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<tr><td>KLM Technology Group

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<tr><td>KLM Technology Group
#033, Jalan Bayu 8/1,
Taman Nusa Bayu,
79200 Iskandar Puteri,
Johor, Malaysia</td><td>Kolmetz Handbook
of Process Equipment Design

SUSTAINABILITY IN
THE PROCESSING INDUSTRY

(ENGINEERING DESIGN GUIDELINES)</td><td>Co Author

Rev 01 – Apriliana Dwijayanti

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</table>

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Testimonials for Kolmetz Handbook of Process Equipment Design

Gautam Meshram - Very informative book and this book is very beneficial for my career

Muhammad Bilal Aslam - this is the best encyclopedia for pipe design, Thanks to Karl Kolmetz for providing comprehensive insights in their encyclopedias on topics like these. Their resources make complex calculations accessible and support engineers in selecting the right pipe sizes for efficient operations.

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INTRODUCTION

Scope

Sustainability is a crucial issue in business today. Companies are recognizing their environmental impact and seeking ways to cut carbon footprints and reduce waste. This drives the need for continuous improvement.

Sustainability starts with conservation. For the processing industry, this means reducing energy while maintaining or increasing production. Top industry producers achieve an average of three percent energy reduction per year.

Sustainability in process design is the integration of environmental, social, and economic aspects into the design and management of processes. It aims to minimize the negative impacts and maximize the positive benefits of the processes on the natural resources, human well-being, and organizational performance. Sustainability in process design is not a one-time activity, but a continuous improvement process that requires monitoring, evaluation, and adaptation.

Industrial manufacturing consumes about 42% of global electric energy. Around 70% of the electricity consumed by industry is converted into motion by motors that power equipment. The chemical industry is the largest energy user of all manufacturing industries and in the top two highest electricity consuming industrial sectors along with iron and steel production. Natural gas, liquefied petroleum gases (LPG), and natural gas liquids (NGL) are the major energy sources used in the chemicals industry.

The goal of achieving sustainability, including its dimension of clear benefits to society and equity, is socio-political and cannot be achieved by technology alone. Yet there is a global technology challenge, especially in the chemical sector, as sustainability can be attained by the development of environmentally benign processes, integration of material constraints, costs and safety, and further increases in energy and material efficiency in producing goods and services.

General Design Consideration

Sustainability is a societal goal that broadly aims for humans to safely co-exist on planet Earth over a long time. The quality of causing little or no damage to the environment and therefore able to continue for a long time. These are great goals, to reduce the impact on the environment. There are many current buzz words used in sustainability discussions. These include;

- Green Energy – Wind, Solar and Hydrogen
- Electric Cars
- Blue Energy – From the sea
- Renewable Kero and Diesel
- Bio Diesel
- Ethanol in Gasoline
- Recycling
- Conservation

Process design is the planning and execution of how a product or service is created, delivered, and improved. It involves defining the requirements, specifications, resources, methods, and systems that enable an organization to meet its goals and customer needs. But process design is not only about efficiency and effectiveness. It is also about sustainability, which means considering the environmental, social, and economic impacts of the processes and their outcomes.

Sustainability in process design is the integration of environmental, social, and economic aspects into the design and management of processes. It aims to minimize the negative impacts and maximize the positive benefits of the processes on the natural resources, human well-being, and organizational performance. Sustainability in process design is not a one-time activity, but a continuous improvement process that requires monitoring, evaluation, and adaptation.

Sustainability is important in process design for several reasons. First, it can help an organization comply with the legal and ethical standards and expectations of its stakeholders, such as customers, employees, regulators, investors, and communities. Second, it can help an organization reduce its costs and risks by saving energy, materials, water, and waste, and by avoiding fines, penalties, lawsuits, and reputational damage. Third, it can help an organization enhance its competitiveness and innovation by creating value-added products and services, improving customer satisfaction and loyalty, and attracting and retaining talent.

Weighing sustainability in process design is not a simple or straightforward task. It requires a holistic and systemic approach that considers the interdependencies and trade-offs among the environmental, social, and economic dimensions of the processes and their outcomes. It also requires a collaborative and participatory approach that involves the relevant stakeholders in the identification, analysis, and evaluation of the sustainability issues and opportunities.

