A guide for business:

Implementing Industry 4.0 to boost energy productivity

Capturing business benefits using adaptive, intelligent, connected energy productivity solutions

AUTHORSHIP OF THIS REPORT

This report is published by the Australian Alliance for Energy Productivity (A2EP). A2EP is an independent, not-for profit coalition of business, government and environmental leaders promoting a more energy productive and less carbon intensive economy.

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Why improve your energy productivity?

Energy is a key enabler for business, but most organisations treat it as a fixed overhead and do not get full value from its application.

Energy price escalation – electricity, gas (and recently oil again) is impacting business competitiveness, particularly because Australian companies generally create significantly less value from every dollar of energy they use than their overseas competitors.

Energy productivity (EP) measures the value created from using each unit of energy. To improve EP, you increase value added by using energy more effectively, and by using less energy.

This guide aims to help companies to improve energy productivity (and reduce average electricity costs through demand management and on-site PV generation) as an integral part of implementing Industry 4.0.

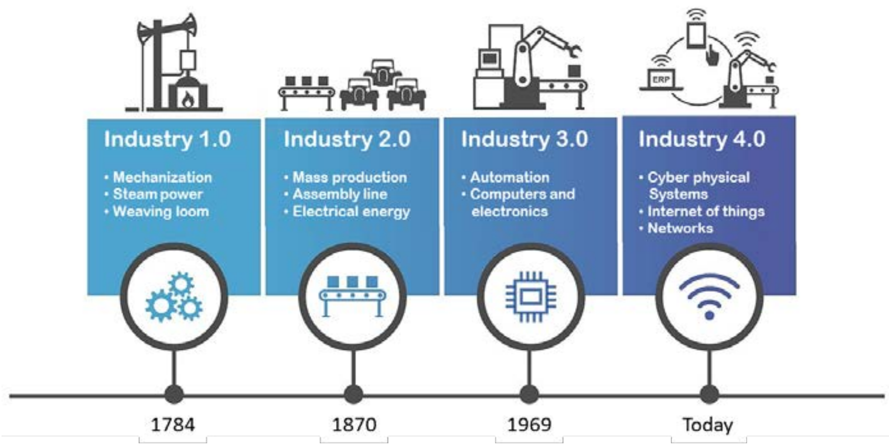
Adaptive, intelligent, connected manufacturing

Industry is undergoing a technological transformation, which is sometimes called the fourth industrial revolution or Industry 4.0.

Industry 4.0 emerged in Germany. A similar approach in the US is called 'Smart Manufacturing', and 'smart factory' is also a term used in Germany. Other countries have their versions (e.g. 'Made in China 2025'). This revolution promises not just improved manufacturing productivity, but also the ability to exchange information with suppliers and customers, facilitating more responsive manufacturing.

The transition to smart, connected industry also allows businesses to better control energy costs, and capture broader business benefits from applying energy better, including increased throughput, improved plant reliability, better product quality and reduced maintenance costs.

Fourth industrial revolution: adaptive, intelligent, connected manufacturing



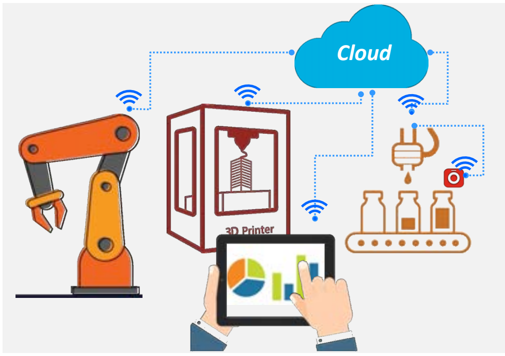
Source of Industrial Revolution images: http://www.btelligent.com/en/portfolio/industry-40/

However, the change to smart, connected industry will not happen automatically. Energy needs to be actively addressed and managed in an Industry 4.0 environment as much as it did in Industry 3.0 or 2.0.

Key elements in the Industry 4.0 transformation are:

- **Flexible equipment and processes** that can respond to information from across the business and beyond, changing product specifications and optimising performance in response to customer needs. To ensure this flexibility converts to high energy productivity, energy using equipment must be able to flexibly adjust to production changes.
- **Access to data streams** from other parts of the business, the supply chain, delivery system, customers – and their customers, as well as from external sources like public agencies (e.g. weather bureau, traffic management authorities, sources of statistical data). To convert these data streams to high energy productivity, we need to be able to measure energy use and understand how this impacts on key production variables.
- **Communication systems and platforms** that are secure and reliable, including for energy use**.**
- **Data analytics** that manage, analyse and convert data into actionable and useful information. Energy productivity metrics should be included in outputs.
- **Organisational capacity**, including change management, and specific Industry 4.0 and energy management skills/knowhow. Do not underestimate the importance of managing the people side of this transformation. Specialist energy competency may need to be built in-house and supplemented with consulting/technology vendor assistance during the implementation of these changes.

Key elements of Industry 4.0



Industry 4.0 Technologies

A range of technologies underpin the Industry 4.0 transformation. Key technologies include: Internet of Things (IoT), enhanced data analytics, cloud computing, more flexible plant, artificial intelligence (AI)/machine learning, and augmented and virtual reality.

Refer to the Glossary of Terms at the end of this Guide for an explanation of Industry 4.0 enabling technologies.

Including energy productivity in your Industry 4.0 program

To successfully transform a manufacturing enterprise, Industry 4.0 enabled technologies need to be applied to monitor energy use and optimise energy use for variable production.

You will need a clear plan to optimise energy use and achieve high energy productivity through this transition. Digitalisation offers lower cost advanced energy management tools to help optimise energy use. However, most companies have inadequate metering of their energy use to even understand the scale of the opportunity.

Energy using plant and systems may need to be modified/designed so they have very low standing energy losses (i.e. energy use at zero throughput) and thus good turndown response, and energy using services like compressed air need to be able to be isolated from plant when not in use.

This guide provides guidelines on how to transform the way you apply energy as you go through the Industry 4.0 journey.

There are many energy productivity opportunities in every business, and we have characterised them below, starting from helicopter level down to equipment level, to assist you to systematically approach this task.

