Teaching manual Sustainable Asset Management according to the MORE4Sustainability model

Instructions for the teacher

This handbook is part of the Interreg NWE project **MORE4Sustainability**, which aims to strengthen awareness and application of sustainable asset management in industry. The focus is on improving **energy efficiency** and **reducing greenhouse gas emissions** through a systematic approach to **Maintenance, Overhaul, Repair and Engineering** (MORE).

Together, these disciplines form the core of technical support for industrial processes:

- **Maintenance**: the systematic maintenance of assets to ensure performance, safety and reliability;
- **Overhaul**: the thorough overhaul or renewal of plant and systems at the end of their life cycle;
- **Repair**: repairing defects or malfunctions quickly and effectively;
- **Engineering**: designing, improving and adapting systems and processes for maximum technical and sustainable performance.

How to use this handbook

This handbook is intended as a **speaker's note** or **written-out lesson content** for those delivering a one-day training course on sustainable asset management. The content follows the structure of the MORE4Sustainability framework and provides explanations, context and examples for each part of the training.

As a teacher, you can read this text:

- **reading aloud or free retelling** during your presentation;
- use to **frame or deepen questions from the audience**;
- use as a **source for additional explanations** of the slides.

The accompanying **slide deck** can be downloaded from https://bit.ly/M4Sdownloads and supports the visual and content structure of the course. It contains the key points, charts and illustrations that connect to the sections in this handbook. It is recommended to use the handbook and slides together.

Personal fulfilment is strongly encouraged

In addition to the basic content, we encourage each lecturer to **enrich** the training **with their own practical examples, insights or cases**. Especially in the section on the **12 operational best practices** (the outer ring of the model), it is valuable to explain how these approaches work in your own experience, where you saw obstacles or successes, and what you learned from them.

Lecturers with a background in maintenance as well as those working in engineering or project management can add their perspective. This really brings the content to life and gives the training maximum relevance for the participants.

So use this handbook as a guide, but feel free to adapt the session to suit your audience, sector or business type.

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Lesson content

Introduction

Sustainable management of physical assets - also known as *sustainable asset management* - is concerned with how we can contribute to sustainability goals through the management and maintenance of business assets. In other words, **what can asset management mean in the context of sustainability?** This question is at the heart of the MORE4Sustainability project, whose insights are brought together in this handbook. We successively discuss *what sustainable asset management is*, why it is especially urgent now, the MORE4Sustainability model (consisting of strategic, tactical, operational and impact levels), and for each level the main points of interest. Finally, we look at how to get from analysis to implementation, followed by a conclusion.

This handbook is based on recent practical experiences with so-called *early adopters*: organisations that are leading the way in integrating sustainability into asset management. Their examples, together with frameworks and best practices, help turn this abstract concept into concrete tools for daily practice. We emphasise that sustainability cannot be "added on" but must be integrated into all facets of asset management. As we will see, this requires a clear strategy and objectives, an appropriate organisation and tools (*tactical enablers*), targeted operational focus areas, as well as measuring the impact.

For you, the reader, it is important to think about your own environment while reading. Do you recognise the examples? Do you see additional sustainability measures that are relevant in your business? The intention is that, after reading through this handbook, you will be able to apply and propagate the principles discussed within your own asset management practice.

What is sustainable asset management?

Sustainable asset management means explicitly considering sustainability in all decisions about assets (plant, machinery, infrastructure, etc.). In practice, this means minimising energy consumption and greenhouse gas emissions over the entire life cycle of assets, without losing sight of operational performance, safety and costs. Asset managers have traditionally focused on reliability, availability and cost control; now an additional dimension is added: environmental impact.

Anyone can talk about sustainability in general terms and come up with loose ideas. But what do you really need as a company to realise sustainable ambitions? **A clear strategy with concrete objectives.** Sustainable asset management therefore starts by embedding sustainability in the business and asset management strategy. This involves formulating explicit sustainability objectives that are relevant to the assets. For example, consider a target to save 20% energy in production within five years, or to reduce the CO_2 emissions of the machinery by 50% by 2030.

Importantly, "sustainable" in sustainable asset management works both ways: we make our assets more sustainable **AND we** ensure that our sustainable initiatives are themselves asset-management wise. It makes little sense, for example, to improve sustainability with a measure that harms safety or makes costs unsustainable. So sustainable asset management continuously seeks the optimal balance between *People, Planet* and *Profit* within the management of physical assets.

In this handbook, we use the MORE4Sustainability model as a capstone. This model divides sustainable asset management into different levels and focus areas so that we can systematically discuss what is

needed to integrate sustainability. But before we dive into that model, we first look at *why* sustainability in asset management is urgent and why action is required right now.

The urgency: why now?

The urgency for sustainable asset management stems from the broader sustainability challenge facing the world. Climate change and environmental degradation are forcing governments, companies and societies to act quickly. In Europe, the course has been clearly set with the **European Green Deal**. This Green Deal, an initiative of the European Commission led by then-European Commissioner Frans Timmermans, states that Europe should be climate neutral by 2050. Intermediate steps include drastically improving energy efficiency and significantly reducing greenhouse gas emissions by 2030 (figures such as ~32% improvement in energy efficiency and ~50% emission reduction compared to 1990 are often mentioned). This is an immense task: everything we produce and maintain must be made sustainable at record speed.