Some of the steps that can weigh sustainability in process design are:

1. Define the scope and objectives of the process design

   Define the scope and objectives of the process design, which include the purpose, scope, boundaries, inputs, outputs, and customers of the process. This will help you clarify the expectations and requirements of the process design, as well as the potential impacts and benefits of the process on the environment, society, and economy.

2. Assess the current state of the process and its sustainability performance

   Assess the current state of the process and its sustainability performance, which include the current resources, activities, flows, controls, and indicators of the process. This will help you identify the strengths and weaknesses of the process, as well as the gaps and opportunities for improvement in terms of sustainability.

3. Generate and evaluate alternative process designs

   Generate and evaluate alternative process designs, which include the possible changes, modifications, or innovations that can improve the process and its sustainability performance. This will help you explore the different options and scenarios that can achieve the objectives of the process design, as well as the trade-offs and implications of each option on the environmental, social, and economic aspects

4. Select and implement the best process design

   Select and implement the best process design, which include the final decision, plan, and execution of the process design. This will help you realize the benefits and impacts of the process design, as well as the challenges and risks that may arise during the implementation

5. Monitor and improve the process and its sustainability performance

   Monitor and improve the process and its sustainability performance, which include the measurement, reporting, and feedback of the process and its outcomes. This will help you track the progress and results of the process design, as well as the opportunities and needs for further improvement in terms of sustainability.

Sustainability in processing can involve:

1. **Process intensification**

   Designing new equipment and coupling it with other unit operations to improve efficiency, reduce energy consumption, and reduce waste

2. **Process improvement**

   Streamlining processes, reducing waste, and improving efficiency to reduce a business's environmental footprint

3. **Using renewable energy**

   Renewable energy is considered sustainable and replenishable, and can emit no or less greenhouse gases

4. **Using eco-friendly materials**

   Eco-friendly packaging materials are made from recycled or renewable materials that are biodegradable and produce little environmental waste

   Many different materials can be used for eco-friendly packaging, all with different qualities. Some of the easiest, most efficient and environmentally friendly options are:

   - Paper and Cardboard — Natural, readily available, reusable, recyclable and biodegradable — paper and cardboard tick all the boxes! They're perfect for packing items that need to be posted, as well as all kinds of takeaway food and drinks.
   - Corn Starch — Ideal for items that have limited use, such as food and drinks. It can be used to make less harmful packaging "peanuts" that protect items sent through the post. It's also biodegradable, leaving a limited impact on the environment.
   - Biodegradable Plastic — Commonly used in postage envelopes or bubble wrap for bulk mailing, this type of plastic starts to decompose when it's exposed to sunlight. It makes a good alternative to traditional, non-biodegradable plastics and is more resistant to liquids than paper or cardboard — great if you need some added durability.

5. **Using recycled materials**

   Recycled materials can be used over a long period of time, barely harming the earth

6. **Reducing waste**

   Reducing waste is a critical component of process improvement, and it has many benefits for businesses. Here are some of the key benefits:

   - Cost savings: By reducing waste, companies can save money on materials, energy, and labor costs. For example, a manufacturing company might be able to reuse or recycle leftover materials, reducing the need to purchase new ones. This can lead to significant cost savings over time.
   - Improved efficiency: When processes are streamlined and waste is reduced, operations become more efficient. This can lead to faster turnaround times, increased productivity, and better overall performance.
   - Environmental benefits: Reducing waste is good for the environment. By using fewer resources and producing less waste, companies can reduce their carbon footprint and contribute to a more sustainable future.
   - Improved customer satisfaction: When companies are able to deliver products or services more efficiently and with less waste, customers are more likely to be satisfied. This can lead to increased loyalty and repeat business.
   - Competitive advantage: Companies that are able to reduce waste and improve efficiency are often more competitive in their industries. By offering lower prices, faster turnaround times, and better overall performance, they can gain an edge over their competitors.

   There are many different strategies that companies can use to reduce waste. Some of the most effective include:

   - Recycling: By recycling materials like paper, plastic, and metal, companies can reduce the amount of waste that ends up in landfills.
   - Lean manufacturing: This approach to manufacturing focuses on reducing waste by eliminating unnecessary steps in the production process.

- Energy efficiency: Companies can reduce waste and save money by using energy-efficient lighting, heating, and cooling systems.
- Digital transformation: By digitizing processes and reducing paper usage, companies can reduce waste and improve efficiency.