The biggest insights often come where traditionally there has not been free information flow – where there are information boundaries between systems/divisions in plants and between organisations in supply chains. So, it is worth looking briefly at least at the big picture before diving too far into the weeds. Here is the way we have approached the opportunities:

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**

There is also potential to reduce your average energy cost through the use of renewable energy procurement, integrated with load management and storage, and this is covered in a separate section.

1. Improve information flow across interfaces between organisations and production lines

Opportunities often exist to achieve substantial energy productivity gains by improving the visibility of information across multiple businesses in supply chains, and across multiple operations on a site.

Industry 4.0 technologies can provide real time visibility of key material variables (e.g. size, temperature, moisture content, location) across interfaces in the chain. This information, accessible from cloud-based applications, can provide a selectively shared view of key product variables, and facilitate a shared understanding of final customer needs, to allow players along the chain with the right incentives to optimise material specification to boost overall energy productivity.

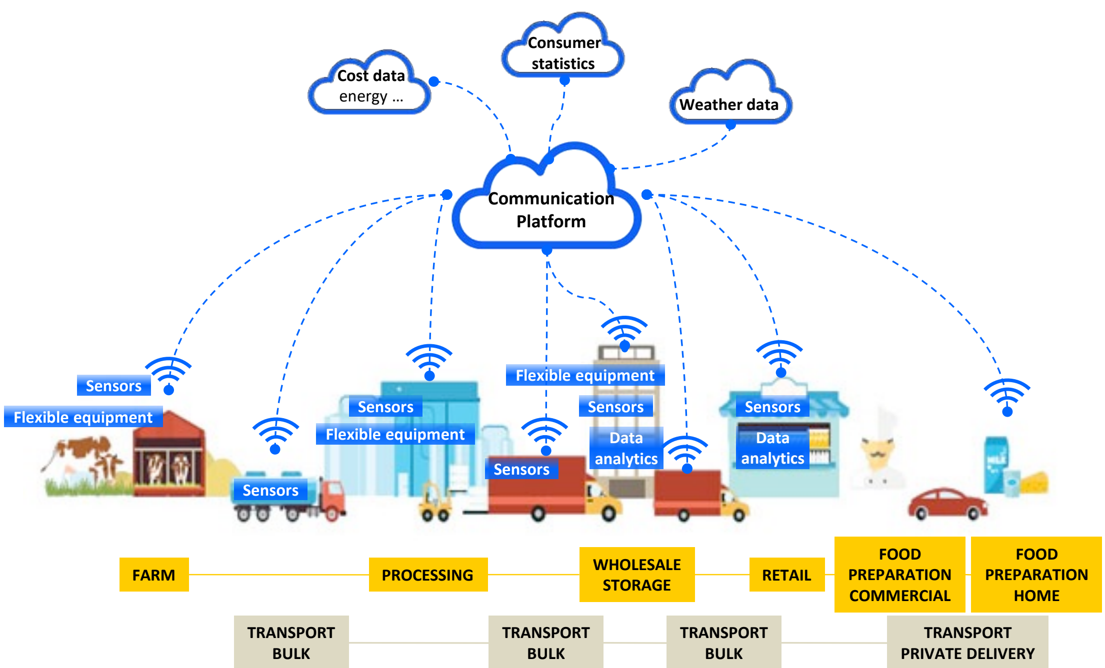
Energy performance benefits across value chains come from:

1. Availability of securely and selectively shared information across the chain, which facilitates changes in operations upstream and leads to reduced demand for energy at the processing stage. For example, where it is feasible to reduce water content of a product earlier in the chain.

   Example: Real-time temperature and location monitoring in the cold chain.

   Companies are starting to improve control of the quality of perishable food by monitoring the temperature and location of these products through the cold chain from farm to shelf, using low cost sensor devices/ transmitters, communication networks and cloud-based applications to collect, report and respond to variances from target temperatures in real time.

Inter and intra-organisation information flow across interfaces using I4.0 technologies in the food value chain



2. The control of key product variables in energy-using processes along the chain (including in processing) that results in greater product value/reduced product losses.

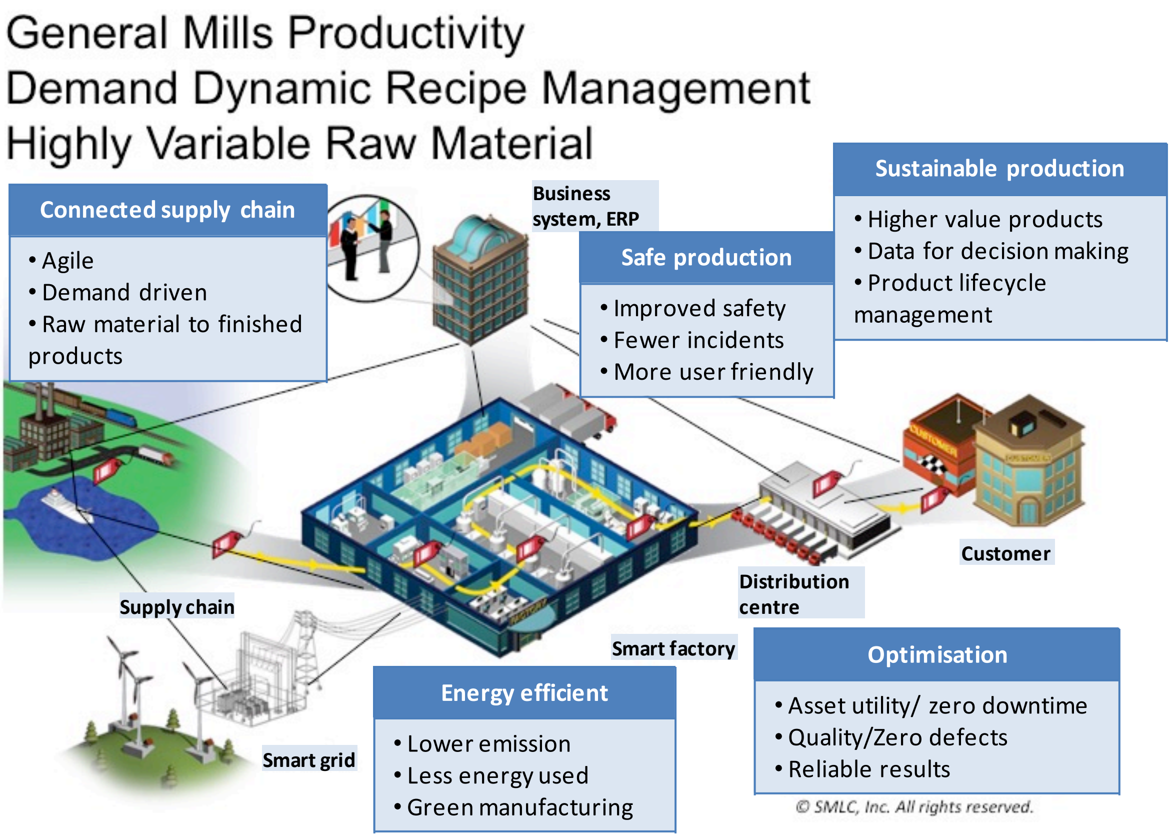
   Example: Oat properties and composition content for manufacturing breakfast cereal.

