Final Report

Smart Sensing and Industry 4.0 Energy Productivity Guide for Business

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Industry 4.0 for Energy productivity

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Industry Report

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Acknowledgement of Country

The authors of this report would like to respectfully acknowledge the Traditional Owners of the ancestral lands throughout Australia and their connection to land, sea and community. We recognise their continuing connection to the land, waters and culture and pay our respects to them, their cultures and to their Elders past, present, and emerging.

What is RACE for 2030?

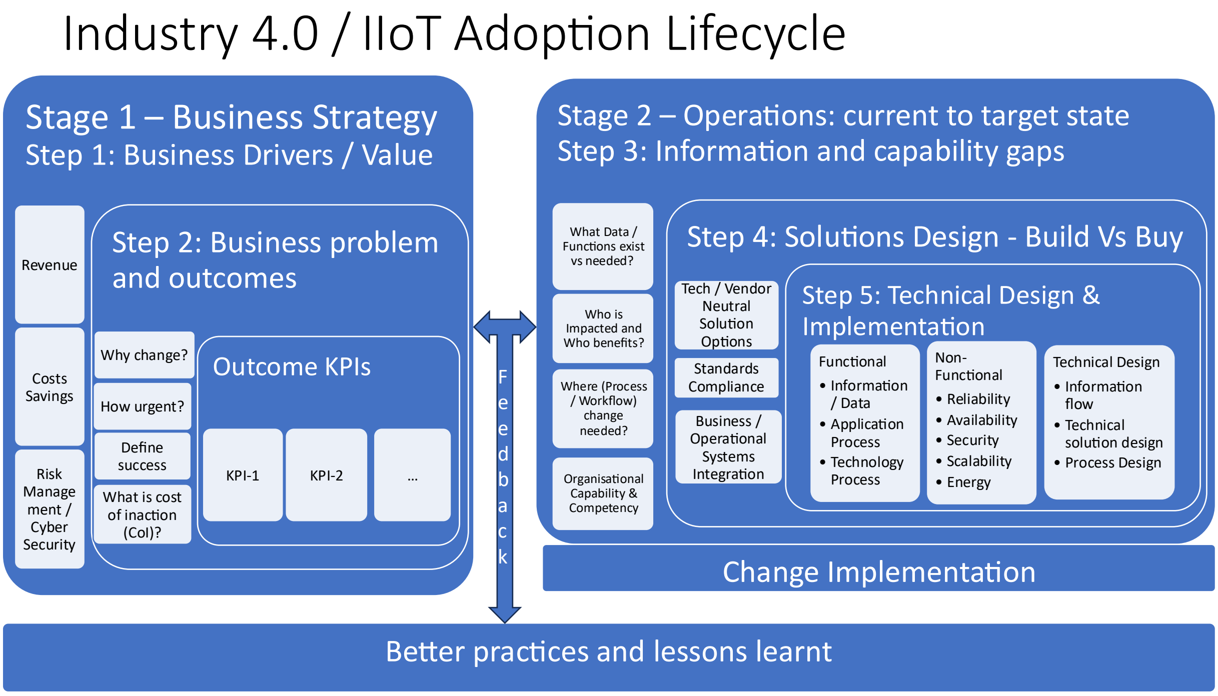
RACE for 2030 CRC is a 10-year co-operative research centre with AUD350 million of resources to fund research towards a reliable, affordable, and clean energy future. https://www.racefor2030.com.au

Disclaimer

Executive Summary

This "Smart Sensing and Industry 4.0 Energy Productivity Guide for Business" is a comprehensive resource aimed at helping businesses implement smart sensing and Industry 4.0 / Industrial Internet of Things (IIoT) technologies to enhance energy productivity. This guide addresses common barriers to implementation and provides a structured adoption cycle, supported by real-world case studies.

The guide's primary objectives are to assist businesses to improve energy productivity using sensing and Industry 4.0 technologies, overcome implementation challenges, and support sustainable operational models. It outlines a two stage, five-step adoption cycle: identifying business needs, defining outcomes and key performance indicators (KPIs), assessing operational considerations, designing high-level solutions, and developing detailed technical implementations.



Case studies from Ego Pharmaceuticals and Tomago Aluminium illustrate successful applications of these technologies. Ego Pharmaceuticals integrated digitalisation and sustainability into their operations, achieving significant energy savings and reduced CO_{2e} emissions. Tomago Aluminium used smart sensing to track molten aluminium, improving business efficiency and reducing risks.

Overall, the guide offers practical insights and good practices for leveraging Industry 4.0 technologies to improve energy productivity, save costs, and support sustainability goals. It provides a clear path for businesses to follow, ensuring successful implementation and long-term benefits.

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1 Introduction

This guide provides a practical reference for businesses to successfully implement smart sensing and industry 4.0 techniques for energy productivity and overcome the common implementation barriers. This objective is framed through a structured adoption cycle, highlighting key questions to answer at each stage, supported by case study examples

The target audience for this guide are business, operations, finance, technology leaders and their teams.

The premise of the guide is that better quality information and automation significantly impact achieving better energy productivity for most businesses. The guide provides a method for determining how to identify and successfully implement smart sensing and Industry 4.0 energy productivity projects for your business.

The International Energy Agency (IEA) (OECD/IEA, 2017) explained the concept of Digitalisation (Industry 4.0) as "the increasing interaction and convergence between the digital and physical worlds," where "the digital world has three fundamental elements:

- Data: digital information
- Analytics: the use of data to produce information and insights for making informed decisions.
- Connectivity: data exchange between humans, devices, and machines (including machine-to-machine), through digital communications networks."

By utilising these elements, smart autonomous systems can 'reason with data' and implement optimal decisions (in real-time) to streamline business processes – leading to improved energy productivity. Digital connectivity and the creation and sharing of information deliver the true power of Industry 4.0.

Utilising Industry 4.0 technology, the IEA found that digitalisation could cut energy use across various sectors by about 10% by using real-time data to improve operational efficiency and that "smart demand response" could provide 185 gigawatts (GW) of system flexibility in IEA countries, roughly equivalent to the currently installed electricity supply capacity of Australia and Italy combined (OECD/ IEA, 2017).

From the Australian Alliance for Energy Productivity report (A2EP, Australian Alliance for Energy Productivity, 2018), the biggest impediments to leveraging industry 4.0 come traditionally from lack of free information flow – where there are information boundaries between systems/divisions in plants and between organisations in supply chains.

Key opportunity areas were:

1. Savings from improving information flow across interfaces between organisations and production lines
2. Improving plant energy flexibility
3. Optimisation of energy-intensive processes and systems
4. Improving the energy productivity of equipment

Preamble

Energy sustainability and affordability are arguably among the most pressing socio-environmental concerns of modern times. They provide the Australian energy sector and energy consumers with the challenge of transitioning so they can supply and use reliable and affordable clean energy in the future.

Utilising Industry 4.0 technologies, the IEA determined that digitalisation could cut energy use by about 10% by using real-time data to improve operational efficiency and that “smart demand response” could provide 185 gigawatts (GW) of system flexibility, roughly equivalent to the current installed electricity supply capacity of Australia and Italy combined (OECD/IEA, 2017).

Thus, the sustainable energy transition and Industry 4.0 share important characteristics that can be interconnected to attain both economic benefit and socio-environmental benefits. Industry 4.0 technologies offer consumers a means to use energy to greater effect and to improve energy productivity. That is, capturing greater value by identifying waste (resources, energy, labour, etc), understanding energy and resource flows and impacts (e.g. CO_{2e} emissions), and then optimising operations, technology application, investment and asset utilisation.

The RACE for 2030 B2 “Industry 4.0” Opportunity Assessment Project Report (Trianni et al, 2022) provided an overview of Industry 4.0 and its application to energy productivity. It outlined the primary services and benefits these technologies offer, specifically focusing on industrial and non-residential services sectors. It also analyses the most relevant barriers hindering their widespread deployment, the major regulatory and governance issues, and the current and emerging business models. The report concludes with a research roadmap for RACE for 2030 in this stream, outlining prioritised potential research initiatives.

The Assessment further confirmed that the energy productivity benefits from applying Industry 4.0 will likely be large. Gross energy savings forecast in this report were $1.1B by 2030-31 and $2.4B by 2034-35, and potential emission reductions of 5.9 Mt CO_{2e} by 2030-31 and 12.9 Mt CO_{2e} by 2034-35.

However, these savings are unrealised due to barriers that hold back the adoption of sensing and Industry 4.0 technologies, e.g.

- lack of information about technologies and potential economic returns.
- personal and collective experiences of failed implementations of technologies, including the costs of past flawed IT projects.
- the complexity of the current wave of technological innovations, and the complexities of successfully implementing the technologies, especially in legacy systems.
- complexity of technological ecosystems and sharing of costs and benefits across stakeholders.
- the sharing of data, including real-time data, between different organisations can pose considerable security and privacy risks.
- conflicting business models with traditional modes of operation,
- understanding the potential for significant impact on entire value chains,
- impact on prices and regulatory concerns, and
- concerns about vendor lock-ins.

Use of this Guide

This guide walks users through the smart (smart sensing and industry 4.0) energy productivity technology adoption lifecycle, starting with uncovering business needs (drivers, outcomes, KPIs) that motivate action and investment, then addressing operational considerations, and finally guiding solution design, technical design and implementation.

