industrial automation to industrial autonomy (IA2IA). We offer a wide range of smart manufacturing solutions and digital consultancy services that will help customers on their digital transformation journey towards autonomous operations.
- **AI consulting and implementation services-** Yokogawa has been working on solving a variety of customer issues around AI that couldn't be solved with conventional analysis methods and have learned that in plants AI can offer value in several ways including Abnormal signal detection, root cause analysis, and quality estimation.

- **Design knowledge for reliable and stable systems** – Yokogawa has designed exceptionally reliable control technology that responds quickly to changes in management goals and operation conditions and establishes the foundation needed for high efficiency, high quality, safety, and stability in plant operations. Yokogawa offers multiple automation and control strategies, architectures, and solutions for every application size and complexity.
- **Actively participating in the development of international industrial security standards** . It is necessary to continuously work on cybersecurity measures and remain accountable for these efforts. Yokogawa has established a system to address cybersecurity threats to its products and shoulders its responsibilities and have also obtained external evaluations and certifications for each development system to ensure strong security.

Technology – Yokogawa’s world-class technology that supports continuous improvement and breakthrough capabilities.

- **Measurement and sensing**- Yokogawa, with its innovative sensor products and services, caters to the needs of industries. By engaging with multiple organizations, including customers, Yokogawa has been continuously providing innovative products and solutions for modern process needs such as high-performance sensors needed to ensure stable and high-precision performance under all circumstances.
- **Control systems** Yokogawa released its CENTUM distributed control system (DCS) in 1975, a world first. CENTUM VP is the ninth generation in the CENTUM series. Known for their rugged performance, CENTUM systems set high standards for engineering and technology excellence while ensuring backwards compatibility with previous system versions and support of the latest technology applications.
- **Information Technologies** – Through the application of many industrial projects that connect through the enterprise, Yokogawa has acquired extensive Information technology knowledge.
- **AI technologies** - Yokogawa leverages it’s extensive domain knowledge and expertise to provide optimal AI technology for process operations. Through an advanced understanding of industrial processes, customer sites, and AI technology, Yokogawa bridges the gap between data and practical insights in applying AI.
- **Process technology** – Through many decades of serving customers in a wide variety of process industries. Yokogawa has acquired detailed knowledge of process technologies through the application of control and measurement. In addition Yokogawa’s digital twin solutions offer benefits across a business’s operation, from asset management and manufacturing to supply chain solutions and data analytics.
- **Simulation technology (digital twin)** Yokogawa’s digital twin solutions offer benefits across a business’s operation, from asset management and manufacturing to supply chain solutions and data analytics. Many companies relying on real-time data from operations supply chain technology and plant process applications benefit from Yokogawa’s digital twin and model applications to meet a wide range of requirements.
- **Continuous and strong R&D commitment**- Yokogawa continuously spends approximately 7% of net sales on R&D activities and are continuously pushing forward with the development of new technologies, with basic research into measurement, control and information, and the development of advanced technologies and digital technologies such as IIoT and AI as the topmost management priorities. Yokogawa is strengthening initiatives to adapt to changes in international codes and standards, and to aid the realization of a sustainable society, the overarching goal of the SDGs.

4. SoS Roles and positioning for Yokogawa

Background and discussion of AG2023 positioning

With the publication of AG2023 and reinforced by Yokogawa's annual reports, sustainability reports, and company profiles, Yokogawa has consistently positioned our role as a "System of Systems integrator".

From statements in the AG2023 vision document

"Yokogawa aspires to become an integrator that will lead the way forward in realizing the SoS"

To what is stated in the 2022 annual report.

"As envisioned for the year 2030, Yokogawa will endeavor to provide value of the SoS to customers by leading the way forward as a system integrator in a world where societies function as a System of Systems concept."

In the 2022 annual report, Yokogawa has used the term "Integrator" as the primary positional statement in trying to convey to stakeholders the role that Yokogawa plays in emerging SoS ecosystems. However, the term "Integrator" in many contexts plays a limited role in bringing value to customers. In getting input from several CMU business heads as well as sales and marketing personnel, the general input is that the term "Integrator" in many cases in an IT/OT context has a limited role in implementing predetermined plans and decisions. We need to consider higher roles in interaction with stakeholders in a Systems of Systems environment that conveys planning, advice, and decision-making.