   Cereal manufacturing depends on an oat supply chain that needs to ensure growing conditions (GMO-free), safety (contamination free), properties (oat quality) and composition (oat and moisture). Increasing the visibility of the feed product specification from the many suppliers opens the door to focus on oat composition relative to product demands, dynamic recipe management and managing energy consumption as a result of transporting, mixing, storing and dealing with the properties and the moisture content of the product (see diagram below).

Checklist questions to find savings

- Are there key product parameters in the raw materials supplied to your plant that particularly impact on energy use? Examples might be product moisture content, size specifications and temperature.
- Would there be value to you if you could see those variables in real time for these materials before they were delivered?
- Are there changes in the material specification supplied that could improve your energy productivity (and potentially save cost for the supplier)?

These same questions can be applied within a plant between different lines/departments where there have traditionally been information boundaries.



2. Improve plant energy flexibility

Industry 4.0 plants are flexible and responsive to customer demands. This flexibility will not necessarily result in energy benefits unless efforts are made to measure and understand the relationship between throughput and energy use.

Much energy using plant and systems are inflexible in their use of energy due to high energy losses even at low throughput, so their turndown efficiency is very poor.

For example, boilers/steam systems and compressed air systems often have very high standing energy losses. Pumping and fan systems also have poor efficiency at turndown if they are controlled with throttling valves/dampers, but variable speed drives are rapidly being adopted to control these systems.

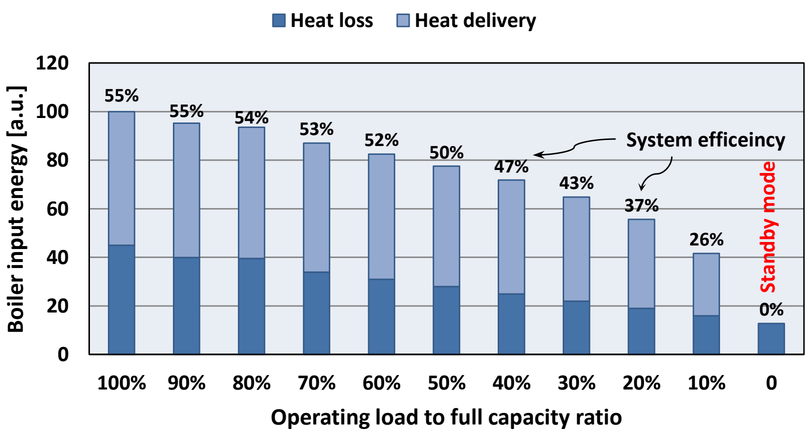
It is possible to determine standing losses by measuring energy consumption at different throughputs and plotting the data. When the energy consumption does not vary much with throughput, standing losses are high (see figure below).

This inflexibility issue can be addressed partially through improved monitoring and controls facilitated by Industry 4.0, but in some cases will need investment in new digitally controlled technology to provide really flexible energy consumption and cost.

Checklist questions to find savings

- Do you have compressed air or steam systems that are significant energy users?
- Can you turn off the supply of compressed air, steam and electricity to process plant when not needed (ideally at the source)?
- Do you have pumping systems controlled by valves, or blowing systems controlled by dampers?
- Does your steam system supply mainly hot water needs?
- Do you have variable speed drives on all lead compressors for refrigeration and compressed air?

The efficiency and heat loss of a steam system for different operating conditions, the horizontal axis is the actual load to full capacity ratio (part load ratio). The standby mode is when there is no heat delivery. We see that there is still heat consumption due to losses.

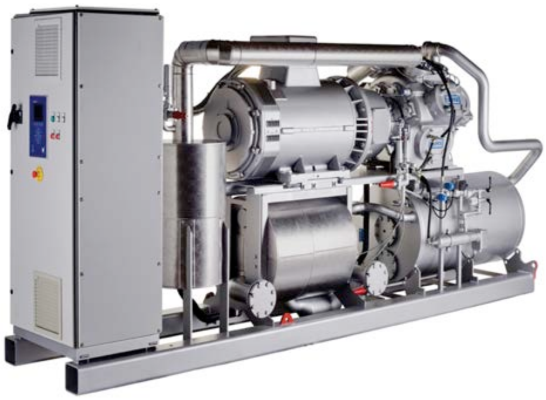


Example: Replacing central boiler and steam systems with localised heat pumps

Central boiler and reticulated steam systems typically have high energy losses at reduced throughput. Where the steam is mainly used for generating hot water, they may be replaced with industrial heat pumps that can supply heat to specific processes and thus have low standing losses and have very high inherent energy productivity (as they can deliver up to 5+ units of heat for every unit of power they consume).

See detailed coverage of this topic here.

Industrial heat pump

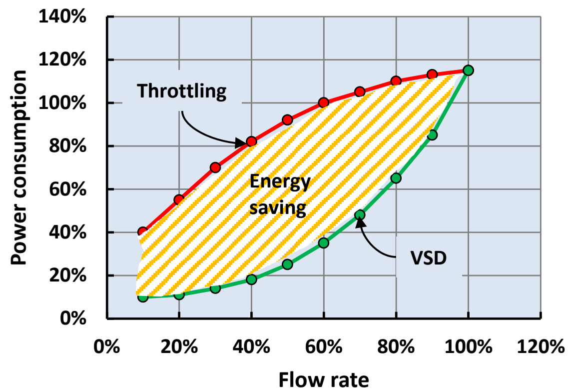


Example: Pumping system with variable speed drive

As can be seen from the graph to the right comparing a pumping system with a throttling (valve) system to an equivalent pumping system with a variable speed drive (VSD) add-on, the system with a VSD is considerably more energy efficient at part load.