Through a series of targeted questions at each stage of the adoption lifecycle, we help businesses clarify key motivations and parameters to successfully deliver projects, while also addressing barriers and managing risks along the way

The lifecycle steps 1 through 5 are represented in Figure 1, which provides a framework that can be used to apply sensing and Industry 4.0 across multiple industries and use cases. The adoption lifecycle begins with stage 1 outlining the business drivers and outcomes sought. In stage 2 we work through the operational state change, overall solution design, technical designs and change implementation. In this stage, we introduce the IoT reference framework (IoTAA, 2022) to provide a simplified layered view of the business, technology, data and security for sensing and Industry 4.0. to assist understanding and design.

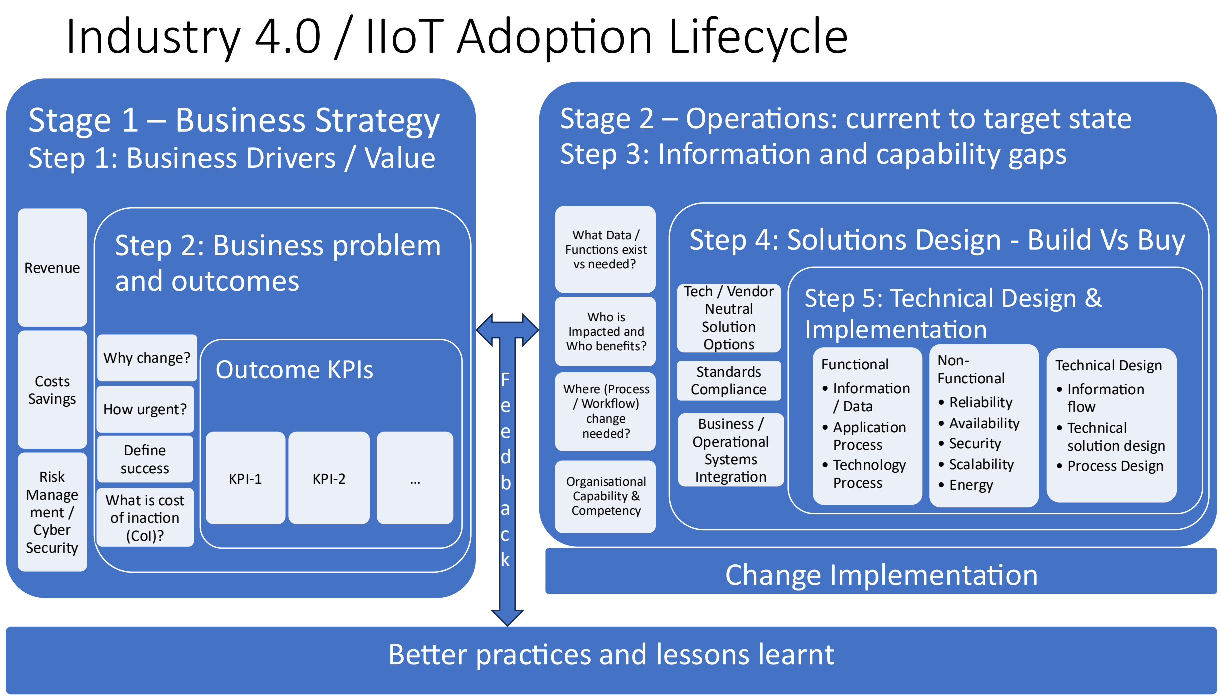

Figure 1: Industry 4.0 / IIoT Adoption Lifecycle

The guide provides case studies of smart energy productivity projects and their adoption lifecycle and outcomes to help understand and demonstrate practical application.

The recommended use of the guide is as follows:

- Navigate through the guide questions for smart energy productivity adoption lifecycle to identify the desired energy productivity outcomes and smart pathways to achieve them
- Review case studies to learn from others' experiences.
- Contact RACE for 2030 or IoTAA for additional information and a nominated energy productivity expert

We invite you to contribute your case study to the knowledge base to support future participants and help shape better practices across the industry.

2 A practical path to smart energy productivity

2.1 Stage 1: Business Strategy

2.1.1 Step 1: Business Drivers / Value

The first step in adopting smart sensing and Industry 4.0 to improve energy productivity (smart energy productivity) is understanding and supporting your business's energy productivity needs and priorities.

The key questions are:

- What are your goals for energy productivity and digitalisation in your overall business strategy?
- What specific energy productivity challenges or opportunities do you have in your business?
- What are the drivers, such as risks or opportunities, that elevate its importance and priority?

A company's business drivers are ultimately shaped by the following three core fundamentals:

2.1.1.1 Revenue management

Realising revenue opportunities that increase market access, improve competitiveness through product differentiation and better customer interaction and experiences.

Energy productivity examples could include:

- Demonstrating and proving sustainability credentials for Customers – Do customers ask for green products, sustainable packaging, etc.?
- Opening and growing international markets and supply chain chains that require energy and carbon credentials, e.g.
  - Digital Product Passports, a tool for collecting and sharing product data throughout its entire lifecycle, are used to illustrate a product's sustainability, environmental and recyclability attributes.
  - The EU Carbon Border Adjustment Mechanism is a carbon tariff on carbon-intensive products imported into the European Union, such as steel, cement, and electricity.
- Reduce utility costs through load rebalancing and scheduling.
- Market positioning through benchmarking of green credentials.

2.1.1.2 Cost Management

Managing cost focuses on using the lowest possible amount of time, energy, and costs across various business processes, including design, build, testing, packaging and distribution.

Key energy productivity focus areas include:

- Reducing energy costs through avoidance of wastage.
- Maximising equipment utilisation through better asset management repair cycles to achieve better overall equipment efficiency (OEE).
- Automating and streamlining processes also enables better allocation of human resources.
- Optimising energy usage per unit of work.
  - e.g. **Case Study: Ego Pharma:** measures and optimises energy per kilo of product.

- Optimising supply chains to reduce inventory, lift throughput and improve reliability and resilience
  - For both production and distribution
  - May require consideration and decisions of environmental attributes of supplies, e.g. green steel and environmental footprint in distribution and packaging.
- Streamlining workflows and operations management.

Improved decision making with accurate, real-time data and data analytics to achieve the above, and for raising traceability, quality, and compliance are common applications of using sensing and industry 4.0 for cost management.

2.1.1.3 Risk management

Managing risk for energy productivity requires accurate and timely data to support decision-making in reducing and managing risk.

Common risks to be managed include:

- Energy pricing for energy price optimisation.
- Energy reliability
- Sustainability compliance requirements (e.g. safeguard mechanism and mandatory financial disclosure)
- Risks around the costs of inaction – balancing the costs of inaction against the costs of action e.g.: reduced market access and energy costs versus risks of project cost and possible failure, is a key strategic issue.
- Risks associated with poor information lack of information to make informed decisions and deliver outcome certainty.

Building on previous industry work helps identify and manage risks more effectively, while also providing a foundation to measure revenue growth and costs efficiency benefits of improving energy productivity.

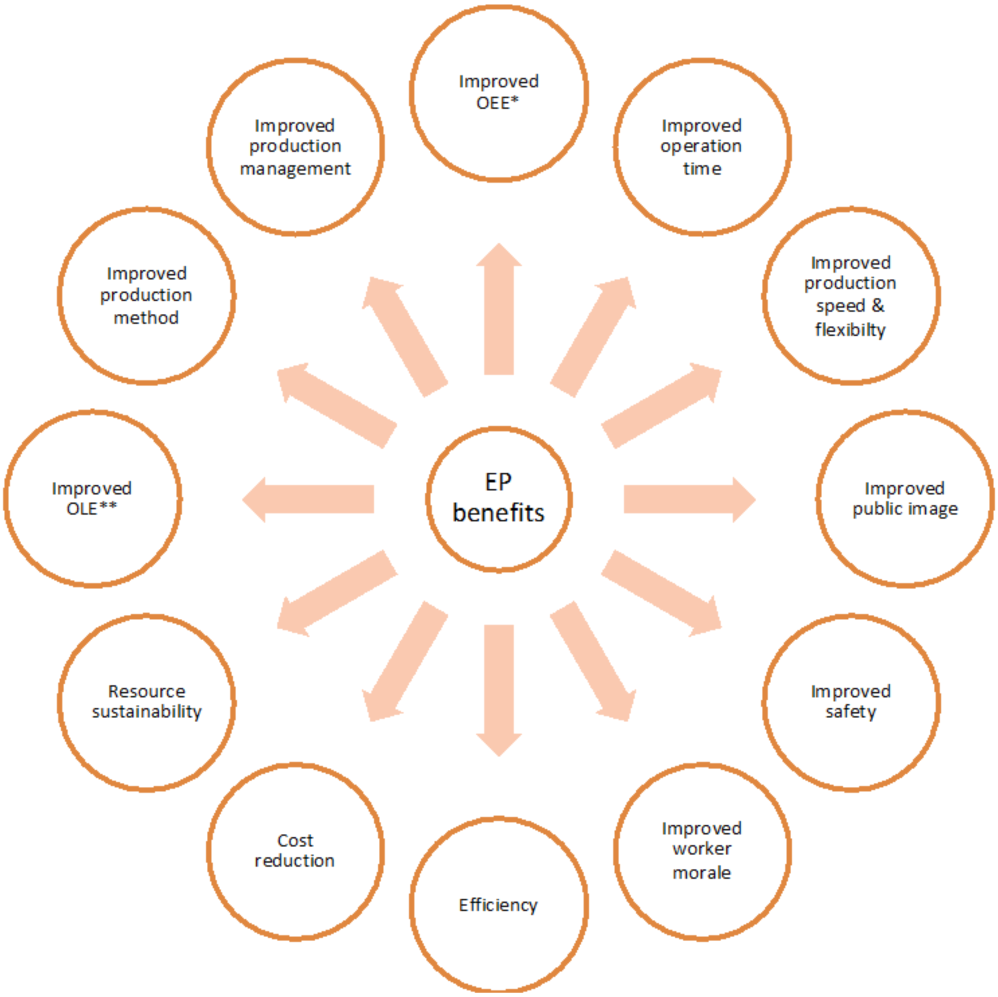

Figure 2: Energy productivity benefits

Figure 2: Energy productivity benefits above (Nehler, 2018) are insightful from a cost and risk management viewpoint summarising the benefits associated with the energy productivity measures. Note: OEE* is Overall Equipment Effectiveness, and OLE** is Overall Labour Effectiveness.