System of Systems positioning that conveys interaction at appropriate levels.

With extensive internal interviews and feedback across Yokogawa, it makes sense to use the "Trusted Partner" messaging at a high level, which conveys the roles of consultant and integrator in engagements with stakeholders in an SoS environment.

Yokogawa: Empowering Systems of Systems Success as a Trusted Partner

Yokogawa is an emerging leader in the domain of Systems of Systems and has a proven track record of providing comprehensive solutions that encompass strategic consultation and seamless integration. As a trusted partner, we guide organizations through the complexities of interconnected systems, offering strategic insights and innovative approaches to drive collaboration, optimize operations, unlock emergent value, and foster sustainable success. We achieve this by performing two distinct roles in an SoS environment.

1. **Consulting for SoS**- Providing comprehensive expertise throughout the process, ranging from initial economic analysis and business model formation to objective setting and trust establishment.
2. **Integration for SoS** - Providing seamless integration of cutting-edge technology solutions throughout all stages of growth and operation of a System of Systems (SoS)

SoS Positioning

Trusted Partner in SoS

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Consulting for SoS

Offering expertise starting from the SoS formation through economic analysis, forming business models, establishing objectives, and building trust.

- Finance Advisement
- Business Model Development
- Economic Analysis
- Stakeholder Facilitator
- Digital Transformation Advisement
- Regulatory and Permitting Advisement
- Government Relations Advocacy
- SOS Architect

Integration for SoS

Offering proven solutions and continuous integration of technology through every stage of growth and operation of an SoS.

- Workflow Orchestrator
- Lifecycle Manager
- Technology and Solution Provider
- Participant Facilitator
- System Performance Assessor

To successfully guide industries toward achieving SoS projects, within the roles in consulting and system integration, Yokogawa identifies certain activities that stakeholders need to fill to operate successfully under a SoS paradigm.

Consulting functions for SoS

Offering expertise from the beginning through building economic analysis, forming business models, establishing objectives, and building trust.

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| Finance Advisement | Work with stakeholders to plan funding to attract the most relevant market funding from private and public resources which will align with the goals of the SoS. |
| Business Models Development | Develop commercial models and risk-sharing initiatives across stakeholders that help accelerate the development of the SoS |
| Economic Analysis | Working with stakeholders to examine, analyze, and predict the economic drivers that will impact the SoS |
| Stakeholder Facilitating | Building trust among stakeholders at the 'C' level by forming and facilitating working groups to align the overall and individual interests of each of the stakeholders. |
| Digital Transformation Advisement | Developing strategies for stakeholders underlying the power of data to fuel advanced digital tools to drive greater efficiencies, resiliency, value, and sustainability across the SoS. |
| Regulatory and Permitting Advisement | Working with business and government stakeholders to navigate the complex process of permitting and regulatory compliance. |

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| Government relations Advocacy | Building relations with governments, think tanks and stakeholders in influencing policy and regulatory change. |
| SoS Architect | Defining, expressing, documenting, communicating, certifying proper implementation of, maintaining, and improving a System of System's architecture throughout a life cycle |

Integrator functions for SoS

Offering continuous integration of advanced technology solutions through every state of growth and operation of an SoS.

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| Workflow Orchestrator | Skilled in seamlessly integrating and harmonizing workflows across independent systems, utilizing autonomous, AI, and digital technologies to streamline activities and optimize efficiency. |
| Lifecycle Manager | Knowledge and experience in managing upgrades, testing, validation, and retirement required in subsystems throughout their lifecycle. Ensures seamless transitions and optimal performance over time. |
| Technology and Solution Provider | Yokogawa provides technology to support the growth and evolution of SoS such as AI, digital twin, sensing, control, and data management. |
| Participant Facilitator | Skilled in fostering collaboration among companies from diverse industries, leveraging their mutual understanding to drive synergistic and emergent value across all participants. Experience in bringing stakeholders together, identifying common goals, and facilitating cooperative efforts to maximize collective benefits. Similar to the consulting role but works at many interactive levels of the organization. |
| System Performance Assessor | Proficiency in establishing metrics and defining methods for assessing performance and conducting evaluations of performance. To benchmark for continuous improvement |

For many of the functions outlined in the above tables, Yokogawa has established consulting capabilities for individual customers but not necessarily for a system of systems environment. All must be aligned with the global IA portfolio work and the global consulting work of Working Group 10.