These external pressures come not only from government and regulation, but also from society and investors. NGOs and the general public are demanding cleaner operations, and new reporting requirements (such as the **EU CSRD - Corporate Sustainability Reporting Directive**) require companies to make transparent how they perform on environmental, social and governance (ESG) issues. For asset managers, this means that they must, for example, provide insight into energy consumption per plant, emissions from their machinery and plans to improve them. However, a recent survey of maintenance and asset management professionals found that at ~70% of organisations, sustainability *still* brings little additional reporting pressure compared to regular maintenance reporting - in other words, people are not yet doing much with it. This underlines that we are still at the beginning of the transition: many organisations talk about sustainability, but only a small leading segment is actually fully engaged in concrete measures. This is precisely why now is the time to step in: starting now prevents lagging behind and can even give you a competitive advantage.

Indeed, along with pressure and obligations, there are also **opportunities**. Once the bar is raised, innovation drives. New techniques and approaches see the light of day under the stimulus of sustainability goals. European industries that are the first to develop such solutions can later export that knowledge and technology, giving them a head start in the global market. Think of innovations in green energy, circular production technology or smart energy-saving systems - here are also economic opportunities for the manufacturing and process industries.

At the same time, a parallel can be drawn with classic asset management: just as years of cuts in maintenance ultimately lead to higher costs and risks, ignoring sustainability investments can lead to future problems. Companies that ignore sustainability now run the risk of stricter sanctions, reputational damage or technically overtaken assets (e.g. plants that will soon be prohibited from running due to emission standards). The urgency is therefore twofold: *avoid pain* (meet requirements in time to avoid problems) and *gain value* (benefit from the improvements and innovations sustainability brings).

In summary, the need to integrate sustainability into asset management has never been greater. External goals (EU Green Deal, UN Sustainable Development Goals such as "Climate Action" and "Affordable and Clean Energy") feed through into business objectives. The challenge is enormous, but with a structured approach it is feasible to move step by step towards climate-neutral and energy- efficient assets. The MORE4Sustainability model introduced in the next section provides an overview model for this.

The MORE4Sustainability Framework (Strategic, Tactical, Operational, Impact level)

To get a grip on sustainable asset management, the MORE4Sustainability project has developed a model that distinguishes four levels or layers:

1. **Strategic level** - *Strategy and objectives*: At the heart of the model is the strategic embedding of sustainability. Here it is about formulating a clear sustainability vision within asset management, including concrete objectives that are in line with the corporate strategy and external obligations. This strategic foundation gives direction to all further efforts.

2. **Tactical level** - *Tactical enablers*: The second layer of the model consists of the organisational and systemic enablers needed to implement the strategy. Think of processes, structures, competences and resources that enable sustainability within the asset management organisation. These tactical enablers form the basic infrastructure: they ensure that you are "ready to go". On their own, they may not save a kilowatt hour, but without them, you cannot achieve large-scale sustainability improvements.

3. **Operational level** - *Operational focus areas*: The third layer (the outer ring in the model) comprises the **12 practical focus areas** - concrete methods and measures - by which you actually reduce energy consumption and cut emissions. This is the implementation level: this is where projects and initiatives are implemented, such as replacing an old engine with a more efficient one, or recovering waste heat from a process. These 12 focus areas are grouped into four quadrants, which correspond to different angles of sustainability within asset management. We will discuss each of these quadrants and their corresponding areas of practice in detail in a subsequent section.

4. **Impact level** - *Results and monitoring*: The fourth (outer) ring of the model represents results: the impact that all initiatives have on sustainability performance, in particular on **energy efficiency** and **greenhouse gas emissions**. On the left side of this ring, you can imagine that we measure the improvement in energy efficiency (e.g. percent less energy consumption), and on the right side the reduction in CO_2-equivalent emissions. This impact level is what ultimately matters - achieving the sustainability goals - and should also be monitored and reported.

This model is not purely theoretical. Within the MORE4Sustainability study, it was used as a capstone to check with various companies *what* they are already doing at each of these levels and *how* effective it is. The finding was that while most organisations are already picking up something in the operational sphere (e.g. energy-saving projects), strategic embedding and tactical support are often still under construction. It also found that certain operational measures have significantly more impact than others. For example, **asset portfolio measures** (such as sustainable plant replacement) are expected to be able to deliver about a third of the improvement needed towards 2030, while direct plant electrification, for example, has a smaller share, as much of the low-hanging fruit there has already been picked in recent years. We will return to these ratios when discussing the focus areas.

In summary, the MORE4Sustainability model offers a holistic view: from strategy to impact. In the following paragraphs, we will explore each aspect in more detail.

Strategy and objectives

Sustainable asset management starts with **strategic decision-making**. This means that the organisation explicitly decides what sustainability ambitions it has and how asset management contributes to them. Some key questions at the strategic level are: *What sustainability goals are we pursuing? How do they*

relate to our mission and other business goals? How do we prioritise sustainability versus cost, production output and safety?

Formulate clear sustainability objectives. Without concrete targets, sustainability remains a vague concept. Companies would do well to include specific KPIs and targets in their asset management strategy. For example, "By 2025, all our facilities will run on 100% green electricity", or "We will reduce our technical energy consumption by 30% in 10 years compared to 2019". Such targets give direction and allow progress to be measured. They can stem from external obligations (e.g. climate objectives from legislation or parent company) or internal ambitions (contributing to a green image, cost savings through energy efficiency, etc.).