Overall, reducing waste is an important goal for any business that wants to improve its operations and become more sustainable. By implementing effective strategies and making waste reduction a priority, companies can reap the many benefits of this approach to process improvement.

7. Other sustainability practices include:

- Waste-to-energy: Use waste as fuel to generate electricity or heat.
- Extended Producer Responsibility (EPR): Hold manufacturers responsible for the environmental impact of their products throughout their lifecycle.
- Report: Communicate an organization's sustainability performance to stakeholders.

Figure 1 showing Total Energy Consumption by End Users. Transportation is 27%, Industrial Manufacturing 32%, Residential 22% and Commercial 19%. An interesting thing to note is the green portion, electrical system losses associated with the generation, transmission, and distribution of purchased electricity which is 25% of all energy used. Estimates are 10% are lost in generation and 15% are lost in transmission. Renewables will reduce the loss of generation, but the transmission loss will remain the same until research develops better transmission systems.

Therefore, for each 1% can reduce in electrical consumption, the actual savings are 1.25%. Most residential and commercial buildings just assume the electrical usage is a cost of doing business, they do not understand the long-term impact to the environment. Residential and Commercial buildings consume 41% of total energy utilized, which is the largest, yet most homes and commercial buildings have poor energy usage and no real energy reduction programs.

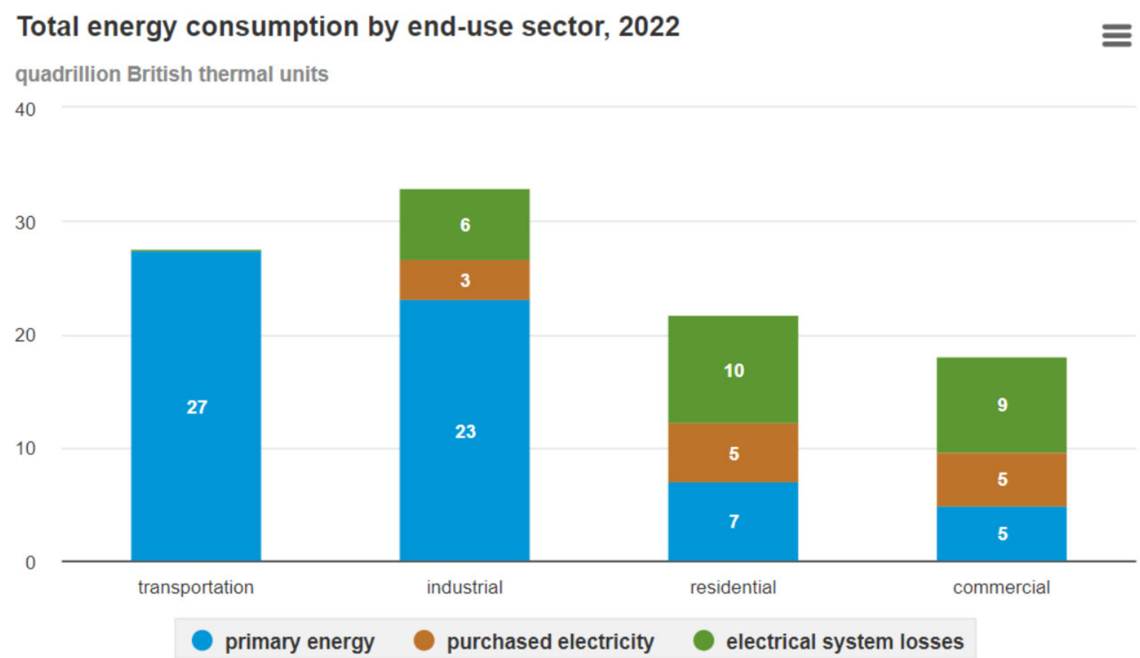

Figure 1. Total Energy Consumption by End Users.

The second largest user is industrial manufacturing, which is 32%. Refining and ethylene contracts are structured where they must purchase all their feedstocks, so they work to reduce energy consumption and flaring due to economics. Some natural gas contracts are structured where they are only paid for the finished product, not what they take from the wells, so there is not the same economic incentive to reduce energy consumption and flaring.