5. Industrial clusters are an opportunity for System of Systems Expertise.

Introduction

In a [January 2023 paper](#) titled “Transitioning Industrial Clusters towards Net Zero”, The World Economic Forum(WEF) goes into detail about how Industrial clusters throughout the world are collaborating to bring about change primarily from a sustainable objective. The paper also highlights 11 industrial clusters that are a part of the Transitioning Industrial Clusters towards Net Zero initiative sponsored by the WEF. In this paper and others that the WEF has produced do not mention the concept of a System of Systems.

But it is clearly a concept that they are utilizing. The report Net Zero initiative aims to build a community of one hundred industrial clusters, which balance economic, social, and environmental impact through strong and expeditious support of developing clean energy markets and maturing decarbonization technologies. Those

100 industrial clusters will represent 1.6 billion tons of CO2 emissions per year or 15% of global CO2 emissions. Through their decarbonization journey, these 100 clusters are expected to generate approximately 17 million jobs and contribute \$2.5 trillion to the global GDP

The following are two examples that Yokogawa has endeavored in industrial clusters that involve System of Systems and the roles Yokogawa has executed.

Joint Study to Achieve Carbon Neutrality at Goi and Soga Industrial Complex

In the Goi region, in the Tokyo Bay industrial area, there are 10 carbon intensive businesses, ranging from a refinery and a steel plant to a quicklime plant. Driven by the NEDO government agency, these companies are looking to reduce their carbon footprint through collaboration.

As a demonstration of a trusted partner, Yokogawa was commissioned to conduct a feasibility study to achieve carbon neutrality at the Goi Industrial Complex. The study, completed in March 2023, concluded that inter-industry collaboration in reducing CO2 emissions would be greater than companies working on their own and that the recovered CO2 can be effectively utilized by the companies located within the industrial complex.



Since the start of the study in 2021, Yokogawa has established itself in several roles that support the creation and maturation of SoS in this multi-industry industrial complex:

- Facilitating - Built trust among stakeholders by forming and facilitating working groups to align the overall and individual interests of each of the stakeholders.
- Assessing system performance – Built proficiency in establishing metrics and defining methods for assessing benchmarks for continuous improvement for all stakeholders.
- Economic analysis – Worked with stakeholders to examine, analyze, model, and predict the economic output that will impact the SoS.
- Providing technology and solutions – Cultivated expertise through work in many types of plants globally and improvements in processes and energy efficiency for single sites as well as the integration of multiple industrial sectors' sites, based on field-proven and advanced technologies.
- Resource Discovery - Worked with stakeholders to attract relevant funding.



Port of Rotterdam(POR)

The Port of Rotterdam Authority is the landowner and harbor master of the port. PoR has a very well articulated decarbonization vision, building a strategy towards CO2 neutrality. In line with this decarbonization vision, there are a number of projects that have emerged in the harbor area.

Yokogawa is involved in a similar project as Goi in Rotterdam and similar project challenges surface here. Together with Port of Rotterdam and other stakeholders, we are exploring the idea of creating an “Industrial Sharing Economy”. How would it be if, after each of the 200 plants in the Rotterdam Industrial Area, have optimized their own operations, we could share data and execute an overall optimization function for energy, CO2, hydrogen, electricity across the whole region.

PoR also recognizes that digital technologies can potentially unlock significant opportunities to accelerate the delivery of the Net Zero strategy. PoR is in a unique position to seed the development of such an environment within the region and facilitate its delivery.



With being awarded MAC (Main Automation Contractor) for several projects within the Rotterdam industrial region, Yokogawa has a unique position to leverage industrial automation insights and work with PoR's ecosystem partners to identify opportunities of collaboration across companies. Within the port there are challenges inherent to complex systems with different firms with their own management and objectives. Yokogawa has acted as a facilitator for firms involved to collaborate, share data and collectively execute cooperative actions that benefit participating firms.

In roles such as facilitator, assessor, and technology provider, Yokogawa could participate in the SoS in planning, data analysis, resource identification, and integration. As the SoS structure matures, the

application of AI and digitalization technologies could be provided by Yokogawa to enable industrial facilities to work together in real-time, where additional synergistic and emergent value will be realized.