When setting sustainability targets, **material aspects** for the organisation should also be considered. Not every sustainability issue is equally relevant to every company. For example, a utility company will have strong targets around carbon emissions and biodiversity, while a machine factory will focus more on energy consumption and waste reduction. A *materiality analysis* (as required under the CSRD) helps determine which themes (e.g. climate change, resource scarcity, water use, social aspects) are most important to your organisation and stakeholders. Asset management can then focus on the environmental themes on which the assets have a significant impact - in industry typically energy and emissions, possibly also resource and water efficiency, noise reduction, etc.

Integrate sustainability into existing strategic frameworks. Often, asset-intensive organisations already have strategic pillars such as reliability, availability, safety and cost control. Sustainability should be added to these, in such a way that it is balanced with the other pillars. In effect, it adds a sixth dimension to asset management. This means, for instance, that investment decisions not only consider *life-cycle costs* and risks, but also the *life-cycle carbon footprint*. Or that maintenance strategies (e.g. run-to-failure vs. preventive replacement) take energy efficiency into account - sometimes it is more energy-efficient to replace a component earlier, sometimes on the contrary to use it longer. The strategy should guide these kinds of trade-offs.

Ensure administrative support. Sustainability must be wanted and supported from the top down. Ideally, there is a clear mandate from top management ("make our operations sustainable, make a plan!") and sustainability is embedded in asset management policy. This could mean governance structures such as a sustainability steering committee or sustainability criteria built into CAPEX/OPEX decisions by default. When executives explicitly demand sustainability as part of asset performance, asset managers and maintenance departments will also take it up more seriously.

Consider balance and feasibility. Strategic goals should be ambitious but realistic. They should take into account production requirements, budgets and safety. If sustainability becomes completely detached from economic reality, you risk jeopardising organisational continuity. A common motto is that the *licence to operate* has three elements: operate safely, profitably and sustainably. If one of those three is extremely out of line (e.g. investments in sustainability causing costs to explode and the company to become loss-making), then it is not a sustainable strategy. Fortunately, it usually does not have to come to that: nowadays, there is a lot of attention and often support (subsidies, knowledge networks) to make sustainability succeed *and* keep it economically viable.

Finally, being strategic about sustainability also means **thinking ahead**: anticipating future regulations and technological trends. A good sustainability strategy for assets, for instance, looks ahead to 2030 and 2040: which plants will be obsolete by then because of emission standards? Do we need to invest in

certain innovations now to be ready later? Strategic asset management and long-term sustainability roadmaps should go hand in hand.

Once the strategy is in place and the goals are clear, the translation to tactical and operational levels can be made. The next step is to ensure that the organisation and resources are ready to implement the strategy - the so-called tactical enablers.

Tactical enablers

By *tactical enablers*, we mean the preconditions and tools needed to realise sustainability goals in practice. You can think of it as "preparing the playing field" on which operational sustainability improvements take place. We distinguish some key enablers: organisation & culture, processes & governance, data & technology, and competences & resources.

Organisation & culture: Sustainability within asset management often requires a change of culture and closer cooperation between departments. Whereas maintenance and production, for example, used to look at each other for cost savings ("energy saving is not my job but production's" or vice versa), now the realisation that sustainability is a shared responsibility needs to grow. An *enabler* in this area is the establishment of mixed teams or working groups that jointly seek efficiency improvements, or the explicit inclusion of sustainability criteria in everyone's tasks. It helps if it is communicated from management that sustainability targets are as important as other KPIs. This creates a culture in which operators, technicians and engineers are constantly alert to, for example, energy waste and opportunities for improvement.

Processes & governance: This concerns embedding sustainability in the processes and decision-making structures of asset management. Specifically, you can think of adjustments such as:

- Inclusion of sustainability criteria in maintenance planning and asset life cycle planning. For example: when drawing up a maintenance concept, we evaluate not only risks and costs, but also energy consumption in different scenarios.
- Adjust investment procedures: every investment request for new assets or replacements must pass a sustainability test (e.g. a calculation of carbon impact or energy savings compared to baseline).
- Extending asset management standards (such as ISO 55000) to include sustainability elements. This could mean periodically assessing sustainability performance of the asset base, similar to how one assesses technical performance.
- Governance-technical: assign clear responsibilities, such as a sustainability coordinator within the asset management department, or regular reporting on sustainability progress in asset committees.

By setting up these kinds of processes, sustainability is "enforced" as an integral part of business operations. Without this enabler, it often remains isolated projects without structural coherence.

Data & technology (monitoring systems): A crucial enabler is having the right information. After all, you can only improve what you measure. Many organisations are discovering that their traditional systems are not yet equipped to measure sustainability performance at the asset level. This is why we see developments such as:

- Integration of **energy and emission data** into asset management systems. Modern production plants provide all kinds of data on energy consumption, temperature, emissions, etc. via sensors and control systems (SCADA, IoT). This data needs to be linked to maintenance systems (EAM/CMMS) to understand the relationship between condition, usage and energy consumption.
- Implementation of **Energy Management Systems (EMS)** that monitor real-time consumption, detect inefficiencies and can generate reports for sustainability purposes.
- Condition Monitoring and Predictive Maintenance systems that not only watch for failures but also for degradation leading to efficiency losses (e.g. a motor that starts drawing more current due to wear).
- Digital twins and analytics: advanced analysis of process data to find optimisations (e.g. detecting unnecessary running of equipment, heat leaking, etc.).