For example, at a flow rate of 40% of full load, the energy consumption of the pumping system fitted with a valve is 80% of the energy consumption at full load (100% flow rate). In comparison, at a 40% flow rate, the energy consumption of the pumping system fitted with a VSD is 20% of energy consumption at full load. Note these are indicative and may vary depending on other factors.

Pumping at part load: valve (throttling) versus VSD



Electronically controlled variable speed pumps

Image: www.au.grundfos.com/products/find-product/alpha2.html

3. Optimise energy intensive processes and systems

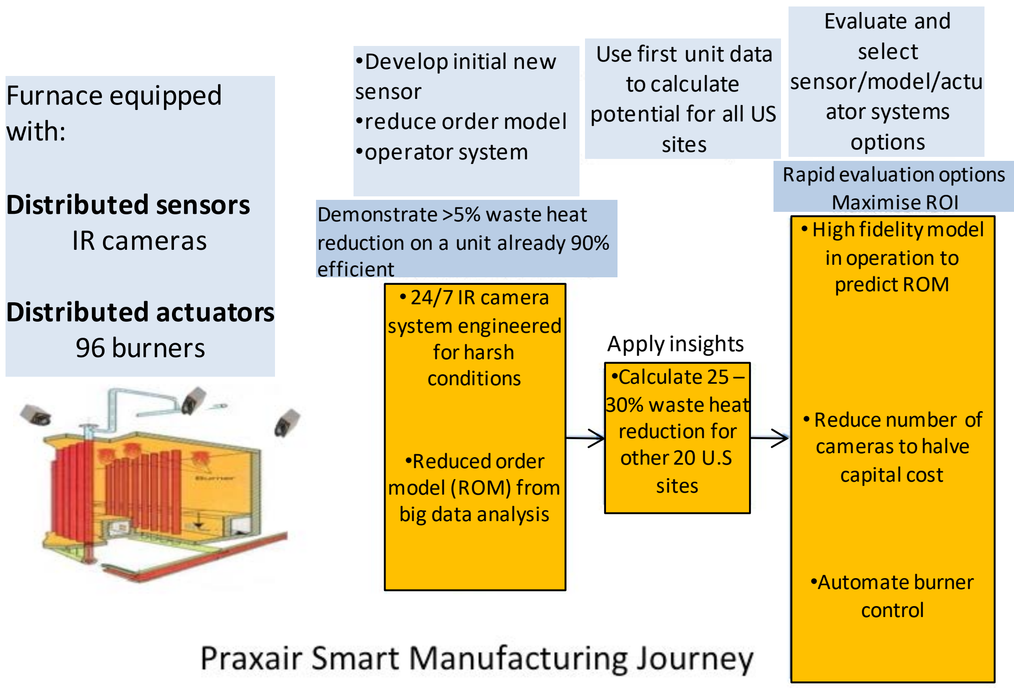
One of the key energy benefits from Industry 4.0 is the potential to optimise existing (and new) energy systems like refrigeration, and core process plant, using enhanced real time monitoring of key variables, and use of artificial intelligence to learn which operational modes deliver the lowest energy outcomes under a range of typical operating conditions.

This includes use of automated visual recognition to identify in real time if a product is being correctly manufactured and making adjustments to keep the product in specification, BEFORE it results in multiple rejects.

Example: Process optimisation at a gas-stream reforming plant[1]

Praxair is a large industrial gas supplier in North America. The company has similar furnace-based manufacturing plants across the U.S. operating with some variation in efficiencies. The Texas branch deployed advanced image sensors for the real time measurement of temperature variations throughout the geometry of the large-scale furnace, variations that relate to optimal product output.

A very large amount of real-time temperature distribution data over time were used to build and optimise a virtual physical model for how temperature, and in particular temperature distribution, relates to the 96 burners. The results of the demonstration were used to project a >25% reduction in waste energy across multiple US sites and the learning resulted in evaluating enhanced approaches.



[1] Final Report, Industrial Scale Demonstration of Smart Manufacturing Achieving Transformational Energy Productivity Gains. Award Number: DE-EE0005763 Project Period: 9/01/2013 – 11/30/2017, PI Thomas Edgar, University of Texas Austin, February 2018.

Example: Intelligent refrigeration monitoring system

The 'Metis' monitoring system involves the installation of a range of sensors on refrigeration systems to track indicators including temperature, pressure, and humidity at various points, and current draw of motors and heaters.

The system is cloud based so data is remotely available 24/7. Each site wirelessly connects to the cloud where data is logged for unit history and trend analysis. Data collected faciliatates remote and auto diagnostics in real-time, enabling preventive maintenance and predictive failure detection.

The monitoring system uses artificial intelligence to learn the operation of a refrigeration system. It recognises and creates an alarm if a fault is identified, including for complex faults such as compressor short-cycling, liquid flood back, excessive suction superheat, blocked condensers and refrigerant loss or overcharge.

Selecting technologies enabled by Industry 4.0

When there is a major investment/refurbishment occurring in your plant, consider alternative processes that have higher energy productivity and are better suited to maximise benefits using Industry 4.0.

Examples include:

- Improved digital processes with lower energy footprints, such as 3D printing (additive manufacturing).
- Modular technologies suited to micro-factories, potentially integrated with upstream activities (e.g. on-farm dewatering) or downstream activities (e.g. micro-breweries).