Other Potential SoS Engagements

The following are four additional examples of Industrial clusters that Yokogawa has been involved in at some level. All of these examples in their initial writeup indicate system of systems behavior. Based on the roles described in section 4, it would be good to reexamine these operations to further clarify the actions and activities Yokogawa has performed to make each a success.

Groningen Gas Field [link](#)

For more than 30 years, the Groningen Gas Field operated in a largely unmanned fashion in the North of the Netherlands. To achieve this objective, Yokogawa designed and implemented a new DCS concept which did not exist at the time the contract for the GLT project was granted by NAM.

To support the sheer size of the field, and the number of assets, and to enable a fail-safe unmanned operations approach, a highly modular, federated design was implemented.

The principles upon which it was built were on the one hand very repeatable due to their sheer simplicity, but also allowed the various assets that comprised the Groningen field to operate in a highly autonomous and coordinated fashion. Although it was not highlighted during the operation of the gas field, the operation had many aspects of a SoS operation.



Optimized Cogeneration System Operation- CEMS for F-Grid Miyagi [link](#)

The community energy management system (CEMS) at F-Grid Miyagi efficiently supplies electricity and heat to consumers in the industrial park while optimally balancing the power purchased from the electric power supplier and the electricity and heat (steam and hot water) generated by the company's cogeneration system (CGS) and solar power generation system. This Industrial Park Smart Community program was developed and is now operated by F-Grid Miyagi, supported by subsidies from the national government after a two-year demonstration experiment. Yokogawa took part in this program and configured the CEMS. The benefits were as follows:

- 1) The CEMS of F-Grid Miyagi optimally balances the electricity and heat generated by its own CGS and solar power generation system with the power purchased from the electric power supplier and efficiently supplies electricity and heat to consumers in the industrial park.
- 2) The CEMS captures the varying power and steam demand, and unit price data of power and gas rates, and calculates the optimum ratios of the power to be generated by the CGS and the power to be purchased.
- 3) During the two-year demonstration experiment from April 2013 to March 2015, costs were reduced by 20% compared with the past.

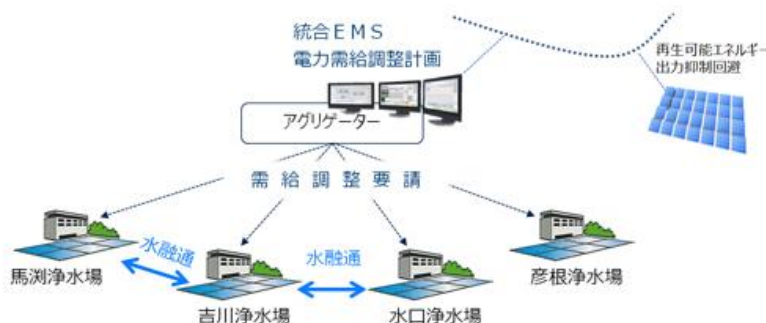
This energy management system has many aspects of an SoS. It would be good to revisit this facility to reexamine the roles Yokogawa has preformed in the past.

Water Purification Plants in Shiga Prefecture Feasibility Study [link](#)

The Shiga Prefectural Public Enterprise Agency takes water from Lake Biwa to four water purification plants and supplies it to waterworks (8 cities and 2 towns) and industrial water supply (60 companies). Although it is blessed with a large amount of water, the altitude of the supply area is higher than the water source, so a large amount of pump power is required for water conveyance, transmission and distribution networks. Efficient use is required.

In this study, with the cooperation of Shiga Prefecture, Yokogawa Solution Service used IoT to predict water and power demand based on operation data of pumps accumulated in existing facilities, and to determine the extent of supply and demand adjustment. Based on this, they calculate the total Megawatts when the pumps of the four water purification plants are controlled in an integrated manner and investigate the feasibility of commercializing the aggregator. In conducting the survey, Yokogawa collaborated with Kansai Electric Power Co., Inc., a joint applicant for this project, focusing on surveys on changes in power demand and surveys on the introduction of renewable energy.

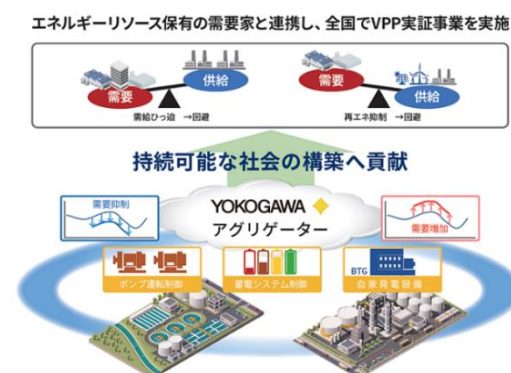
Supply and demand adjustment using integrated energy management system (EMS)



In recent years, attention has been focused on the energy resource aggregation business, which obtains compensation by aggregating energy resources on the side of multiple consumers and controlling supply and demand.