At the end of Step 1, you will have identified:

- What are the important energy productivity challenges or opportunities in your business and what is the priority for those?
  Case Study: Tomago has shown risks reduction and costs avoidance through preventing expensive rework for molten aluminium process loads.
- Are they supported by your overall business strategy?
  Case study: Ego Pharma has a strategic sustainability focus to address customers' sustainability concerns through greener skin care products.
- Does your business have a digital strategy that will support smart energy productivity?

2.1.2 Step 2: Determine business outcomes and metrics/KPIs for energy productivity

A strong alignment of business outcomes with business drivers is essential to justify investments in projects and new technologies. This section guides businesses in establishing clear business metrics to support smart energy productivity projects. It includes the identification of key performance indicators (KPIs), such as return on investment (ROI), and the assessment of potential risks. Businesses can build a robust business case to support adoption by focusing on these metrics, ensuring that investments are strategically aligned with overall business objectives and deliver measurable results.

KPIs also guarantee that performance is measured from a larger business perspective. This study focuses on the KPIs associated with smart energy productivity projects in the industrial and non-residential building market contexts.

The key questions are:

- What business outcomes (as determined in step 1) do you want to achieve from identified smart energy productivity, sustainability needs, and priorities?
- Why change? e.g. competitive pressures, Energy availability risk…
- Why now? e.g. supply chain constraints, regulatory compliance…
- What happens if status quo is maintained i.e. cost of inaction?
- What would success look like? What business metrics or KPIs would support these outcomes?

The (Energy Action, 2021) website provides an overview of common energy business metrics as indicated in the following paragraphs.

2.1.2.1 Energy Consumption Metrics

- Peak Demand: The highest level of energy demand observed in a given period
- Base Load Energy: The constant minimum level of demand on an electrical system

Understanding peak demand is essential for cost management and ensuring the energy grid's stability. Monitoring base load energy helps identify waste and improve overall energy use patterns.

2.1.2.2 Energy Cost Metrics

- Time-of-Use Costs: Costs vary by the time when energy is consumed
- Demand Charges: Costs incurred based on the highest level of energy demand

By tracking these costs, businesses can strategically shift high-energy processes to times when energy is cheaper, thus saving operational costs.

2.1.2.3 Energy Intensity

This metric measures energy efficiency, typically expressed as the energy used per square metre or production output. It is a vital indicator of how well a building or operation uses energy for its size.

2.1.2.4 Carbon Footprint Metrics

Greenhouse Gas (GHG) Emissions: Total emissions from a company's operations

Quantifying the carbon footprint helps businesses understand and manage their environmental impact, which can also influence company reputation and compliance with regulations.

2.1.2.5 Renewable Energy Percentage

The percentage of energy sourced from renewable resources is a key indicator of a business's commitment to sustainable energy use, for both Scope 1 and Scope 2 emissions.

2.1.2.6 Energy Savings Metrics

- Efficiency Improvements: The quantifiable reductions in energy use due to efficiency measures

Energy efficiency savings may apply to a complete process or the energy-efficient use of a particular piece of equipment.

2.1.2.7 Return on Investment (ROI)

- Payback Period: The time it takes for an investment in energy efficiency to pay for itself

Calculating ROI and the payback period is critical in justifying investments in energy productivity projects.

2.1.2.8 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a common metric used in the manufacturing sector for quantifying the quality, performance, and availability of a device, machine, or workstation. Nevertheless, OEE can be applied not only to machines but also to the workforce and materials, which can affect the energy productivity performance of products.

At the end of Step 2, you will have identified:

- The business outcomes you want to achieve from the identified energy productivity and sustainability needs and priorities.
- The relevant business metrics or KPIs that would support these outcomes.

2.2 Stage 2: Operations: current to target state:

Understanding sensing and industry 4.0 requirements and successful implementation requires more than selecting appropriate technologies; it demands a strong operational foundation.

Steps 3 through 5 consider the critical operational considerations necessary for solution design and effective technology adoption. Topics include understanding the data and information gaps, developing a technology adoption strategy, assessing technology maturity, detailed technical design that considers functional and non-functional requirements and developing a change management plan that ensures the benefits of the project are realised. Additionally, it highlights the importance of fostering a culture of change, ensuring organisational readiness, and complying with data privacy and security standards. By addressing these factors, businesses can scope the changes in moving from the current to the target state, including sensing and industry 4.0 initiatives, maximising the chances of long-term success.

2.2.1 Step 3: Identify information and capability gaps to achieve outcomes

Many businesses, especially long-established ones, find it challenging to capture real-time data. They often still own legacy machines or equipment with limited to no network connectivity, lack operational flexibility, and operate with proprietary data and communication formats. Production data are sometimes collected manually and can only be processed offline. The manual data entry process is also prone to error.

Key Questions are:

- What are the information and information management requirements to achieve your smart energy productivity outcomes and track and manage KPIs?
  - Are there data access issues due to data silos, and what are they?

What data management processes and tools do you have? E.g. the ability to pull together data sources from multiple places and analyse

- What are the information gaps? E.g. what is being measured and not, accuracy of data, reliability of data, timeliness of data

2.2.1.1 Capability gap assessment to identify transition needs

Capability gap assessment provides a structured way to evaluate the difference between current business capabilities (a combination of people, processes and technologies) needed to achieve the identified energy productivity business outcomes.

Understanding your capability gaps allows your businesses to narrow down solution design scope and provide an early indication of investment choices.

Key questions for capability gap assessment

- What business capabilities and gaps exist to achieve your smart energy productivity outcomes?
  - E.g. Smart heat pumps, Building Management Systems (BMS), Data connectivity networks …
  - What Industry 4.0 technology (Smart sensing, …) or systems capabilities and gaps do you have?
- What skills gaps exist in your teams or leadership?

2.2.1.2 Suggested Activities

Several methods can be employed to undertake a capability assessment. Common methods include:

- **Define the project's future state**
  Create a roadmap showing the needed information, technology, people, and process capabilities.
- **Mapping core business capabilities**
  Use capability maps to identify critical and supporting business functions.
- **Conducting an audit of existing processes and technologies**
  Review operations to see what's manual, automated or digital.
- **Stakeholder workshops and self-assessments**
  Engage staff to evaluate current skills and processes.
- **Analyse KPIs and performance data**
  Use data to assess how well current capabilities meet goals.
- **Categories Gaps**
  Group gaps into Skills, Technology, Process, and Resource types.
- **Prioritise gaps with a capability heat map**
  Focus on high-impact, easier-to-address gaps first.

At the end of a capability gap assessment, you will have identified:

- A defined target future state and the data and business capability gaps that will need to be addressed to achieve your energy productivity outcomes
- Skills gaps in your teams or leadership to deliver the outcomes
- Additional technology or systems to support making the required change
- Identified capabilities that are inefficient, outdated or manual that need to be addressed.

2.2.2 Step 4: High-level solutions design - Build vs Buy choice

After identifying important data, information, and capability gaps to achieve your priority smart energy productivity outcomes, the next step is to design a high-level solution and make choices for implementation.

The key questions for this step are:

- What are the sensing and systems (Industry 4.0) capabilities that are needed for your energy productivity project?
- To what extent and at what cost can your existing systems be upgraded to meet the sensing and systems requirements?
- What new (vendor-agnostic) solutions are available that can provide the data and functions to deliver desired outcomes?
- Do you have an overarching technology-agnostic digital strategy to accommodate existing or new technical solutions?
- What technical design and implementation skills do you need to implement the solution? Are they available internally, or do they need to be supplemented externally?
- How do the target candidate solutions integrate with business and operational systems (covering people, processes & technology)? What Integration challenges exist between current and new systems?

- Would you benefit from a proof of concept (POC) and/or proof of value (POV)? This may be helpful for novel or complex projects.
- What considerations are there for lifecycle management (build, operate and maintenance, decommissioning, …) of the solution options?

The buying and building of sensing and industry 4.0 solutions for businesses ultimately fall into three general categories, which depend on several key factors, including availability of in-house skills, urgency and time required to implement, cost and confidence in suppliers and staff.