Intelligent refrigeration monitoring

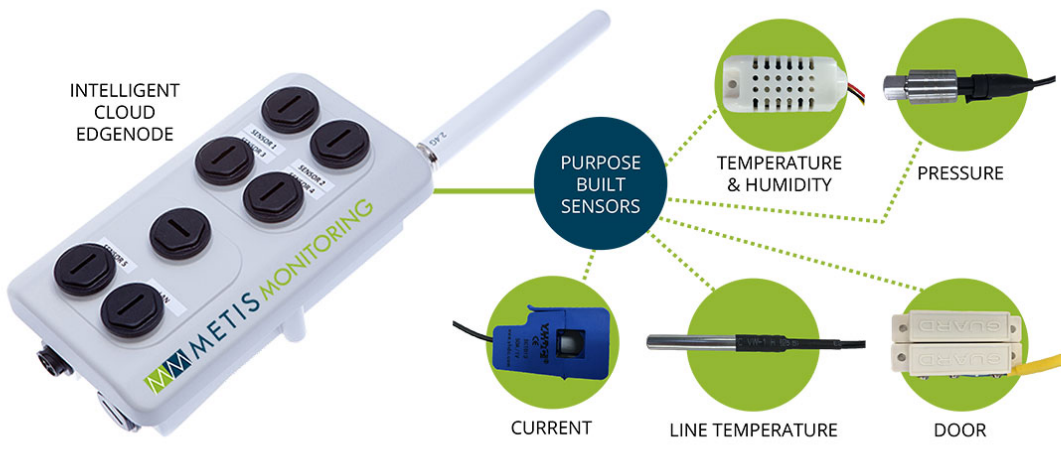


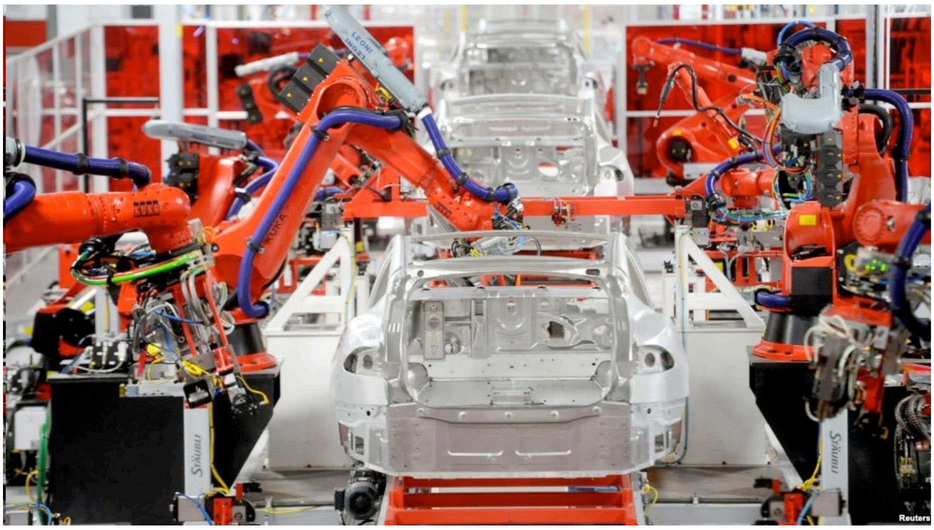
Image: http://metismonitoring.com.au

Automation to remove lighting/air conditioning

The uptake of automated systems and robots reduces the need for human presence in industrial buildings and warehouses, facilitating lower energy consumption to maintain lighting, comfort conditions and air quality.

This energy saving can be significant because maintaining comfort conditions in industrial buildings tends to use more energy than expected because in most manufacturing buildings, infiltration is significant, high ceilings make heating systems less effective, significant ventilation is required in some manufacturing plants to maintain the air quality, and these building tend to have a large footprint.

Comparison of human operated and fully automated production plants



4. Improve the energy productivity of specific equipment

The key issues to consider are:

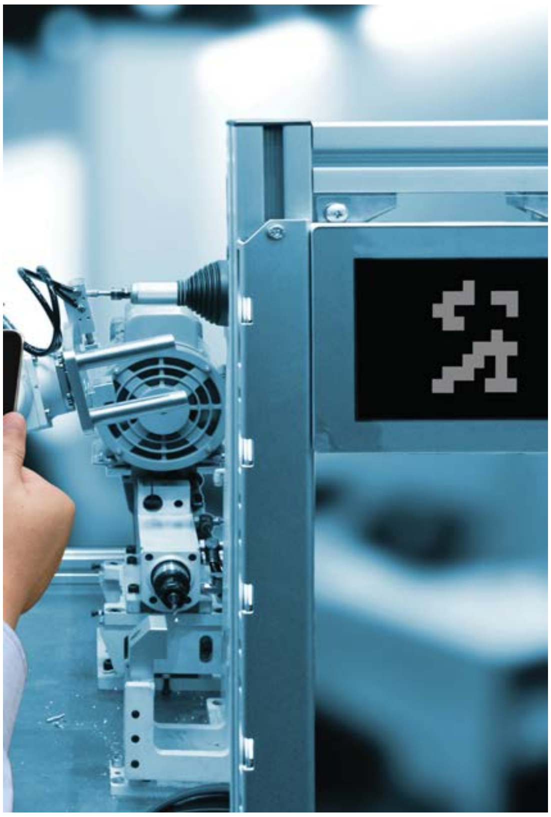
1. Select energy using equipment like motors and compressors to facilitate Industry 4.0 to deliver energy performance benefits.

- Size equipment so that it will normally be controlled to operate between 75 and 90% of rated load. Motors, for example, generally operate at peak efficiency in this range, but efficiency falls away markedly below 50%.
- All equipment should be Industry 4.0 compatible – digitally controlled, well instrumented – including energy metering, with suitable communication interface, with energy efficient turndown and automatic switching when not required.
- Replace motors when damaged with new Industry 4.0 compatible, high efficiency equipment, and do not rewind.

2. Use condition monitoring to ensure ongoing efficient operation of equipment, particularly rotating plant and equipment.

Checklist questions to find savings

- Have you checked to see whether larger motors are running lightly loaded and could be replaced with new smaller, more energy efficient models?
- Do you always replace motors or do you rewind them?
- When you buy new equipment, is it specified to be Industry 4.0 enabled and include energy metering?
- Do you use real-time condition monitoring on rotating equipment to ensure energy efficient operations and reduce downtime?