Virtual Power Plant Demonstration with Kobe City Waterworks Bureau [link](#)

Since 2018, the Kobe City Waterworks Bureau has participated in Yokogawa Solution Service's Virtual Power Plant (VPP) demonstration project as a resource. In this demonstration, Yokogawa Solution Service converts signals related to control that regulates power demand into information such as the



activation time required for implementing demand response and the amount of supply and demand adjustment. Notify the system installed at the station. Based on the notified information, this system calculates and presents the power supply amount and control amount to respond to DR. Based on the presentation of this information, the waterworks bureau aims to implement DR and create resources by changing the control of pump power distributed in each area of Kobe City. The demonstration, which started at four pumping stations, increased to 17 pumping stations in FY2020, attracting

attention as an example of further utilization of distributed energy resources. This is another operation that demonstrates SoS behavior and outcomes and it should be revisited to see what additional value Yokogawa has provided in the initial success.

Kawasaki Zero-Emission Industrial Complex- [link](#)

[Announced by the WEF in January 2023](#), the industrial cluster Kawasaki Carbon Neutral Industrial Complex joined the WEF Transitioning Industrial Clusters towards Net Zero initiative. This cluster with petroleum and chemicals at its core, as well as steel and electric power industries, is pursuing hydrogen deployment, carbon recycling and the use of regional energy optimization. Main initiatives implemented by Kawasaki Zero-Emission Industrial Complex are:

1. Acquisition of joint certification of ISO14001 for the entire industrial Complex
2. Setting of higher reduction targets than emission standards of the generated environmental burden
3. Joint reception by the neighboring businesses of the electricity from the surplus electricity
4. Effective use of sewerage water after advanced treatment as an alternative for water for industrial use
5. Utilization of sewerage sludge ash a raw material in cement in nearby factories.

In this cluster it is unknown of exactly Yokogawa's presence and involvement but should be investigated further.

6. Conclusion

This document has summarized all the work that has been done in the expansion of the concept of Systems of Systems for Yokogawa since its introduction in AG2023. The next steps are to build marketing content based on the concepts outlined to position Yokogawa as a thought leader in this emerging market and for businesses in Yokogawa to promote the SoS concept and to present to the marketplace Yokogawa's unique competencies to serve the System of Systems market as it continues to grow.

7. Appendix- Other concepts around System of Systems

This appendix highlights several topics that have been brought up as relevant by different businesses, COEs and subject matter experts that relate to System of Systems. Each of these should be explored further and built as additions to Yokogawa's SoS market messaging.

Firms of Endearment

Firms of Endearment is a 2007 management book that assesses performance of companies that fit defined criteria of a holistic approach to stakeholder relationship management in five groups: Society, Partners, Investors, Customers, and Employees, and looks to qualitative metrics to measure these characteristics. It has been suggested that Yokogawa uses the concepts in this book and additional writings of the authors to adapt our culture in serving as a trusted partner in a System of Systems.

Some of the attributes are:

- FoEs freely challenge industry dogma. This willingness means that they do not fit into the norms that Wall Street is comfortable with and leads analysts to criticize FoEs that pay wages and benefits above industry standards.
- FoEs create value by aligning stakeholder interests. FoEs regard all their stakeholders as assets. FoEs have an uncanny ability to transmute stakeholder groups from separate, sometimes competing groups into a cohesive system in which the value of the whole is greater than the sum of the parts.

- FoEs are willing to break traditional tradeoffs. Instead of “if/then” or “either/or,” the alternative style of thinking — “both/and” — opens the mind to accommodate seemingly contradictory conditions.
- FoEs operate with a long-term perspective. And not make operational decisions based on projected or actual quarterly earnings.