In practice, getting all these data streams right is proving to be a challenge. Often, energy and process data are spread across different systems and consolidation is needed to get an overview of *"where does our energy go in the plant and where are the biggest losses?"*. Nevertheless, this investment in data and technology is essential. Companies that are ahead in this can make more targeted decisions and provide evidence of sustainability gains achieved.

Competencies & resources: Tactical preconditions also include having the right knowledge and sufficient resources. Sustainable asset management sometimes requires new expertise: think energy auditors, specialists in CO_2 footprint analysis or maintenance technicians with extra training in energy-conscious working. It can be useful to retrain employees or attract new profiles, such as an *Energy Manager* who focuses specifically on energy issues within the maintenance department. In addition, resources (budget, tools) should be made available. For example: budget for a pilot with an energy-efficient technique, or purchase of measuring equipment for compressed air leak detection. Without allocated resources, plans remain stuck.

Creating awareness also falls under this: arrange internal sessions, toolbox meetings or workshops to share successes and keep everyone focused on sustainable thinking. If mechanics understand that, for example, a small action like lubricating a mechanism on time prevents energy loss, they will be more motivated to do so. This coincides with the culture change mentioned earlier.

In summary, the tactical enablers ensure that your organisation is ready to integrate sustainability into asset management. You lay a foundation, so to speak. You build on this with the actual implementation initiatives - the operational focus areas where you will tackle energy and emissions. Without a strong foundation (strategy + enablers), individual actions will have less effect or be unsustainable. However, if you have these layers in place, you can start working systematically and effectively on the many technical and operational improvements that are possible. In the next section, we discuss those *operational focus areas* in detail.

Operational focus areas (the 12 practice areas)

At the operational level, the actual sustainability interventions happen. The MORE4Sustainability framework distinguishes **12 focus areas** - these are the concrete themes or categories in which measures can be taken to reduce energy consumption and greenhouse gas emissions. These 12 are grouped into four quadrants, each corresponding to a particular angle of optimisation. We address each quadrant separately and give examples of corresponding measures.

1. Asset portfolio optimisation

Goal: Make sure you have the **right assets** to operate sustainably. This quadrant mainly looks at the *composition and renewal of* your asset park: which installations do you have, which ones need to be replaced or modified to be more sustainable?

Within asset portfolio optimisation, we distinguish three focus areas:

- **Electrification of installations:** This involves replacing systems that currently run directly or indirectly on fossil fuels with electric variants. Many mechanical or thermal processes that traditionally ran on gas, diesel or steam can be electrified. Consider replacing an old natural gas-fired forklift with an electric one, or installing electric heaters instead of an oil-fired steam boiler. Electric drives are often more efficient and can be powered by green electricity, reducing both energy consumption and emissions. A real-world example is **plant electrification** at a steel producer: Tata Steel in the Netherlands has announced it is switching from traditional blast furnaces (running on coking coal) to electric arc furnaces. This is an extreme example of electrification - it requires huge investments, but it is expected to reduce CO_2 emissions by around 40%. So electrification can be a great sustainability benefit, provided the electricity used is green. In most factories, electrification is not an entirely new phenomenon: numerous auxiliary machines (pumps, fans, transport equipment) have already been electrified over the past 10-20 years. As a result, *marginal gains* are now sometimes smaller, but there are certainly still parts (such as process heat generation) where electrification can play a role.

- **Sustainable asset replacement:** Every asset has an end of life. This focus area is about **the right time and the right way to replace** with sustainability at the forefront. Traditionally, you replace an installation when it is technically or economically written off. Sustainable asset management asks, *"When replacing, can we choose a more environmentally friendly alternative, or even replace it earlier purely to achieve sustainability gains?"* It is often true that a new asset is technologically much more efficient than a 30-year-old one - so you automatically make gains in energy efficiency. But the question is whether that is enough or whether an even more sustainable alternative is available. For example, replacing an old gas boiler with a new one: the new one will be more efficient, but perhaps a heat pump is even more sustainable. Asset managers should therefore look explicitly at energy consumption, emissions, use of materials, etc. when replacing, and where possible choose *the greenest alternative that is functionally satisfactory*. In some cases, this may mean phasing out an asset *earlier* than strictly necessary because the sustainability gains are huge (e.g. replace an old leaky refrigerant in cooling systems before they are fully end-of-life, to avoid high F-gas emissions). The study found that "sustainable asset replacement" is likely to make the **biggest contribution** of all operational areas. Companies are prioritising this because it fits quite logically with existing replacement plans but with sustainable optimisation.

- **Redesigning production processes (production process re-engineering):** This is the most far-reaching area of focus within asset portfolio optimisation: you change the way you produce to become fundamentally more sustainable. Strictly speaking, this affects both production and asset management, but it cannot be missing because it can have a huge impact. Think of process innovations or adjustments that lead to much lower energy consumption or emissions. For example, a chemical company switching to a new process that requires less heat, or a food factory organising evaporation steps more efficiently. As a concrete example, a sugar factory in the Netherlands adapted its cooking and evaporation process, as a result of which they emit 60%

less CO_2 than in 1990 and expect to achieve a 75% reduction by 2030. They achieved this by cleverly optimising their process and reusing heat, without building a completely new factory. Energy consumption fell by 14% and residual heat loss is now almost zero. Such an intervention often requires significant investment and cooperation between process engineers and asset managers. Asset management plays a role to implement and manage the changes in existing plants. In many organisations, this kind of innovation comes up as part of R&D or production improvement, but a mature asset management organisation will be proactive in this and steer towards solutions that are both operationally reliable and sustainable.