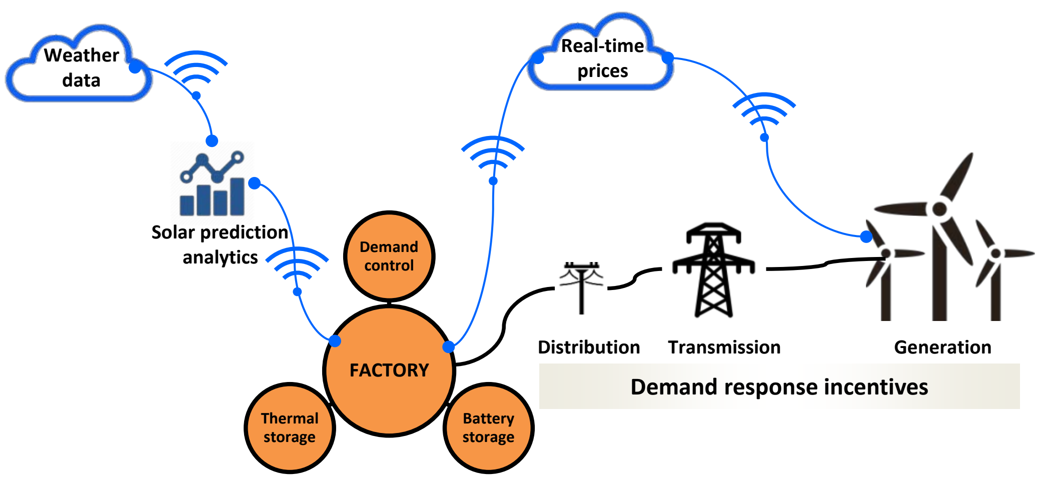
Optimisation of the energy supply chain

The following are opportunities to use Industry 4.0 technologies to reduce your average electricity cost.

- Optimise benefits from your solar PV installation and/or renewable power purchasing agreement (PPA). Industry is installing PV as prices continue to plummet, but often on-site generation of power is not optimised by using demand control to reduce peaks. Companies are also now starting to buy renewable power using corporate PPAs, but again, because this provides cheap supply only when generating, demand control has an important role to maximise the use and value of this resource.
- Demand control: The main action most companies can take now to reduce energy costs is to control peak demand in response to network tariffs, through monitoring your load profile and either shedding discretionary loads or using energy storage to reduce load peaks. (The energy storage used could be batteries, but these are often too expensive to be economic at present, and thermal or material storage could be more attractive.)
- Demand response: There are trials being conducted of demand response incentives that reward sites for reducing their energy usage significantly for relatively short periods when the supply system is short of power to meet demand. This can be an attractive option for sites with controllable loads or energy storage. While most companies believe it is not possible to control site loads in this way, with expert advice it can often be shown to be possible and economically attractive using Industry 4.0 enabled automated control.

In the future it is likely that businesses will be able to optimise their electricity costs by controlling electrical loads and storage automatically in response to price signals from the supply network and availability of on-site power generation using Industry 4.0 technologies.

Optimisation of the energy supply chain – lower costs for the network and consumers



Energy metering – if you can't measure it, you can't manage it: Control of energy use in Industry 4.0

Companies piloting Industry 4.0 in their operations are starting to consider how energy should be integrated into these trials because energy is now so expensive. The first question you should ask yourself when considering this challenge is:

- Do we have adequate energy metering?

  and then,

- Can we relate the consumption of energy (in core processes as well as ancillary energy using plant like air compressors) to the key operating variables which impact throughput and quality?

If the answer to these questions is 'no', then it is important to develop an energy information plan.

Suggested steps to doing this follow:

- Develop a plan to work out where you think out how you might use the additional information, and who will use it, in what format. Engage with users to identify useful information and suitable format, timing, etc.
- Define the key energy uses which have the greatest impact on throughput and quality and meter those.
- Also meter the largest energy consuming equipment if not covered in the previous step – typically 10-20% of energy using equipment will use 80-90% of the energy.

Some challenges you will face are:

- Accessing boards for electricity metering when the plant is running
- Real-time measurement of gas and steam energy use is expensive and requires plant shutdowns to install.

There are developments using Industry 4.0 technologies which show promise for resolving these challenges in future, including the use of artificial intelligence (AI) to recognise digital signatures of particular equipment and using this to provide submetering from measurements at the main board, and using 'digital twin' computer modelling. For example, it is envisaged that the vibrational or acoustic behaviour of moving devices such as fluids, motors etc. can be detected by low cost sensors and correlated to the energy consumption using AI algorithms.

Predictive/modelling tools in Industry 4.0

Conventional enterprises of the Industry 3.0 era have evolved and gradually optimised over years/decades to run efficiently and cost effectively for specific production schedules. In these plants, introducing operation variations for further optimisation or producing new products normally requires lengthy and costly reorganisation, restructuring, and redesigning of the production lines or even the whole enterprise.

Intelligent Industry 4.0 factories are and should be capable of continuously optimising and varying their manufacturing lines. This can't be fully realised unless the factory's responses, including its energy flow, to variations are predictable and measurable. To do so, two important tools are required:

- A digital twin model (DTM) of the manufacturing line that predicts the energy flow and productivity of the processes in different modes of operation, and
- A network of sensors and monitoring devices distributed across the plant to connect the digital model to the live data from the shop level.

A DTM is a virtual representation i.e. computer simulation of the mathematical model of a physical system such as a manufacturing line. A building energy management system is a simple version of such a system. A DTM uses real-time data from sensors and external sources such as suppliers to provide continuous productivity performance statistics. Anyone looking at the DTM data can see how the physical system is functioning in the real world.

The DTM can be extremely helpful to quickly predict the consequences of complex instructions and variations before physically implementing them at the shop floor level. This can include the:

- Energy performance of varying the production schedule
- Economic benefits of adopting new technologies and equipment such as renewables, heat pumps, etc.
- Monitoring and verifying the performance of the existing and newly adopted equipment and technologies, and
- Remotely monitoring and modifying the way the manufacturing line is operating.

Bottom line energy benefits from Industry 4.0

Energy prices have escalated rapidly in Australia in the last decade and most companies have not gained real control of their energy costs, let alone reinvested in plant and systems to make step change improvements in their performance. A focus on energy when implementing an Industry 4.0 program can deliver energy savings of 20%+ and, more importantly, often overall plant productivity can be substantially improved in energy intensive processes and equipment by focusing on energy related solutions. The International Energy Agency (IEA) found that energy projects on average generate 2.5 times the energy savings through other productivity benefits – our experience is that the multiplier is generally much higher.