1. **Custom Build**
   Provides maximum freedom in design, avoids vendor lock-in, and opens up the opportunity for a unique competitive advantage. This approach, however, requires considerable in-house expertise and reliable partners and often leads to time delays and cost overruns.
2. **Buy and integrate**

   Provides a faster solution based on proven technology and allows for external support for part of the solution. This approach may require the management of more stakeholders and increased solution complexity – e.g. for technical integration)
3. **Buy Outright (standalone CAPEX based) or Purchase as a Service (as OPEX based)**
   Allows the use of proven technologies with predictable outcomes, with fewer in-house skills required. This approach comes at the cost of less flexibility in customisation and differentiation.

   An increasingly valuable model is purchasing the solution as a mixture of outsourcing vs insourcing, opex vs capex at capability level solution (people, processes, technology).
   This model is often attractive for small to medium enterprises, as it allows relatively rapid adoption, reduces upfront expenses and shifts the solution's responsibility for operation and maintenance (OAM) to service providers.

All require longer term (than the project) underlying business technical architecture and consideration to enable future flexibility (e.g. to prevent vendor lock-in) and forward the evolution path for ongoing business improvement and adaptability.

Key questions for selecting the design and implementation model are:

1. What model is suitable for your organisation's capabilities and finances?
2. What are your evaluation criteria for potential technology solutions and/or vendor choices?

At the end of this step, your business should have a good basis to decide whether your solution evolves from your existing technology infrastructure or whether new sensing and Industry 4.0 technologies are required.

At the end of Step 4, you will have identified:

- The sensing and systems (Industry 4.0) capabilities to enable your energy productivity project outcomes.
- The extent your existing systems can be upgraded to provide the sensing and systems capabilities.
- The new (vendor-agnostic) solutions that can fill the technology capability gaps.
- How your upgraded/retrofitted systems and new solutions fit within your overarching technology strategy

- The technical design and implementation skills you need to implement the solution, and whether they are available internally or need to be supplemented externally
  Case Study: Ego's strategy: "Wherever possible, we build skills in-house. We find that we achieve higher quality delivery."
  Case Study: Tomago' lifecycle management: "We realised that technical feasibility wasn't the only challenge. The critical risk lies in losing knowledge held by a small number of people. That's why we transitioned to external partners, such as SAPHI Engineering, for sustainable support."
- Determined the Go / No Go decision with a business case to support it.

2.2.3 Step 5: Technical Design and Implementation

In designing an effective smart sensing and Industry 4.0-based project, it's critical to consider digital and physical components of the technical solution design. The design process must be anchored in a clear understanding of the operational processes required to achieve business outcomes in functional terms, e.g. business processes, application processes, technical processes (both physical and digital) alongside the non-functional requirements, including availability, performance, reliability, security, and scalability.

These elements underpin the digital design and shape how technology is applied to achieve operational improvements. By identifying and documenting end-to-end requirements first, organisations can transition from high level to detailed design with clarity, ensuring that the technical solution supports immediate functionality and long-term adaptability.

This section introduces a structured approach to unpacking functional and non-functional needs, laying the foundation for designing effective smart energy productivity solutions.

2.2.3.1 Functional requirements

This section covers the changes required for information processing and supporting required business functions and end-to-end business processes or value chains.

Key questions are:

Information and data design and modelling implications

- How do we gather and process the information and data needed to meet desired energy productivity-centred business changes?
- How does new information and data affect the information processing and technical requirements?

Application processes

- What changes are required to physical application processes (e.g. sensing, transport, energy conversion, etc.), and how should they integrate with digital applications for data exchange and functional controls?
- What changes are required to digital application processes for business support systems (e.g. customer management, supply chain management, billing etc.) and operational support systems (e.g. infrastructure management, maintenance quality control, service management, etc.)?

Technology processes

- What changes are required to physical infrastructure technology processes (e.g. machines, sensors, tools, etc.), and how should they integrate with digital applications for data exchange and functional controls?
- What changes are required to digital technology infrastructure (e.g. computers, controllers, communication networks, analytics, data storage, devices, tools, etc.)?

2.2.3.2 Non-Functional requirements

This section covers the non-functional aspects of technical solutions to support business functions or required value chain changes. Identifying non-functional requirements is a critical step that is often not well done. These requirements ensure that your solution performs to the required standards.

The answers to the following questions help to identify "what data and control requirements are needed?"

Key Questions are:

Reliability

- From a business perspective, how reliable does your process, product or service need to be?

Availability

- From the operations perspective, what are the availability requirements for Plant & Equipment?

Security

When considering any digital solutions, ensuring compliance with the organisation's data privacy and security policies and standards is essential.

- What are your security and data privacy policies?
  Your policies would cover standards, compliance requirements or constraints for domains including but not limited to Network security, System security, Application security, Device security, Data security, and User access security.
- What are your AI policy guidelines?

Scalability

- From a business perspective, how scalable does your design need to be? E.g. your product/service or processes?

Optimal Energy requirements

- From an operational perspective, what are solution energy constraints or requirements? E.g. data centre energy consumption, battery powered vs passive energy vs powered sensors, ...

Legal, Regulatory and Environmental

- What data and functional controls are needed to comply with Legal, Regulatory or Environmental management?

By this stage of Step 5 – you will have identified the following:

- The key functional requirements for solution design.
- The key non-functional requirements.

  Case Study: Ego Pharmaceuticals: "Initially, it started as a proof of concept—just an idea to test whether the technology could solve the problem. But we quickly realised it was much more than that. The technology matured, and the operational infrastructure was ready to support it. We now had to make it work as a line of business solution."

2.2.3.3 Detailed technical solution design

Information Flow

A key step in designing an effective smart sensing and Industry 4.0 solution is understanding the flow of data—where it originates from, where it travels to, and how it is used across the organisation. In practice, data doesn't follow a single, linear path. Information from a single sensor might feed into multiple systems: operational dashboards, workforce management tools, energy monitoring platforms, or analytics engines. These complex, multi-directional flows often only become clear through a detailed mapping of business processes and interactions.

Starting the design conversation from the data itself can be a powerful approach. By identifying what data is needed, where it goes, and what decisions or services it supports, teams can uncover the underlying digital functional components required to deliver the information flows.

Technical solution design

After mapping out the flow of information through the required business processes, the next step is identifying the technology components (existing and new) that enable the required outcomes.

Ideally, the technical design of a (energy productivity) solution will build from and leverage a company's digital strategy and use an open reference framework that can help unpack various digital solution elements and how they may work and integrate with existing systems.

Process design

To effectively support information flow and technical solution design, start by clearly defining the business objectives the solution aims to achieve. Next, map both current and future-state processes, identifying where changes will occur due to the introduction of digital technologies like sensors. This includes designing how information is captured, interpreted, and moved through systems — often referred to as the digital thread.

A successful design considers both physical and digital components, ensuring they work together to enable seamless, near real-time data flow. Where possible, introduce automation to reduce manual effort and improve efficiency. Rather than treating process and technology design as separate steps, approach them iteratively, with each informing the other to create a cohesive and effective solution that meets the intended business outcomes.

One effective way to do this is using an established framework for design and implementation that integrates information view, business view, user view and architecture design view.

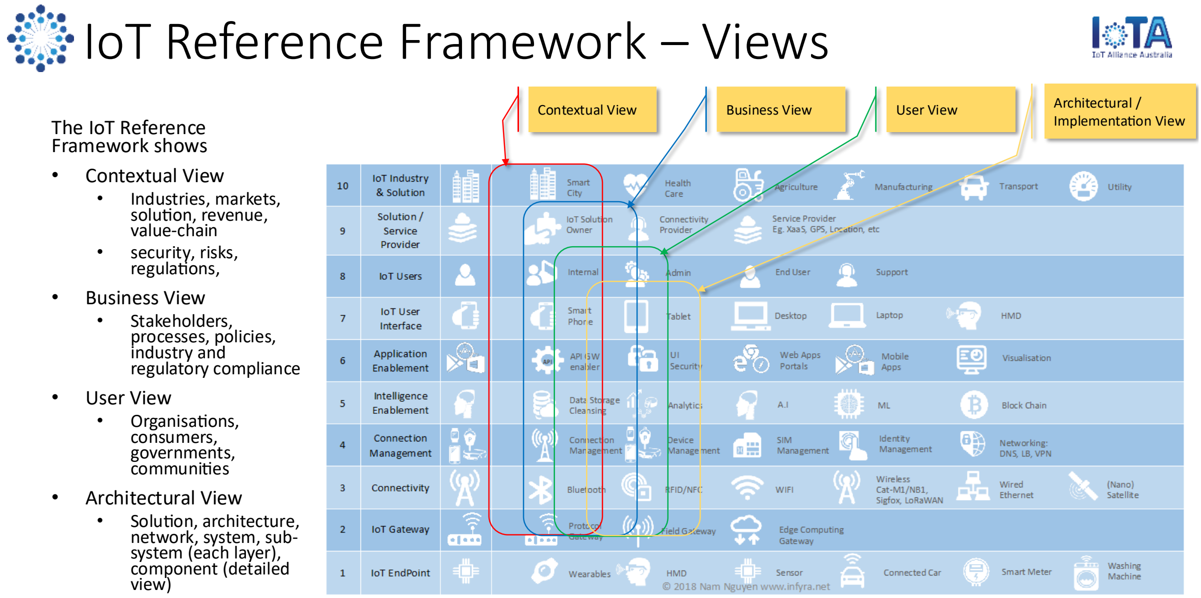

Figure 3: IoT Reference Framework

Figure 3: IoT Reference Framework above (IoTAA, 2022), shows one such framework to guide analysis and implementation.