Why asset portfolio optimisation? All three areas above have in common that they prepare your "asset base" for a sustainable future. They are pre-eminent initiatives where, by investing now, you achieve future benefits. According to findings among early adopters, these measures contribute strongly to longer-term goals. Many companies have already invested heavily in modernisation (e.g. replacing old inefficient installations) in recent years, but this will continue in the coming decades with even heavier sustainability glasses on. It is logical to link sustainable asset portfolio optimisation to natural investment moments (end-of-life, capacity expansion, etc.), but sometimes there are also external incentives (new legislation, subsidies) that justify early investment. Asset managers would do well to evaluate their entire asset portfolio *for sustainability*: which assets are "laggards" in terms of efficiency or emissions, and what is the plan to bring them on track?

2. Asset health optimisation

Goal: Keep your assets in **optimal condition** so they operate efficiently and cleanly. This quadrant focuses on maintenance and operations: through proper care and monitoring, you get the best performance from existing assets, with minimal consumption and emissions.

We can identify three related focus areas here:

- **Condition monitoring & predictive maintenance:** Detecting and addressing wear, misalignments or deviations in a timely manner prevents not only failures but also inefficiencies. For example, a pump that becomes internally fouled or a bearing that wears out is going to use more energy for the same output. By condition monitoring (via sensors or regular inspections), you can get a picture of this kind of degradation. *Predictive maintenance systems* can analyse trends in vibrations, temperatures, currents, etc. and indicate when an asset is likely to become inefficient or defective. This allows you to take preventive action - for example, clean a heat exchanger as soon as heat transfer drops, or align a motor before it causes damage - and thus keep energy consumption structurally low. Many companies say they actually "always do this" under the guise of good maintenance, but in practice there are often gains to be made by specifically focusing on energy and emissions in the maintenance strategy.
- **Precision maintenance and calibration:** Besides major maintenance, daily fine maintenance also affects durability. By precision maintenance, we mean all the small measures that ensure equipment operates in optimal condition. These include: correct alignment of rotating machinery, applying correct lubricants (to minimise resistance), regular calibration of measurement and control systems so that processes do not run richer/greater than necessary, timely replacement of filters so that clogging does not occur, and so on. Such activities are part of the regular maintenance programme, but by carrying them out consistently and meticulously, you prevent creeping extra energy consumption. A simple example: an air compressor that leaks a little or keeps losing pressure unnecessarily due to poor maintenance costs significantly more electricity

over a year. By plugging leaks and maintaining compressors optimally, you save energy and also indirectly reduce CO_2 emissions (especially if the power is not 100% green).

- **Maintain optimal operating conditions:** This is about operators and maintenance working together to keep assets within their **best performance range**. Many plants have a "sweet spot" in terms of load or setting in which they operate most efficiently. If they run at half power too often, are in frequent start/stop mode or operate at unnecessarily high pressures/temperatures, for example, energy is lost. Asset health optimisation means having procedures in place to quickly correct anomalies. For example, a steam pipe that becomes poorly insulated is quickly repaired, a burner that gives off soot is immediately adjusted, a fan that is unbalanced is immediately balanced. This requires both line operators and maintenance technicians to be well trained and aware, and to monitor performance together. Modern techniques like real-time efficiency monitoring per machine can help here (for example, you see the efficiency of a compressor drop and know that maintenance is needed).

The general principle in asset health optimisation is: **a sustainably managed asset = a well-maintained asset.** In fact, sustainability here is close to classical technical performance. An asset that is in top condition will usually also run economically. Yet the explicit focus on sustainability is important, because sometimes it puts just different emphases. For instance, a maintenance department that has been heavily cost-driven may be tempted to stretch maintenance intervals; but with the knowledge that worn parts require extra energy, there is a new argument precisely for not postponing everything.

Many companies are in familiar territory in this area - after all, this is the core of asset management: taking care of your installations. Some organisations already have extensive reliability and maintenance excellence programmes similar to this, others can still make great strides (there are also companies that honestly admit that their maintenance levels are "well below par", which directly means that unnecessary waste also occurs). It pays to draw up a "sustainable maintenance plan", in which you specifically name which maintenance activities and monitoring are needed for energy and emissions conservation.

3. Energy consumption optimisation

Goal: Use assets and processes **as efficiently as possible**, minimise energy losses and maximise energy utilisation. This quadrant looks at operational management and process optimisation with a view to saving energy.

Here are three main areas of focus:

- **Energy recovery and reuse:** In almost every industrial process, energy is lost somewhere, often in the form of heat that is blown off into the environment. Recovering this energy is a powerful means of reducing overall consumption. Examples: heat recovery systems on furnaces or cooling plants, where released heat is captured via heat exchangers and returned to be used elsewhere (e.g. for preheating raw materials or heating buildings). A telling example is the idea of supplying residual heat from a factory via a pipeline to a neighbouring company - such as a factory sending its excess heat to a nearby car factory (Volvo) to heat its paint shop. Such symbiosis ensures that energy is put to good use rather than wasted. Besides heat, one can also think of energy recovery in other forms, such as using a braking energy recovery system on cranes or conveyor belts, or harnessing differential pressure energy (expansion turbines on gas pipes, etc.). Residual heat utilisation and energy recovery often require one-off investments in additional systems, but significantly increase overall efficiency.