Some of the ways in which FoEs fulfill their keenly felt societal obligations:

- Encouraging employee involvement. FoEs encourage and reward employees for volunteering time and talents to support initiatives that benefit the local community. Patagonia has an environmental internship program that gives employees up to two months a year of paid leave to volunteer with an environmental organization of their choice.
- Nurturing local communities. FoEs strive to make themselves welcome in local communities and endear themselves by responding quickly to local exigencies.
- Cultivating global community. FoEs strive to be exemplary global citizens, going well beyond local requirements, even when local regulations are less demanding.
- Improving competitive context. FoEs are adept at aligning social and economic goals.
- Focusing on sustainability. FoEs strive to operate in environmentally friendly ways.
- Cooperating with governments. FoEs view governments as important partners in facilitating their ability to achieve their broad purposes and create a better world for everyone.

An Industrial Sharing Economy

Yokogawa envisions an evolving process industry where the potential for optimization extends beyond individual plant control, encompassing the interconnections between various plants and businesses. The era of large industrial plants is undergoing a transformation, as process industries shift towards a modular, distributed, and inclusive system. This transition emphasizes robust integration between plants and the seamless connection between plants, industrial enterprises, supply chains, and society.

This trend is being further propelled by the imperative of collaborative efforts to achieve ambitious Net-Zero objectives. Although companies are making commendable strides to reduce their carbon footprints, they are encountering diminishing returns in their individual improvement endeavors. The next level of progress hinges on system convergence, necessitating a novel architectural paradigm that prioritizes the following aspects:

- Highly integrated industrial processes and technology
- Extensive sharing of resources
- Embracing the principles of the Circular Economy

By embracing these fundamental principles, companies can unlock new avenues for improvement and drive sustainable transformation at a broader scale.

However, for Yokogawa, a company traditionally focused on industrial automation, these shifting dynamics require a fundamental reevaluation of our operational foundations. In the past, our infrastructural design principles emphasized separation, isolation, control, and

reliability. In today's landscape, our focus has shifted towards integration, sharing, security, and, notably, providing solutions that extend beyond addressing isolated issues within a single company. Instead, we are actively working towards seizing a multitude of opportunities that arise from collaborations between different companies.

Consequently, Yokogawa envisions an industrial ecosystem that is progressively transitioning towards a holistic System of Systems (SoS). This new paradigm acknowledges the interconnectivity and interdependence of various components within the industrial landscape, emphasizing the need for cohesive and harmonized approaches. By embracing this approach, Yokogawa aims to foster a collaborative environment that maximizes efficiency, innovation, and the realization of shared goals within the broader industrial community.

The challenges in realizing an SoS

Envisioning a future where industrial producers, consumers, and industrial clusters or hubs optimize their production and consumption through secure and private sharing of real-time information presents numerous benefits, such as a more efficient and cost-effective system that can effectively reduce carbon emissions. However, implementing such a system would inevitably require substantial changes to existing infrastructure and processes, accompanied by the challenge of obtaining consensus among all parties involved (SoS stakeholders) to share information and coordinate their actions.

For a System of Systems, the challenges are technical, organizational, managerial, governance-related and thus often also political – the constituent systems are owned by different parties, and then we need standards etc. to make them interoperable.

We tend to approach SoS too much as a complex technical system. In reality, a SoS is about how to harvest the potential synergy between multiple systems. A SoS also involves multiple Profit and Loss (P&L) statements. Meaning: if you optimize for one company it is a technical / mathematical problem. While if you optimize between companies, you get strategic / trust issues.

Furthermore, establishing secure and private mechanisms for data sharing and analysis would be crucial, as well as developing incentives to encourage participants to embrace the new system. Undoubtedly, achieving the potential advantages of this integrated approach would involve overcoming a range of technical and logistical obstacles.

Therefore, while the integration of companies through a System of Systems (SoS) offers clear benefits, it also presents several hurdles to overcome, including:

- **Infrastructural Changes:** Significant modifications to current infrastructure would likely be necessary to support the implementation of a cohesive SoS.
- **Information Sharing:** Encouraging all stakeholders to share relevant information securely and privately may prove challenging due to concerns over data ownership and privacy.

- Reluctance to Coordinate: Convincing all parties to coordinate their actions within the SoS framework may require addressing potential resistance and fostering a cooperative mindset.
- Security and Privacy: Protecting the integrity and confidentiality of sensitive information within an SoS is paramount.

Effectively addressing these challenges would be essential to realize the full potential of a System of Systems and unlock the numerous benefits it promises.