These frameworks help guide thinking across different layers of service delivery and assist in mapping technical components and interfaces to support the capabilities needed at each level to support business outcomes. A generic framework can be a good starting point. Nevertheless, it helps clarify the connectivity, visibility, and system components needed for your solution.

For an overview of Industry 4.0 technologies and their applications, refer to section 2 of the Opportunity Assessment (Trianni, et al., 2022).

Key questions to address in technical solution design are:

- How does your company's digital strategy support the required information flow and guide technical design?
    - What automated data is generated, captured, and processed?

- What digital reference framework or company architecture do you use to identify technology gaps and compare technical options?
- What technology (e.g. Computing, Connectivity, Storage, Sensing, Controls, etc.) constraints do you have to move to a future state? E.g. existing contractual obligations.
- What technology options do you have to reach the target state from a functional and non-functional perspective?
    - By evolving your current technology to the required target technology.
    - By introducing new sensing and Industry 4.0 components for the technical design solution.

By this stage of Step 5 – you will have identified the following:

- The information flow pathways and management to support the energy productivity outcomes
- The technical components and design to support:
  - Functional needs, e.g.
    - Sensors for temperature, energy consumption meters, equipment utilisation, stock movement
    - Sensor requirements around environmental and functional factors such as temperature, humidity, shock, movement, vibration and many more
    - Connectivity needs for sensors and data exchange, such as Wi-Fi, Long Range Wide Area Network (LoRaWAN), cellular, …
      Case Study: Tomago: specialised requirements for sensors operating in 960ºC environment, Wi-Fi coverage at a GPS blackout area.
    - Data storage, e.g. in-house, cloud, centralised, and at the edge.
    - Analytics and decision-making tools.
    - Application software and APIs required for integration into existing or external systems.
    - Management software, e.g. for device management, data sharing.
  - Non-functional needs, e.g.
    - Performance attributes such as latency, size of data storage, connectivity bandwidth, and outdoor resilience of sensors (e.g. IP68 - water resistant in fresh water to a maximum depth of 1.5 metres for up to 30 minutes)
    - Security and privacy attributes include access rights to controls and data.

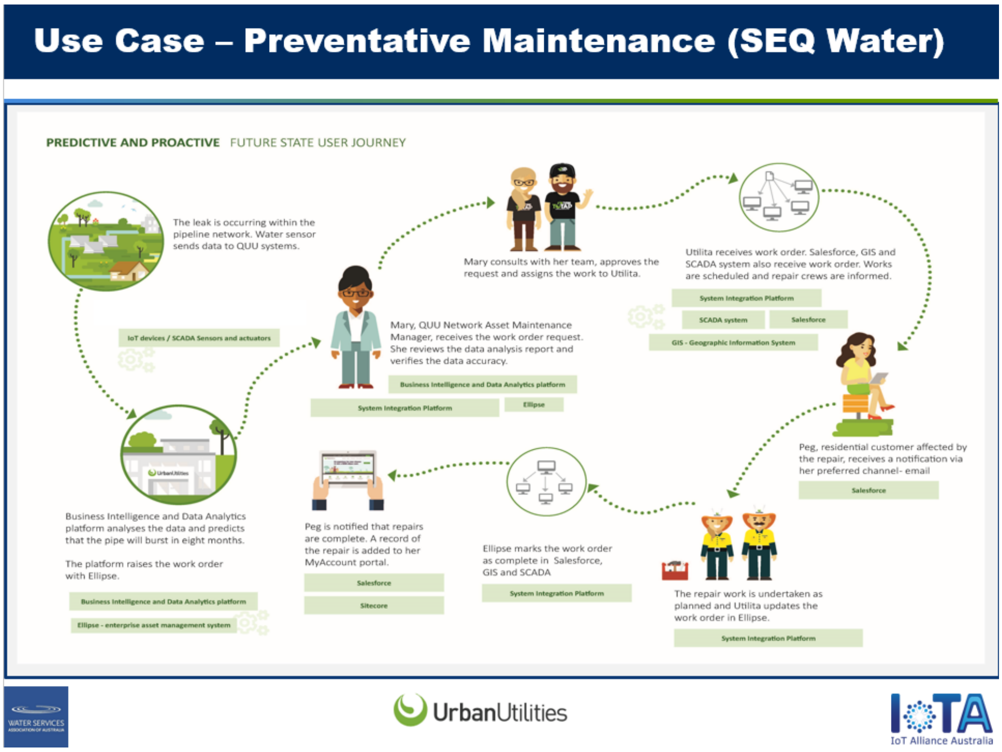

Figure 4: UrbanUtilities Information flow for preventative maintenance

Figure 4: UrbanUtilities Information flow for preventative maintenance (Water Services Association of Australia (WSAA)/ Internet of Things Alliance Australia (IoTAA), 2021) demonstrates how information supports a predictive and proactive maintenance program.

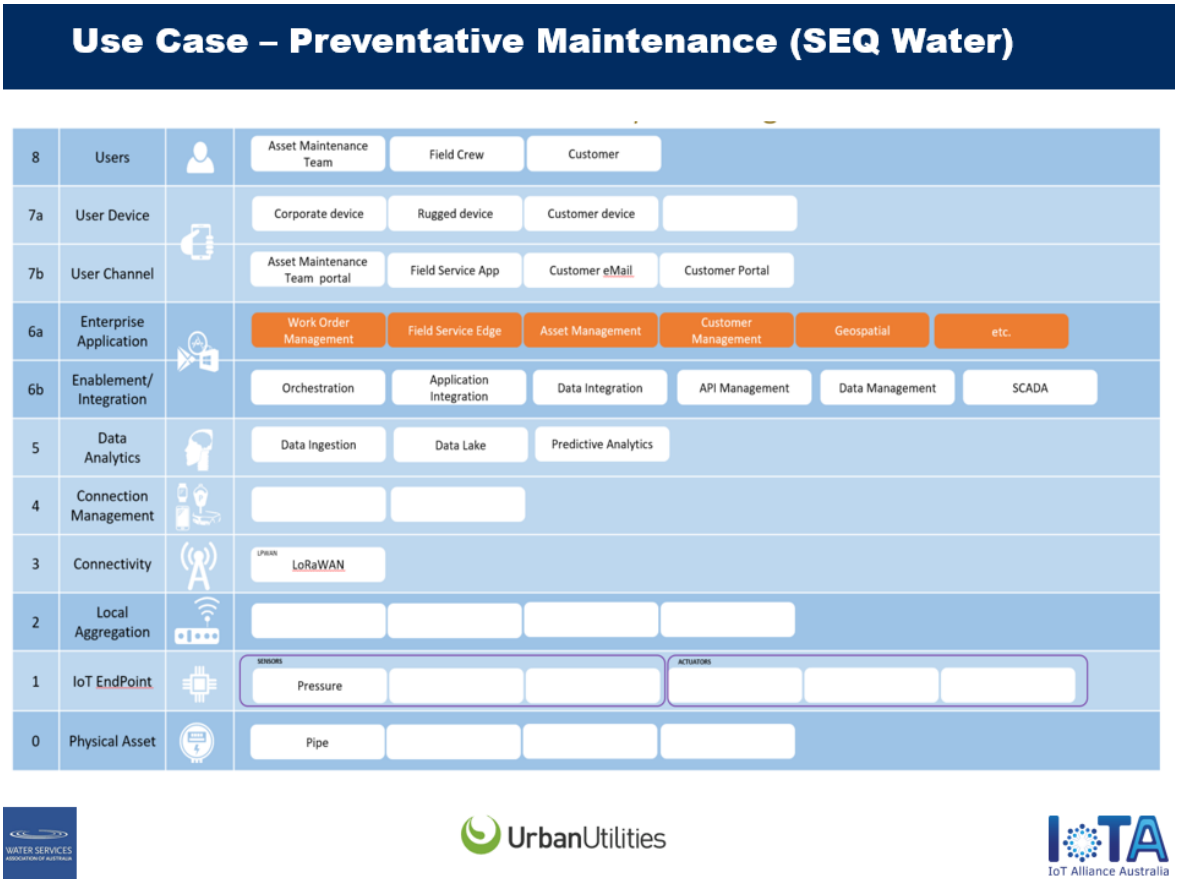

Figure 5: WSAA/IoTAA Digital Reference Framework (DRF) Overview

Figure 5: WSAA/IoTAA Digital Reference Framework (DRF) (Water Services Association of Australia (WSAA)/ Internet of Things Alliance Australia (IoTAA), 2021) shows all the required technical components to deliver a comprehensive solution for preventative maintenance.

2.2.4 Change implementation

Alignment with business needs, understanding and recognition of desired outcomes, and good technical design considering operational considerations are key to successful implementation. However, this will come to naught without well-planned and executed change management.

Realising the benefits of your project requires

- Documenting current processes and the transition to target physical and digital processes
- Developing and training programmes for support, operation and users who are affected by the change, supported by effective communication strategies
- Fostering management and employee buy-in and engagement
- Collaborating with and informing affected external partners and stakeholders

By methodically working through the project adoption lifecycle, there are several necessary and essential points of interaction with affected stakeholders. For example, including customers, management, finance and marketing during stage 1 and engineering and operations take a more leading position during project execution and implementation during stage 2.