- **Process and system optimisation for energy efficiency:** this is a broad area that boils down to optimising the way the process runs to use less energy per unit of product. This is where industrial process knowledge comes in: it may mean, for example, adjusting batch sizes to enable continuous running (requiring fewer heating/cooling cycles), or optimising the sequence of production to reduce downtime and start-up. Identifying excess capacity is also important: many plants are designed with wide margins and therefore often do not run at their optimum point. For example, by regulating back excessive power or using a variable-speed pump instead of a valve that throttles 50% of the flow, you reduce waste. It also includes improving insulation of tanks and pipes, eliminating compressed air and steam leaks (a known major energy leak in factories, for example, is leaking compressed air pipes, which continuously give the compressor extra work), and reducing standby consumption (turning equipment off completely when not in use, smart automation that turns things off). In fact, this covers all operational excellence measures with energy glasses on. Companies often discover surprising areas for improvement through energy audits, for example, "Why does pump X continue to run at night when the line is idle?" or "Can we set the temperature of this bath 5 degrees lower without losing quality?" - Such questions lead to optimisations.

- **Use of advanced energy control and management:** in a more modern context, energy consumption optimisation also involves smart management of energy supply and demand. For example peak shaving or demand side management: temporarily switching off or shutting down large energy consumers during peak moments to avoid peak loads (and high costs). Or buffering heat/cold so that appliances can work more efficiently (e.g. running a cooling installation continuously at optimal point and storing cold in a buffer tank, instead of continuously adjusting). This sometimes requires additional infrastructure (batteries, buffer tanks), but ensures more even, efficient energy management. Finally, awareness on the shop floor is also crucial here: operators need to understand that every meter left open or every machine running unnecessarily means direct energy loss. Energy management systems can provide real-time feedback to operators ("energy consumption per tonne of product is now 10% above standard") to help them improve continuously.

Example and effect: Practice shows that energy consumption optimisation is often a collection of many smaller actions that together have a big effect. In the sugar factory case cited earlier, part of the success was due to process optimisation and heat reuse - something we see in figures as 14% energy savings. In other companies, we see projects like "optimise compressed air system" saving 5-10% of total electricity consumption, or "better insulation & condensate return in the steam boiler" saving thousands of cubic metres of gas, for example. This quadrant is thus very rewarding to *achieve results* relatively *quickly*: many measures pay for themselves through energy cost savings. Early adopters indicate that until 2030 most investments will be focused on these kinds of optimisations and redesigns, as these are often the easiest to justify prudentially (as opposed to, for example, complete process redesigns or whole new assets, which fall in quadrant 1 and are often more expensive/long-term).

4. Greenhouse gas emission optimisation

Goal: Reduce **GHG** emissions further, especially those not already reduced through energy reduction. This quadrant focuses on directly reducing GHG emissions (CO_2, but also other gases such as methane, nitrous oxide, F-gases) through specific measures.

Key focus areas are:

- **Detection and elimination of leaks and unwanted emissions:** In industrial plants, various greenhouse gases can escape outside the "deliberate" combustion of fuels. Examples: methane leaks in gas transport or oil storage, refrigerant leaks (many refrigerants have a very high greenhouse effect), diffuse emissions of process gases in chemistry, but also something like a vent valve that directly discharges CO_2 or other gases. Detecting these kinds of *fugitive emissions* is a spearhead. Leaks can be detected with special cameras (infrared leak detection for methane, for example) or sensor programmes. Measures are then taken such as better seals, more regular gasket replacement, plant engineering changes to eliminate emission points, or simply repairing broken valves and flanges. A well-known initiative is LDAR (Leak Detection and Repair) programmes, which aim to systematically detect and seal all leak points. The impact can be big: a small continuous leak of a high-pressure gas can emit tonnes of CO_2 equivalent per year. By preventing this, you have immediate gains without changing the production process - it is often a relatively low-level measure (actually good maintenance) with a big environmental benefit.

- **Emission treatment and capture:** this is a more technical area: ensuring that the emissions that do arise are neutralised or captured as much as possible. For conventional air pollutants (NOx, SOx, particulate matter), filters and scrubbers have long existed. For greenhouse gases specifically, you can think of *CO_2 capture (CCS)* or conversion technologies, and post-treatment of, for example, nitrous oxide (in the fertiliser industry, N_2O is broken down with special catalysts). Although CO_2 capture is still under development and not universally applicable, some plants are commissioning pilot plants to, for example, capture and store or reuse part of their flue gas CO_2 (e.g. in greenhouses or for carbonate production). This also includes flaring of residual gases in the oil/gas sector: in place of releasing methane directly into the air, they burn it into CO_2 (which is better in terms of greenhouse effect, albeit still emissions). The ultimate goal in the future may be to capture emissions at source so that virtually no greenhouse gases are released into the atmosphere, but that is not yet feasible in the short term for many sectors. Yet we already see e.g. biogas plants being fitted with gas reprocessing so that methane does not escape, or blast furnaces experimenting with binding CO_2 to slag.