The following table shows benefits from real projects in the US reported by CESMII[2]. Initial energy reachability equals potential economic/energy productivity increase that is immediately foreseeable. Critically, CESMII's experience shows that these savings are generally increased by learning over time, and then multiplied by replication at other similar facilities.

Initial Energy Improvement Reachability	Operational Focus for Initial Energy Reachability	Real Time (RT) Advanced Sensing Control & Modeling for Initial Energy Reachability
Paper 15-25%	Evaporation; drying; unit & line operation integration	RT process sensing; control; predictive modeling; enterprise optimize
Steel 20 – 25%	Hot rolling; continuous casting; unit & line operation integration	RT property sensing; control; RT analytics; RT high fidelity modeling; enterprise optimize
Metals 20 – 30%	Forging; heat treatment; casting; tooling; unit & line operation integration	RT property measurement, control; machine modeling; high fidelity analytics
Glass 5 – 15%	Melting; heating; precision operations; finishing; supply chain; unit & line operation integration	RT process/property sensing; analytics; model validation; prediction; enterprise optimize
Food 15 – 20%	Heating; drying; demand response; dynamic recipe; unit, line supply chain operation integration; custody chain	RT sensing; prediction and diagnostics; dynamic supply chain enterprise optimize
Micro Electronics 20 – 30%	Precision operations; tooling; line operation integration; tool & machine supply chain	RT multi-tool data aggregation; diagnostics and predictive modeling
Oil & Gas, Chemical 5 – 10%	Heating; compression; cooling; unit constraints; reduce off spec unit & line operation integration	RT sensing; high fidelity modeling; control; diagnostics; predictive modeling
Coatings 20 -25%	Precision operations; material management; unit & line operation integration	Image processing; analytics; high fidelity modeling; control; optimization
Plastics & Composites 20% - 25%	Heating; compression; cooling; tooling; coatings; reduce off spec unit & line operation integration	RT properties; control; diagnostics; predictive modeling; enterprise optimize
Manufacture/ Utility 15-20%	Heating; grid load mgmt.; demand response, renewables; distributed generation	RT energy measurement; ecosystem energy management
Aerospace Parts	3D printing; precision parts; tooling; energy dependent parts; line operations; supply chain;	RT supply chain data; advanced sensing; imaging; chain of custody; tooling

[2] www.cesmii.org

Implementation Planning

This section contains a how-to guide for businesses starting their Industry 4.0 journey and provides an incremental approach for adoption of Industry 4.0 technologies for energy productivity, as a first stage in the transformation from conventional manufacturing to adaptive, intelligent and connected manufacturing.

Starting the journey

This is where a business manager hits lots of jargon, grand visions and promises. The Internet of Things (IoT), the cloud, data analytics, artificial intelligence, Industry 4.0, Smart Manufacturing and energy productivity are just some of them (see the Glossary of Terms at the end of this document).

There is plenty of reason to be confused and sceptical. But this won't protect a business from the wave of disruptive change flowing through our economy. Just as the smart phone and internet have changed our daily lives, modern technologies and services are transforming manufacturing.

Manufacturing activity is spreading beyond its traditional industries, while services are replacing or supplementing physical production. The hot bread shop and micro-brewery are really micro-factories integrated with retail outlets that compete with large scale producers. Downloading music has replaced manufacture of physical media and the equipment needed to play them. A design business may use a 3D printer instead of a low volume component manufacturer.

Step 1: Choose a task or process to start

You are embarking on an exciting and challenging journey. But it will take planning, time, effort and resources. And you will learn from experience, making mistakes and gaining surprising (and often profitable) outcomes.

Every journey starts with a first step and an achievable goal. So, focus on an aspect of your business where you (or your managers or technical staff) see potential for improvement, or where change is necessary. Don't tackle something first that is 'mission-critical' to your business viability.

A process that involves significant energy consumption or costs, where equipment may need to be replaced, upgraded or expanded is a good place to start. For example, as discussed earlier, equipment with high energy losses which may be reduced using digitally controlled technology to provide flexible energy consumption.

Step 2: Ask some questions

Look around to identify:

- Who in this sector or other sectors has already made changes that I can learn from?
- Which suppliers, consultants, researchers, industry associations and/or contractors are familiar with emerging smart solutions – recognising that they will all have their own agendas and preconceptions! But learn what you can from them – or encourage your relevant staff to engage.

Ask your staff questions such as, what information, if provided when you need it, would allow you to:

- operate your equipment better?
- identify emerging problems with equipment sooner?
- when and in what form would you need this information?

Ask yourself what information, with what timing and in what form, could help you to manage and plan better. Where or how could this information be sourced.

Ask what changes to equipment, practices or other factors would be needed. For example, you may need to fit variable speed drives and equipment to monitor key parameters to a machine or equipment, so it can adjust to changes in inputs.

Check for disruptive possibilities. Could something emerge that could change the situation so this change is affected by other factors from other innovative paths?

And explore the kinds of energy productivity benefits your business might gain if the benefits that have been flagged through your explorations can be captured. Make some rough estimates of the value of these benefits to your business. This will help you to decide on the initial scale of resources to allocate.

This process could open your eyes to many possibilities. But you will need to pursue some more thorough processes and allocate resources for them.

Step 3a: Serious analysis – what services are provided?

It is important to understand the fundamental services that are being provided. These include the services to end-use consumers as well as within the process and business. For example, a narrow interpretation, such as 'This provides steam to drive xx process' does not explore the fundamentals. What is the outcome of the process the steam supplies, and what temperature and how much heat does it really need?

Within the organisation, steam may be used to provide heat that is not needed if heat is recovered. Or processes that do not even need heat, such as high pressure processing, centrifuging, etc. A process may not require such a high temperature.

Step 3b: Understand the systems

This step is best integrated with assessment of the services being provided. Services are provided by systems, which are often complex.

Analysing energy and material balances often identifies waste of energy, resources, money and time.

It may also reframe opportunities. For example, analysis of a steam system can identify large energy losses and significant unrecognised costs. Incremental improvements can be made to cut these losses. Analysis may also lead to recognition that one process is at the end of a long leg of steam pipe, so savings or changes in the heat source may allow that section of steam pipe to be shut down. Also, once energy waste is reduced, alternative solutions that previously looked impracticable may become attractive. For example, targeted infra-red electric heating may economically replace wasteful use of gas, even though each unit of energy is much more expensive.