Key questions for managing your change implementation are:

- Who is affected by the energy productivity solution?
  - Is there a supporting training and information plan?
- How have the existing processes changed, and what new methods are needed to support the operation of the sensing and Industry 4.0 energy productivity solution?
- What is your plan to ensure the operators and users adopt and support the changes?
  - Did you apply a specific process or methodology for change management?

2.3 Better practices and lessons learnt

This guide provides a method for determining how to identify and successfully implement sensing and Industry 4.0 energy productivity projects for your business.

Each business's circumstances are unique. The questions in the guide are designed to identify your business' motivations for embarking on a sensing and Industry 4.0 energy productivity project and the specific and relevant business, operational, and technical decision flow to achieve a successful outcome.

While the questions are general, the case studies we have included, and our experience point to some recognised better practice lessons, which are included below.

- Projects driven by real business needs and management support are more likely to overcome technical barriers.
- e.g. Ego Pharmaceuticals with their sustainability drivers
- Success should be based on and measured against business outcomes defined upfront, albeit unanticipated additional benefits often arise
- Businesses with a well-defined digital strategy and a certain level of digital maturity in their infrastructure will easily adopt sensing and industry 4.0 solutions for energy productivity.
- Understanding the change in business capabilities (people, processes, and assets) by starting with information and data flow is a good approach.
- Planning data integration from the beginning (avoiding the data siloes) is key.
- Case Study: Ego: "The first step was getting the data on the network to build a foundation. We could take it further from there. Without integrated data, there was no point in talking about advanced analytics.
- Defining the non-functional requirements early is crucial to ensuring the solution meets expectations. However, this action item is often left too late.
- Competent skills in design and integration are important. For example, Ego built in-house capabilities, whereas Tomago outsourced to Saphi.
- Stakeholder engagement and management through the adoption cycle is essential to ensure the changes are well-designed, understood, and process changes are adopted.
- ROI is generally reliably measured only after 6 months of solution in production.

3 Case studies:

The following two case studies—Ego Pharmaceuticals and Tomago—illustrate practical examples of the technology adoption journey. While they broadly align with the core principles of the adoption lifecycle outlined in this guide, real-world implementations rarely follow a linear or uniform path. Steps may be repeated, bypassed, or adapted based on context, constraints, and evolving priorities.

These examples highlight selected aspects of each company's journey, acknowledging that different organisations experience and prioritise stages of adoption differently. Readers are encouraged to consider these case studies with that flexibility in mind, as the adoption pathway should always be tailored to the unique circumstances of each business.

3.1 Ego-Pharmaceuticals

Digitisation & Sustainability are strategic imperatives: How Ego integrates a digitisation & sustainability roadmap into Business as Usual

Australian manufacturer Ego Pharmaceuticals, based in Melbourne, has grown from humble beginnings in 1953 in a suburban Melbourne laundry to a leading global brand. With more than 730 employees across 15 countries, there are over 400 staff based in Victoria.

Ego, a skincare leader backed by science, offers a comprehensive range of over 120 different products. Key export markets include Asia, the Middle East and the United Kingdom. Well-known brands include QV Skincare, DermAid hydrocortisone and Zatamil, Aqium hand sanitisers, Resolve antifungals, and MOOV Head Lice and insect repellent.

BUSINESS STRATEGY

Background

In recent years, the family-owned company has embarked on a strategic transformation to fuel business growth. The strategy included developing new and upgraded facilities, which presented an opportunity to modernise operations and advance digitalisation. A 12-point program was initiated in 2017, and by 2025, eight projects have been completed, delivering significant business benefits.

As part of its broader strategy, the leadership team also embedded corporate social responsibility, sustainability, design excellence, and digitalisation during this strategic transformation. The goal was clear: enhance operational efficiency, improve resource management, and align with modern sustainability expectations.

BUSINESS OBJECTIVES

The Need for Change

During the company's expansion, an opportunity emerged to automate the monitoring and managing warehouse conditions, particularly for temperature-sensitive raw materials and finished goods. Glen Fleming, Chief Operations Officer, Ego Pharmaceuticals, shared that the existing process relied on manual data loggers, requiring staff to physically retrieve and analyse information in Excel spreadsheets. This traditional method delayed the identification of temperature deviations, making timely corrective actions difficult.

The team recognised that areas of improvement extended beyond warehouse management, as highly skilled engineers and technicians were diverted from higher-value tasks to perform routine manual data collection. Additionally, complaints regarding the HVAC system required physical inspections, which impacted productivity. The management team, led by Dr Jane Oppenheim, CEO, recognised that a modern digitisation and automation approach was the way to overcome these inefficiencies.

Strategic Shift: Automation and Digitalisation

Embarking on the journey to modernise operations, the company implemented a Building Management System (BMS) during the design phase of its new facility. The decision to automate temperature monitoring through sensor-based technologies meant that real-time data would replace manual logging, providing instant insights and alerts that enabled proactive intervention. Engineers and technicians could redirect their efforts towards higher-value initiatives by eliminating manual processes, significantly boosting productivity. Additionally, HVAC issues could now be diagnosed remotely, reducing the need for on-site inspections and accelerating response times. The new system also enhanced energy efficiency, allowing for smarter climate control and minimising energy waste.

Step 2: Business problem and outcomes

Embedding Sustainability into Operations

As a values-driven organisation, the company had long considered sustainability in its projects but lacked a unified approach. This situation changed in 2019 with the establishment of a Sustainability Committee.

Glen Fleming remembers “Having the right people on the committee with appropriate decision-making power has driven behavioural change and over time has reinforced the fact that we are a sustainable organisation and focus on doing things in a sustainable way.”

Bringing together senior and functional leaders, the committee played a pivotal role in identifying, implementing, and tracking sustainability improvements. Internal communication efforts ensured that sustainability became embedded in company culture, fostering a shift in mindset across all levels of the organisation.

To drive meaningful change, the committee met regularly, fostering continuous learning about sustainability trends and best practices. Utility bills were analysed to monitor energy and water consumption, but did not provide sufficiently detailed data to make high-quality decisions. Now, the BMS provides detailed data to guide decision-making. The company made different decisions by reassessing equipment options through a sustainability lens. In one example, Ego selected a fully electric machine instead of a traditional machine that utilises compressed air, leading to significant energy savings. Sustainability considerations also became a core part of project planning, ensuring that any environmental impact was factored in from the outset rather than as an afterthought.

BUSINESS METRIC

Measuring Impact

To assess overall progress, the company used utility bills to track gas, electricity, and water consumption reductions. To identify opportunities and measure the impact of specific changes, the company used sub meters installed into electrical distribution boards and the water and gas systems. Over time, they refined their measurement methods to convert gas and electricity consumption into grams of CO_2 emissions data per kilogram of production. Real-time BMS data allowed for precise energy optimisation, demonstrating tangible efficiency gains. Engineering projects were also closely aligned with sustainability targets to ensure measurable impact, reinforcing the company's commitment to environmental responsibility.

Stage 2 – Operations: current to target state

Technology Selection

The choice of the BMS was guided by the HVAC consultant's recommendation. While the selected system ultimately proved suitable, the experience underscored the importance of carefully evaluating technology choices from the outset. Changing platforms midstream would have been costly and disruptive, highlighting the need for foresight in digital transformation initiatives.

Hardware and Sensor Integration

The first deployment focused on temperature monitoring in the warehouse, revealing early challenges with sensor relocation and calibration. Lessons learned from this experience influenced future projects, leading to the selection of more flexible and easily maintainable devices. To avoid data fragmentation, the company ensured that all sensors — measuring temperature, humidity, electricity, water, and gas — were fully compatible with the central platform.

Avoiding Data Silos

Integrating multiple data sources into a unified system proved to be an ongoing challenge. The company quickly recognised that fragmented data systems could hinder efficiency and informed decision-making. Ego is now working on an integrated data approach to maximise the value of digital investments, ensuring that insights are easily accessible and actionable.

Refining User Requirements

With each project, the company honed its process for defining user requirements, eventually developing a comprehensive User Requirements Specification (URS). This document details hardware needs, data points, accuracy requirements, and communication protocols, ensuring a structured and consistent approach to technology implementation.

From Proof-of-Concept to Operational Deployment

One of the most valuable lessons learned was the importance of simplicity in proof-of-concept (PoC) projects. Some previous initiatives stalled due to unaligned objectives and excessive customisation. The company realised that adapting processes to fit standard platform functionality yielded better results than over-engineering bespoke solutions. Streamlining initial implementations significantly increased the likelihood of successful adoption and scalability.

Change Implementation

A Hybrid Project Management Approach

To effectively manage projects, the company adopted a hybrid methodology that balanced structured waterfall planning with agile flexibility. The iterative design process engaged users and key stakeholders from the beginning, ensuring alignment and reducing resistance to change. While collaboration was encouraged, decision-making was streamlined to avoid delays caused by excessive consultation. This approach minimised risks associated with handovers and improved user acceptance, ultimately accelerating project delivery.

Capabilities

Skills Development and Workforce Expansion

Since 2011, the company has grown from a team of three engineers to 25 highly skilled professionals. In 2021, the company formed an Automation team to provide a strong focus on automation and data-driven solutions, with each project serving as an opportunity to refine internal capabilities. The company prioritises building in-house expertise rather than relying on external consultants, believing this approach delivers high-quality outcomes and long-term value.