- **Switching to green alternatives (for energy and processes):** While this may be partly outside asset management's direct influence, it should be mentioned: using **renewable energy sources** or climate-neutral raw materials. If an asset manager can ensure that all the electricity used by his plant is 100% renewable (e.g. contractual procurement or self-generation via solar panels/wind), then indirect carbon emissions fall dramatically. Similarly, switching from, say, grey natural gas to biogas or hydrogen as fuel can eliminate direct CO_2 emissions (hydrogen) or make it circular (biogas). These kinds of decisions are often taken higher up in the organisation (purchasing energy, investing in power generation), but the asset management organisation can propose and implement initiatives such as installing solar panels on the plant site or installing a biogas unit for the boiler. It also includes replacing highly climate-unfriendly auxiliary materials with greener versions - think of replacing refrigerants with high GWP with new types with low GWP. This is an extension of sustainable asset replacement (quadrant 1) but is specifically focused on the *type of emissions* an asset generates.

Notes: Measures in this quadrant are sometimes difficult to trace directly back to the asset manager's responsibility, but they are essential. We often see that when companies start to get their energy efficiency right, attention shifts to the remaining emissions. Some of these already reduce automatically as energy decreases (burning less gas = less CO_2, which is "free-rider effect"). Others don't, such as leaks or certain process emissions - you need to address those specifically. Early adopters report that this area

is not yet under heavy pressure (for example, many companies do not currently have to report their methane leaks unless they are covered by specific emissions trading), but that this is likely to change in the future. Think possible stricter rules for F-gases or methane, or a price on all CO_2 emissions. So it is wise to anticipate this.

In practice, some simple things can be done immediately: e.g. conduct a leak check round and fix anything that leaks - this requires limited costs and delivers immediate results. Other things like carbon capture are more strategic and could be part of long-term innovation planning.

Relationship between the quadrants: It is important to note that these four quadrants complement each other. Improvements in energy consumption (quadrant 3) often automatically already lead to improvements in greenhouse gas emissions (quadrant 4), since energy in industry is usually linked to fossil emissions. Only when you are almost fully on renewable energy should you look at other gases in quadrant 4. So the order is largely logical: first make sure you have the right assets (quadrant 1), then that they perform well (quadrant 2), then use them as smartly as possible (quadrant 3) and finally get rid of the last emissions (quadrant 4). Of course, in practice, you can work on several fronts in parallel.

Now that we have explored the 12 practice areas and seen many examples, the question arises: how do you put all this into practice within your organisation? What steps do you go through to get from analysis to actual implementation? We will discuss that in the next section.

From analysis to implementation

A major challenge in sustainable asset management is converting all possible improvements into a concrete **plan of action** for your organisation. The journey from analysis to implementation ideally proceeds as a structured process, which we outline here:

1. Analyse the current situation: Start by mapping where you are now in the aforementioned areas. For example, perform a baseline measurement or sustainability scan on your assets: What is the current energy consumption per installation? Where are the biggest losses? How much CO_2 do we emit and where does that come from (which sources, which leaks)? Are there already initiatives in place and what have they achieved? This analysis phase often includes identifying the *gap* between current performance and the formulated goals (from the strategy). If your goal is 30% energy reduction, where can you go to achieve it? You might see that 10% can already come from an ongoing LED lighting project, 5% from better maintenance, etc., and discover that there is still a 15% "gap" for which new measures need to be devised. Use the 12 focus areas as a checklist not to forget anything: look at them one by one and determine whether there is potential or need.

2. Identify and prioritise actions: Based on the analysis, you are likely to come up with a list of possible projects or actions. It is rarely possible (or useful) to do everything at once, so prioritisation is essential. Several criteria come into play here:

- **Impact on sustainability:** how much savings or emission reduction will the measure yield? (Quantitative if possible, e.g. kWh or tonnes of CO_2 per year).
- **Investment and return:** what does it cost and what does it yield financially? Some measures pay for themselves within a year (low investment, high energy savings), others have a longer payback period or no immediate financial return but are needed for compliance.

- **Feasibility & urgency:** is the technology ready? Does it fit the schedule (e.g. can it coincide with a maintenance shutdown)? Are there external deadlines (such as legislation coming into force in 2 years, making it urgent to do something now)?
- **Risks and dependencies:** do measures bring operational risks? (For example, a production change could mean risk to product quality - you need to factor that in). Are there dependencies between measures (e.g. install measurements first before you can implement optimisations)?

Based on this consideration, you can draw up a **roadmap**: which actions do we do short-term, medium-term and long-term? A typical outcome is that you choose a mix of so-called *low-hanging fruit* (easy wins, often operational, immediately executable) and larger investment projects that need careful planning. For example: "Next year, we will conduct a leak detection programme and optimise compressed air - low investment level, immediate savings. Within 3 years we want to replace the first old furnaces with new electric ones - high investment level, requests budget start now. And towards 2030 we are exploring a possible process redesign for the largest plant - innovation project, depending on technological developments."

3. Make a business case per key measure: Especially for the larger investments, a solid business case is needed to get internal approval. This is where the link made earlier with strategy and financial framework comes into play. A business case for a sustainability initiative usually includes:

- Investment (capex) and operational costs (opex) over the lifetime of the measure.
- Benefits: energy cost savings, possible maintenance cost savings, possible revenues (e.g. sale of recovered heat or certificates), and avoided emission costs (think of CO_2 levies or emission rights saved). Less tangible benefits such as improved image or compliance with future legislation (risk avoidance) can also be named.
- Resultant: key figures such as payback period, internal rate of return (IRR), net present value (NPV) over x years, and contribution to sustainability goals (% reduction).