Demonstrate the value of an SoS

In several Yokogawa investor presentations and earnings calls, during the concept description of becoming an integrator of SoS, Investors have asked questions of the value of System of Systems and its market size. This is an indication that tangible value is documented in Yokogawa's SoS engagements in the roles and functions that Yokogawa executes.

Examples of Synergistic and Emergent behavior

The stakeholder definition that Yokogawa uses shows that there is two different sources of value when a SoS emerges . The first is Synergistic value which is created when two or more entities interact or collaborate to produce a combined effect that is greater than the sum of their individual effects. The value results from cooperation, collaboration, or interaction between the parts, leading to improved efficiency, innovation, or competitive advantage.

The second, emergent value arises from the interaction of parts within an SoS, where the overall value output cannot be exactly predicted beforehand. The value is observed when the relationships and interactions between components lead to new properties or behaviors that were not present or apparent by the individual systems themselves.

Understanding the complex interconnection of energy, material, and data flows as well as differing management and objective structures that make a SoS, the established practices of System of Systems management, engineering, and management are essential in building synergistic and emergent behavior that benefit all stakeholders.

To give examples of these two different values in the value chain.

At the Plant Level

- Synergistic value– Energy Optimization across Equipment, Unit, and Plant – reduces energy costs and increases energy availability across operations
- Emergent value – Operational and Information standards and procedures are developed, which become shareable best practices.

At the Enterprise Level

- Synergistic value- Standardizing Plant Energy Optimization philosophy and implementation across Enterprise Fleet provides visibility of energy bad actors, bottlenecks and operational best

practices across equipment, operations, etc. Best practices and knowledge are shared, across teams and regions.

- Emergent value- As the Energy landscape transforms, the Enterprise is positioned to adopt and meet operational and ESG targets.

Supply chain Level

- Synergistic – Optimizing Plant Fleet loading & consumption needs creates an Opportunity to share, sell or purchase energy with other providers or external entities for revenue or ESG goal achievement.
- Emergent – As external entities adopt similar standards & procedures, Energy Transactions between companies become more optimized, traceable and visible.

Industrial cluster

- Synergistic – In this Energy Sharing economy, entire Industrial clusters achieve the benefits of increased energy availability, visibility, reliability and stability of costs, common best practices, and energy model adoption.
- Emergent – As entities participate in an Energy Sharing economy, the opportunity is created for shared Energy Infrastructure modernization, balancing investment in Energy with other regional or synergistic enterprises, grid modernization, electrification, hydrogen or other non-fossil fuel energy currencies become more achievable with the strength of the Industrial cluster.

Society level

- Synergistic - Industrial energy sharing and grid modernization helps to drive infrastructure for the energy transition in society (e.g. e-mobility, hydrogen infrastructure, Smart City innovation)
- Emergent - Energy transformation in society creates new opportunities for innovation in businesses across all sectors, improving quality of life as well as driving opportunities for human creativity, driving the leaders and industrial workforce of the future.

In identifying different kinds of synergistic and emergent value as Yokogawa continues to advance and refine its knowledge of System of Systems, it may be a topic that Yokogawa can identify, produce marketing content and thought leadership to differentiate in the market. Two identified topics that may have a large impact and require further research are:

- Safety is the ultimate emerging behavior. The idea and systems become more connected, it may provide opportunities for improvement in safety performance by identifying risks that span across systems
- Synergistic value of autonomy and System of Systems. The concept of significant advancement in autonomy in the constituent systems in an SoS environment will drive more connection opportunities which will in turn drive more autonomous behavior.

Competitive strategy

In pursuing the “Trusted partner in SoS”, Yokogawa’s primary competition throughout the value chain will not be traditional automation vendors, but large consulting firms such as Accenture, McKinsey, and

KPMG. It is necessary to show differentiation from these firms and how Yokogawa can bring value to the stakeholder table in a Systems of Systems environment.

In section 4 of this paper, there were 25 identified competencies that are known across our customer base through Yokogawa's actions and deeds and not through marketing. There are many of these attributes listed that the large consulting firms completely lack such and deep process knowledge or IT/OT integration experience. Also, the complete category -Yokogawa's world-class technology that supports continuous improvement and breakthrough capability cannot be matched by management consulting firms.

With Yokogawa's trust built into many stakeholders in a System of System environment, a bottom-up opportunity strategy is possible.