"Wherever possible we are building skills in-house. We find that we achieve higher quality delivery." Glen Fleming, Chief Operations Officer

Mapping Solutions

System Integration and Automation Strategy

The digital transformation journey began with integrating factory production equipment into a unified network. As the initiative expanded, building services were also connected to the system, creating a comprehensive automation framework. Initially, the focus was simply on getting systems online. Once connected, the company explored ways to leverage data for better decision-making. Over time, advanced analytics became an integral component, enhancing operational insights and efficiency.

Glen Fleming remembers, "The first step was getting the data on the network to build a foundation. We could take it further from there. Without integrated data, there was no point talking about advanced analytics.

Build versus Buy

When considering technology investments, the company follows a pragmatic approach. Standard solutions are purchased when commercially available, while custom-built systems are developed for complex integrations where an off-the-shelf product is not an option. In cases where existing solutions are viable but require optimisation, the company configures them to align with business needs.

Compliance and Process Integration

While automation supports regulatory adherence, it cannot replace strong processes and skilled personnel. The company uses automation as a tool to identify potential compliance issues early, but human oversight remains essential to ensuring full regulatory compliance. Glen Fleming observes *"The primary benefit of the automation is to tell us where to look, and tell us early, while the problem is still small."*

RESULTS

ROI and Cost Savings

The company's commitment to automation and digitalisation has translated into significant compounding financial and operational benefits. Despite the higher initial software and hardware investment, automation has reduced labour-intensive commissioning costs, ultimately lowering overall project expenses. Over 18 months, the company identified approximately $60,000 in annual savings by optimising electricity consumption and reducing material waste without requiring additional capital expenditure. CO_{2e} emissions per kilogram of product are carefully tracked using kilowatt-hour and megajoule consumption data, allowing the company to align sustainability initiatives with stakeholder expectations. A major outcome is a 33% reduction in CO_{2e} emissions per kilogram of product since 2019.

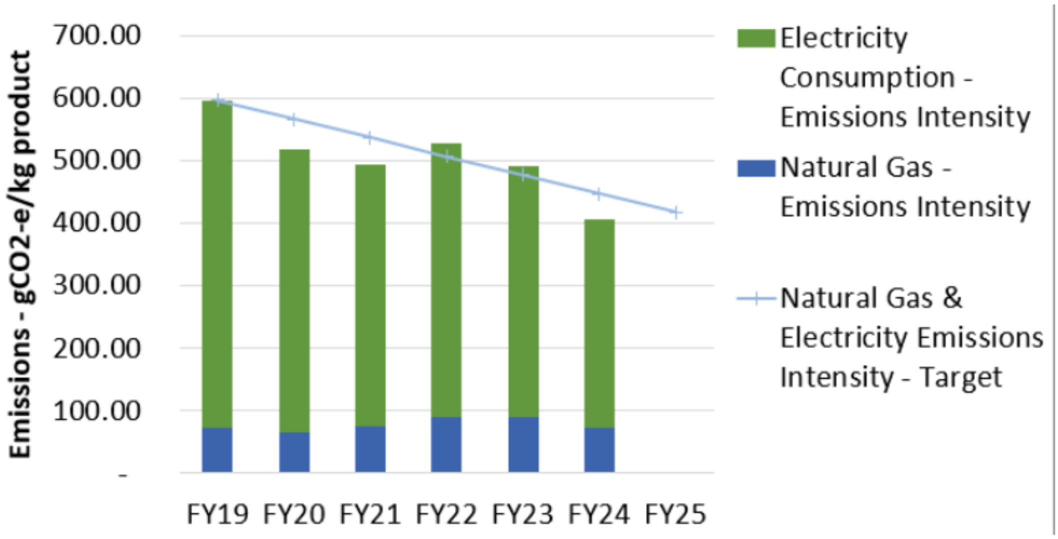

Figure 6: Ego Pharmaceutical gas and electricity emissions intensity vs target, FY19 – FY24

Better practices and lessons learnt

A key takeaway from this transformation journey is the importance of planning data integration from the outset. Without this foresight, organisations risk struggling with fragmented systems that limit the potential of their digital investments. Prioritising data connectivity in every project, regardless of scale, ensures long-term benefits that may not be immediately apparent. It is important to iterate designs at every project stage and not be afraid to modify user requirements even after project execution. This iterative approach ensured that the result met their evolving needs. Furthermore, technology adoption is only as effective as the workforce behind it. Investing in training, skill development, and engaging with end users early in the process ensures digital transformation efforts translate into tangible operational efficiencies.

Ego Pharmaceuticals realised that sustainability must be embedded into daily business processes rather than treated as an occasional priority. Consistent communication driven by the Sustainability Committee on sustainability efforts helped drive behavioural change, while the BMS data provided clear insights into energy usage. This data-driven approach enabled informed decision-making, leading to cost savings and more effective sustainability initiatives.

Personal Perspective: The Future of Manufacturing in Australia

Looking back, Glen is certain, "We can't be competitive in ten years' time doing things the same way we are doing them now. We need to improve our productivity and get more output from the same number of people."

Looking ahead, Glen believes that "Smart Sensing and advanced technologies are no longer optional for Australian manufacturers — they are essential for survival."

Rising input costs and limited pricing flexibility make efficiency gains imperative. To remain competitive over the next decade, manufacturers must embrace modernisation, improve productivity, and maximise output without expanding their workforce. We must continue to invest in the skills of our current workforce and focus on training and development because the long-term success of the industry will depend on leveraging technology to drive continuous improvement and operational excellence.

3.2 Tomago Aluminium

Adopting Smart Sensing for Molten Aluminium Transport: A Journey to Operational Efficiency

Tomago Aluminium is Australia's largest aluminium smelter and contributes $2.2 billion annually to the Australian economy, of which $800 million is spent locally. Operating 24 hours a day since 1983 in the Hunter Region, the organisation is one of the industry's most dynamic and innovative manufacturers of aluminium.

BUSINESS STRATEGY

Background

In 2017, Tomago started investigating Industry 4.0 and smart sensing technologies. The first project involved a crucial operational process: transporting molten aluminium in large containers, or ladles. Losing track of these ladles as they move across a large plant environment causes operational delays and the risk of disrupted production and expensive rework.

Still of a ladle from the process video - https://youtu.be/JTYXS9eXxg4

BUSINESS OBJECTIVES

The objective of moving from manual to automated location tracking was seemingly simple yet uniquely challenging: Ladles, weighing approximately 10 tonnes, were used inside enclosed sheds covering an area of 5 square km. Dennis Moncrieff, IT Superintendent at Tomago, led the team in addressing this challenge.

"*The problem was locating a ladle that has no power source and is routinely exposed to 960° temperatures. There was nothing in the market that could fit the requirements. The other challenge with this area is it's GPS denied.*"

A feasible solution for this challenge needed to withstand extreme heat. Sensor-based electronics cannot be attached directly to the ladles due to the risk of overheating. The location data needs to be accurate as the recovery of the ladle is time-critical.

Dennis highlighted "*If a ladle cannot be traced and the temperature goes below 880^o, the metal solidifies, and you end up with an expensive blob. This means a costly and challenging remedial process is needed. Smooth continuous operational production processes are at risk, causing compounding effects.*"

The desired outcome was higher operational efficiency in moving metal, reducing misplacement risk, reducing the risk of serious event leading to risk of lost time injury (LTI) and minimising operational disruption in a continuous manufacturing environment.

BUSINESS METRIC

Measuring Impact

The business identified several measurable outcomes to support a sustainable, robust, industrial-strength solution.

These included improving asset location visibility to reduce recovery time, automating tracking processes to minimise manual effort, and increasing asset utilisation to reduce delays and improve overall efficiency.

Quantifying the direct ROI before full implementation is difficult due to the lack of historical data on the specific incidents the system aims to prevent. However, the Cost of Inaction (CoI) is demonstrably high, evidenced by the significant expenses associated with solidified aluminium, production downtime, and the extensive labour required for recovery. Furthermore, the potential for enhanced efficiency in the ladle movement process represents an indirect but valuable return.

Given that no suitable solutions were readily available in the market at the time, Tomago's team decided to engineer and design the device and overall RFID-based solution internally. However, the constraints of this approach related to engineering challenges, connectivity coverage and location accuracy soon became apparent. Dennis focused the team on the development of sustainable and supportable business solutions.

Dennis recalls "*Initially, it started as a proof of concept—just an idea to test whether the technology could solve the problem. But we quickly realised it was much more than that. The technology matured, and the operational infrastructure was ready to support it. We now had to make it work as a line of business solution.*"

Operations: current to target state

Adoption Journey over the years

The journey began in 2017, with the intention of tracking ladles in a GPS-denied environment using RFID. Early challenges included extreme heat and non-invasive mounting. By 2019, success led to broader trials—temperature, vibration, even pandemic-era personnel tracking—but scope creep slowed progress. "We lost focus chasing too many use cases," comments Dennis. In 2022, the team refocused on ladle tracking. Wi-Fi infrastructure had matured across the facility, eliminating the need for an additional dedicated IoT network (i.e. LoRAWAN). The prototype transformed into a scalable, sustainable solution delivering measurable business value.