In practice, participants in the MORE4S project found that such a business case often **turns out more positive than previously thought**, provided you take all factors into account. Many people assume that sustainability mainly costs money. But examples show that energy savings, for example, are often immediate financial savings - sometimes investments are recouped within two to three years. Of course, there are also measures that are expensive and do not pay off in hard euros (such as carbon capture), but they can be legitimised from a strategic point of view or future obligations.

Preparing the business case is sometimes iterative: first explore globally (order of magnitude cost/benefit) to see if something is worthwhile, then, if necessary, request detailed calculations and quotes to remove uncertainties. Tools like LCC (Life Cycle Costing) with CO_2-price scenarios, or simulation models for energy savings, can help to get more reliable figures. There are also calculation tools and databases available (e.g. standards for CO_2 footprint by machine type) that provide input.

4. Decision-making and planning: with an elaborated roadmap and substantiated cases, management can take decisions. This is where it pays off if the strategic frameworks were clear: investments that fit within the agreed sustainability strategy are prioritised. A formal decision leads to an implementation project or programme. Plan the implementation carefully: make sure there are project leaders, budget is set aside, and KPIs to monitor progress.

5. Implementation and change management: implement measures according to plan. Technical implementation (e.g. installing new equipment) goes hand in hand with change management - people often need to work differently or perform additional work (such as more frequent measurements, new maintenance routines). Communicate successes in the interim to keep momentum. For example, if an initial pilot gives a great result ("Machine X retrofit has delivered 15% energy savings"), share that internally. This motivates and legitimises the continuation of the roadmap.

6. Monitor impact (PDCA): Close the circle by measuring the results and comparing them with the targets. The impact level from the model comes back here: did the measures indeed deliver the expected energy savings (e.g. measure total consumption, do you see a decrease? correct for production changes) and emission reduction? Report this within the organisation and also externally if necessary (think sustainability reporting). Celebrate milestones achieved, but also learn from setbacks: if something had less effect than hoped for, analyse why and adjust. Sustainable asset management is a continuous improvement process. You can keep going through the PDCA cycle (Plan-Do-Check-Act): after implementation, do new analyses, pick up the next priorities, etc. This is how you increase maturity step by step.

In many cases, it pays to make this entire process part of the organisation's regular annual planning and improvement cycles. For example, integrate it into the annual maintenance planning cycle or the strategic three- or five-year plans. Ultimately, you don't want sustainability initiatives to stand alone, but to be as much a part of asset management as, say, a reliability programme.

A final tip for implementation: **make use of examples and knowledge sharing.** See how other companies (the early adopters) approached it, what obstacles they encountered and what solutions worked. This can be done through industry organisations, training courses or networks such as BEMAS (Belgian Maintenance Association) or the Dutch NVDO. Sometimes there are also subsidy programmes that financially support parts of implementation, or government campaigns that make knowledge available (such as RVO in the Netherlands for energy saving in industry). Seize those opportunities to accelerate your roadmap.

Conclusion

Sustainable asset management has grown from a buzzword to an essential part of professional asset management practice. In this handbook, we have seen that to be truly effective, sustainability must be embedded at all levels: from strategic objectives to operational implementation and feedback of results.

Some key points to remember:

- **Integrate sustainability into strategy:** Without a clear goal and support from management, it remains non-committal. Establish what you want to achieve (e.g. saving energy, becoming carbon neutral, meeting certain standards) and communicate this within the organisation.
- **Provide the right framework conditions:** Build an organisational culture, processes and information provision that enable sustainability. Everyone must be aware that this is not a one-off project, but "the new way of working". Metrics and competences must support this.
- **Implement concrete improvements in all relevant operational areas:** From modernising your asset fleet, through smart maintenance, to process optimisations and emissions management - sustainability is multidisciplinary. Together, small steps can have big effects. Prioritise measures

that are both environmentally and economically profitable to gain momentum, and combine them with some visionary projects needed for the long term.

- **Monitor and steer for impact:** In the end, it's all about results. Therefore, keep measuring and evaluating. Celebrate when a target (such as X% less energy consumption) is met, and set new targets to continuously improve towards the finish line of climate neutrality.

The case studies of early adopters leave us optimistic: although many organisations are still in the early stages, there are already plenty of successful examples demonstrating that sustainable asset management *works*. Companies have demonstrably managed to lower their energy intensity and reduce emissions, often while maintaining or even improving reliability and cost positions.

It is not an easy path - there will be technical challenges and investment dilemmas - but the effort pays off. Moreover, it is inevitable: the world demands and expects clean, efficient industry. Asset managers play a key role in this.

In conclusion, we would like to stress that knowledge sharing and training are important here. Make sure the teams on the shop floor understand *why* certain changes are being made and *how* they can contribute to them. For example, consider holding internal workshops or having employees certified in sustainable asset management. It is not about an official title or diploma, but about ensuring that the core principles are understood and can be applied. When the outlines - as discussed in this handbook - have really come across, you can legitimately say that your organisation is well on its way to becoming a "master in sustainable asset management" (to use that term informally).

Sustainability is not a one-off project but a journey of continuous improvement. With the knowledge from this handbook, you will be equipped to continue that journey in a planned and confident way, on your way to a future-proof, efficient and responsible business. Good luck!