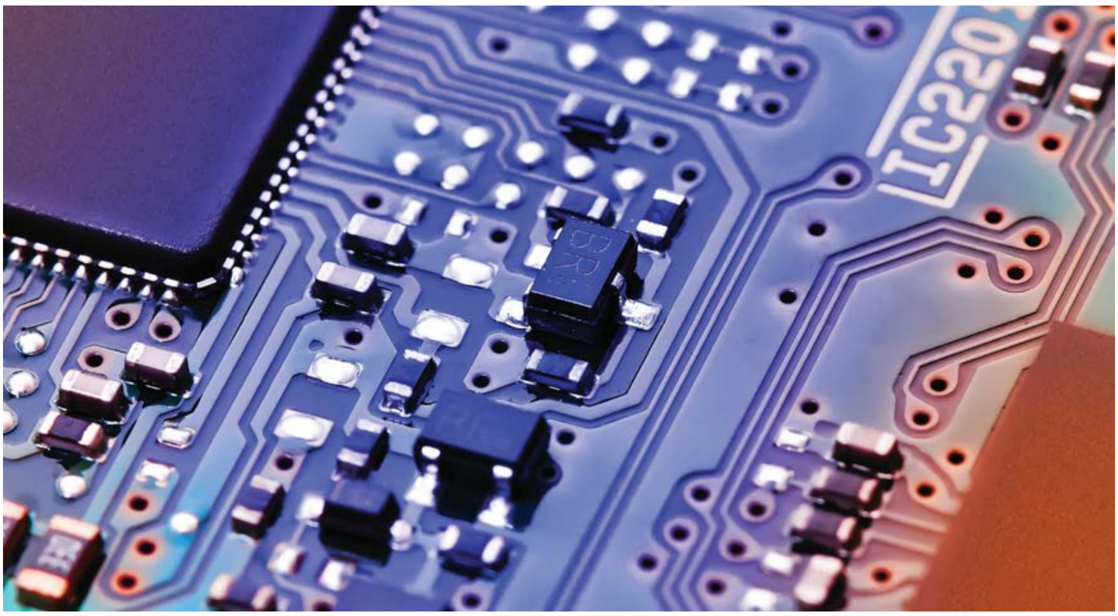
Step 4: implement smart options you are confident will bring benefits while building your experience, networks and capabilities

Transformation is not 'all or nothing'. But you need to start. By now, you should have defined some clear opportunities. These may apply technologies or practices well-proven by others, and that your in-house or contract technical staff can supply, install and maintain. You may add new technology initially as a back-up or supplement, then transition to greater use over time, while keeping the previous equipment as a back-up. Make sure you incorporate adequate monitoring and benchmarking capability so that you can evaluate the benefits and understand the causes of any teething problems or shortfalls in performance below expectations.

Riding the bus to adaptive, intelligent manufacturing

Apply the experience you have gained to other areas in your business. Build relationships with suppliers who can support your transformation. Consider larger, longer term investments and develop strategies and plans as you gain confidence.

At the same time, you will see increasing potential to capture more benefits, such as integrating behind-the-meter renewable energy, energy storage and energy management, and considering energy trading and cost optimisation through peer-to-peer trading, demand response and further energy efficiency improvement.



Glossary of terms

The following is a summary of terms used in this report. Further detail on each of these terms can be found in the Transforming Energy Productivity in Manufacturing report.

Internet of Things (IoT)

The Internet of Things (IoT) refers to a range of networked data collection and communication devices, hardware and software that can be deployed across plants, systems, subsystems, and equipment to monitor certain physical variables. IoT technology includes advanced sensors with a capability to upload digital information onto a database via a data communication network/protocol. Sensors are becoming smaller, cheaper, battery/solar powered and capable of monitoring multiple variables

The connectivity of the sensor can be realised with the help of different technologies. Some of these technologies allow for connecting hundreds of sensors to a single communication gateway.

Cloud computing

The practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer

Cloud platforms can enable:

- access to powerful data computation, storage, transfer capability without the need for setting up an independent high-end IT system, and
- create a platform that is accessible by all the stakeholders of a complex supply/manufacturing chain.

Artificial Intelligence (AI)

AI is a computer system able to perform tasks in human interpretable forms that normally require human intelligence, such as visual perception, qualitative analysis, feature interpretation, speech recognition, decision-making, and translation between languages

Machine learning (ML)

ML is a subset of AI. Machine learning can be distinguished from expert systems in that data are used to learn interpretable tasks, behaviours or actions. ML systems learn patterns of behaviours and have the ability to modify themselves when exposed to more data, i.e. when structured appropriately, machine learning can learn and adjust to new behaviours reflected in the data without human intervention. Learning algorithms are optimisation algorithms; they learn from the data they are exposed to by minimising the error between what is learned and what is observed

Data analytics

Data analytics is the process of examining data in order to draw conclusions about the information contained in the data. Technological advancement is allowing faster analysis of larger data sets.

Sensors

Data in smart enterprises originate from sensors. Sensor technology is continuously improving with the costs declining. (See Internet of Things)

Smart Manufacturing

A term used primarily in the US. The goal of Smart Manufacturing is to enable all information about the manufacturing process to be available when and where it is needed across the entire manufacturing supply chain and is broadly consistent with Industry 4.0.

Energy productivity

Energy productivity (EP) refers to the value created from using a unit of energy.

The full detailed Transforming Energy Productivity in Manufacturing report is available here.

An industry guide to innovative process heat technologies is available here.

2xEP Doubling Australia's Energy Productivity

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The Australian Alliance for Energy Productivity has been leading business transformation through activities including:

- Research and analysis that is identifying emerging technologies and business models and documenting case studies and issues relevant to progress towards doubling Australia's energy productivity by 2030.
- Reframing ways of thinking about energy, in particular:

  - Energy Productivity (increasing economic and business value from each unit of energy consumed).

  - Value chain thinking, which highlights the interdependence of industry sectors within a supply chain as well as the customers of intermediate products or services and end-consumers.

  - A systems and services focus, so that the fundamental services valued by consumers are identified, and the complex technical, financial, business and other systems that deliver these services are understood.

  - Information exchange, through sector working groups, and events such as a recent Innovation X-Change.

  - Advocacy and engagement with governments.

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