CAPABILITIES

While the solution originated internally, with a technically skilled employee spearheading the initial development, the company sought external vendors for specialised industrial-grade RFID components to ensure sustainable solutions. System integration, configuration, and testing remained an in-house effort. However, as the solution matured and the need for long-term scalability grew, the company partnered with local firms to provide firmware, software, and hardware manufacturing.
"*We realised that technical feasibility wasn't the only challenge. The critical risk lay in losing knowledge held by a small number of people. That's why we transitioned to external partners, such as SAPHI Engineering for sustainable support*." notes Dennis.

Solutions Design – Build Vs. Buy

Managing stakeholder expectations alongside a fast-evolving technology landscape was a key challenge. The approach focused on achieving practical standardisation despite the difficulty of applying fixed frameworks in a rapidly changing IoT environment. To strike a balance, the team implemented baseline requirements—such as cybersecurity protocols, data ownership, and local data access—while remaining flexible to new technologies. This helped contain risk, align priorities, and progressively build governance around emerging solutions.

Data Governance, Architecture and Standards:
A core strategy was retaining local copies of operational data, as relying solely on vendor-hosted systems wasn't viable for this on-premises operation. Local access enabled better integration with internal systems and improved insights. Instead of rigid standards, the team applied practical governance principles—ownership, portability, and accessibility—while staying open to innovation. Close collaboration with developers enabled customisation, benefiting both the business and vendors.

Network Management:
Managing network segmentation in complex industrial environments was challenging, particularly across IT/OT boundaries. Some devices introduced cyber risks through unsecured cloud connections or local servers. Balancing innovation with strong security protocols was essential to mitigate threats and ensure system integrity.

Cybersecurity and Data Duplication Standards:
The team simplified security requirements to encourage vendors to embed cybersecurity early. They also mandated data duplication —maintaining internal, on-premise data management with access to raw data alongside vendor dashboards—preserving data sovereignty without disrupting user experience or innovation.

CHANGE AND IMPLEMENTATION

To commercialise the new innovative solution, Dennis defined and focused on three key areas. All three components—the firmware, the mapping software, and the device manufacturing—were transitioned to external experts to extract undocumented knowledge and prepare the business for future growth.

Limited internal resourcing, concentrated among critical staff members, resulted in insufficient functionality, documentation, knowledge transfer, scalability, and maintainability. This approach created a high dependency on individuals and increased the risk of system disruption or knowledge loss.
Dennis decided to engage external experts *"We brought on three local companies with expertise in each area—to get that knowledge out early and set us up for scale."*

Business and Technology Alignment

Before introducing standards and governance, business teams would independently adopt technology, bypassing IT due to its limited capability in this space. Now, with clear processes and supplier engagement protocols, IT is proactively involved. When teams bring new solutions, IT swiftly assesses needs, engages suppliers with defined requirements, and facilitates secure data integration—without interfering in business-specific dashboards or analytics. This shift has transformed Tomago's IT from a reactive function to an enabler of business outcomes. Today, IT provides infrastructure and ensures data availability and security while end users focus on extracting insights, aligning both business and technology roles for optimal value delivery.

Dennis summarised *"The core problems that that IIoT / Industry 4.0 solves is getting more data to create better actionable insights. Retaining that data and correlating with internal data, we just end up with a better solution"*

OPERATIONAL CONSIDERATIONS

A key challenge was integrating new technology into the operational workflow, especially as workers often encountered it only when a work order appeared, with no prior awareness or training. To bridge this gap, work instructions were developed with the help of SAPHI Engineering, enabling fleet mechanics to perform installations and maintenance. However, a critical oversight was the lack of ongoing maintenance inclusion in work schedules, leading to failures when equipment wasn't regularly checked. This gap highlighted the need for continuous monitoring and maintenance, a crucial lesson for the team. The experience shifted the role of IT from a service provider to a solution facilitator, focusing on operational sustainability.

RESULTS

Since the project addresses a problem not previously measured directly, establishing clear quantitative KPIs upfront was challenging. The project has successfully progressed from a functional proof of concept to a more sustainable and scalable solution that is ready for operational deployment.

Tomago's commitment to safety drove the investment in the system to reduce the likelihood of a serious event, defined as one that could possibly lead to a lost time injury (LTI), from unlikely to rare.

Real-time ladle location tracking enables consistent metal flow and reduces unplanned downtime, supporting operational continuity. Automated tracking replaced manual processes, improving operational efficiency. The system also reduces remedial costs by preventing ladle misplacement and solidified metal incidents, avoiding delays, rework, and additional labour. Leveraging existing wireless infrastructure allowed for a faster, more cost-efficient implementation without significant capital expenditure.
Dennis is confident, *"We've been able to improve operational efficiency and avoid the costly mistakes of misplaced ladles and solidified metal. The solution has become a vital part of our operations."*

Better practices and lessons learnt

While ultimately successful, the project provided valuable lessons that helped refine the company's approach to IoT implementation.

"The biggest takeaway was ensuring we didn't lose sight of the problem we were trying to solve. Once we focused back on ladle tracking, we saw measurable improvements." remembers Dennis.

Key lessons included staying focused on core business value—asset visibility and risk reduction—and aligning project timing with infrastructure maturity to reduce costs. Purposeful prototyping with clear paths to production was vital, as was early cross-functional collaboration across engineering, operations, and IT. Early vendor engagement could have avoided rework, while planning for maintenance and lifecycle management proved essential. Lastly, involving operational teams early ensured smoother adoption and long-term success.

FUTURE OUTLOOK

Looking ahead, the company plans to scale its successful ladle tracking solution across 300+ mobile plant assets, boosting efficiency and asset utilisation. As the system expands, infrastructure upgrades will support new sensing capabilities and richer data insights. Strengthening vendor partnerships and enhancing analytics will be key to unlocking predictive maintenance and refining the broader IIoT strategy.

"Now that we've proven the value of this solution, we're excited to expand it across other areas of the business. The future holds even more potential for automation and efficiency," concluded Dennis.

Dennis Moncrieff says the IoT industry can engage better with the market:

The IoT vendor landscape can be overwhelming and fragmented, often presented with polished solutions that don't reflect the reality of the problems many businesses face. In my experience, vendors tend to showcase ideal outcomes, with beautiful dashboards and impressive tech, but they rarely address the underlying issues. Vendors need to shift the focus to showcasing the real problems they solve, rather than just the shiny results. Many industries, especially in sectors like mining, may not have the infrastructure for grand solutions. Instead, they need simple, practical tools that address everyday maintenance needs—like tracking oil viscosity for equipment care.

Sharing Tomago's perspective with Industry peers:

For SMEs looking to embrace IIoT, the advice is to **identify a clear operational challenge and actively seek out and pilot affordable, focused solutions available in the market**. By starting small and iteratively building on successes, SMEs can begin their journey towards leveraging the benefits of Industry 4.0 technologies.

Dennis recommends, "*Identify where your problem truly lies—whether it's in maintenance, operations, or finance. Then, head to the right industry event. Whether it's IoT, industrial automation, or IT, you'll find technologists solving the problems in small leaps. Start with the specialists, get their ideas, and then bring in the wider team—maintenance, operations, IT—because a well-executed solution can elevate everyone, often at little cost."*

4 Glossary of key terms

BMS (Building Management System): A computer-based control system installed in buildings that monitors and controls mechanical and electrical equipment, such as HVAC, lighting, and fire systems.

Capital Projects: Significant expenditures that will improve a business. These are often investments in equipment, new facilities, or other tangible assets.

CO2 Emissions: Carbon dioxide released into the atmosphere because of activities such as burning fuel, expressed as a measure of the amount of gas released.

Data Logger: An electronic device that records data over time, such as temperature, humidity, or pressure. This can be used in a variety of settings.

Digitisation: The process of converting information into a digital format, often accompanied by changes in the overall system or business operation.

ERP System: Enterprise Resource Planning system; software that is used by an organisation to manage various operations such as supply chain, accounting, and project management.

HVAC (Heating, Ventilation, and Air Conditioning): Systems used to control temperature, humidity, and air quality in buildings.

Industry 4.0

Industry 4.0, also known as the Fourth Industrial Revolution, refers to the integration of digital technologies—such as artificial intelligence, automation, and data analytics—into manufacturing and industrial processes. This transformation enables timely decision-making, increased productivity, and enhanced flexibility in operations.

Internet of Things (IoT)

The Internet of Things (IoT) describes a network of physical objects—"things"—embedded with sensors, software, and other technologies that connect and exchange data with other devices and systems over the Internet. These devices range from everyday household items to sophisticated industrial tools.

Industrial Internet of Things (IIoT)

The Industrial Internet of Things (IIoT) refers to the application of IoT technologies in industrial settings, encompassing interconnected sensors, instruments, and devices networked together with computers' industrial applications. This connectivity allows for data collection, exchange, and analysis, leading to improved efficiency, productivity, and reliability in industrial operations.

Key Performance Indicator (KPI): A quantifiable measure used to evaluate the success of an organisation or a particular activity.

PLC (Programmable Logic Controller): A specialised computer used to automate industrial processes and machines.

Proof of Concept (PoC): An initial, smaller-scale implementation of the IoT solution, likely developed by individuals with an "engineering background".

Proof of Value (PoV): A concept related to proof of concept, focusing on demonstrating the tangible business value of a solution

Return on Investment (ROI): A performance metric used to evaluate the efficiency of an investment or to compare the efficiency of multiple investments. It is typically expressed as a percentage.

User Requirements Specification (URS): A document that details what a user needs from a system or product, including its functions, characteristics, and constraints.

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