The chemical industry is one the largest energy consuming industries in the United States, spending more than $ 17 billion on fuels and electricity in 2004. Including feedstock, the chemical industry consumed 6,465 TBtu or 28% of all energy consumed by the manufacturing industry in the United States in 2002 (U.S. DOE, 2005c). The large volume organic chemical industry on which this study focuses consumed approximately 70% of the total energy used in the chemical industry.

Ammonia is the largest producer for fertilizer, refining is second and ethylene is third in total tons produced. Refining and Ethylene are large energy intensive industries, and they have been studied to reduce total energy consumption. The energy per ton has been greatly reduced in the last 50 years. Attached is a graph of refinery energy.

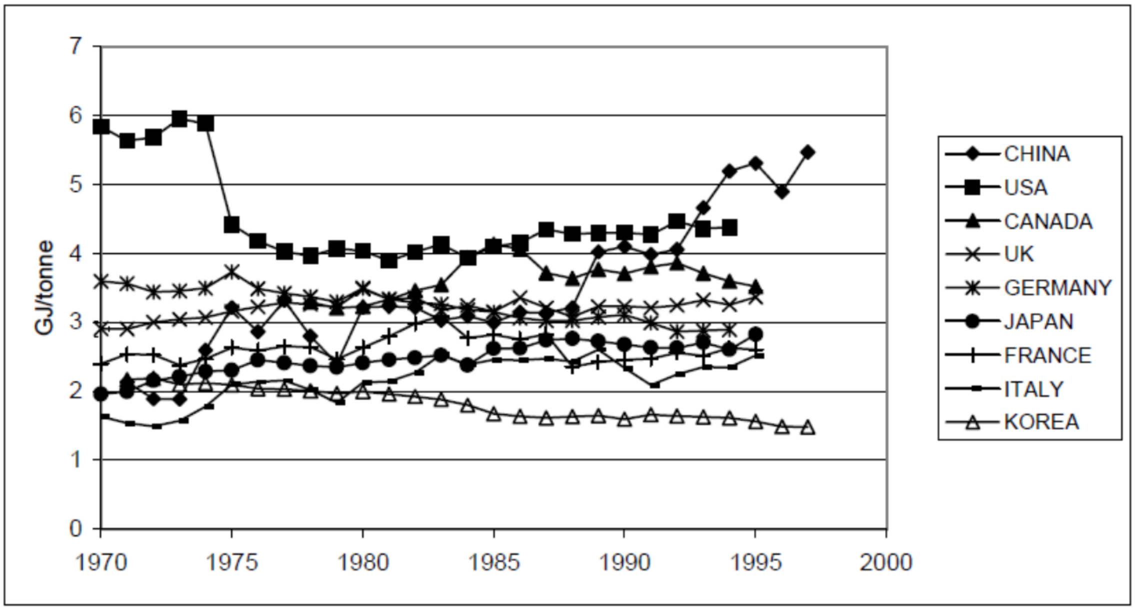

Figure 2. Graph of refinery energy (IEA, 2000)

Steps to reduce energy consumption.

1. Conduct an energy audit. This will identify inefficiencies and opportunities for saving energy.
2. Forming an energy reduction team and tracking past performance and current performance. It is important to assign cost to energy.
3. Use renewable energy. Renewable energy sources like solar or wind power can save money and reduce greenhouse gases.
4. When you replace equipment, you replace it with higher efficiency equipment. Equipment designed today has higher efficiencies than even 10 years ago. Take advantage of current designs.
5. Current distillation equipment has higher capacity and efficiency than sieve deck trays, which most towers have installed. Distillation is a very high component of

energy, for some plants 50% of energy usage. Even a small energy saving is a large monetary amount, several million USD per year. You need to know what your current tower efficiency and what energy saving in USD a small revamp might bring. Tray revamps are relatively low cost, compared to the current energy prices. You should at least calculate the numbers.

6. Heat exchangers are designed poorly, because they are awarded to the low-cost bidder, leading to low energy recovery and higher energy consumption in the adjacent heaters. When you replace a heat exchanger do not replace in kind, upgrade to a fouling resistance, higher efficiency design. This may be several million USD per year. Many times, heat exchangers set the maintenance schedule, and a few extra months is several million USD for large plants, and this is almost pure profit.
7. Pump and Motors designed 20 years ago had about 80% efficiency. Current designs have greater than 90% efficiency.
8. Redesign production processes: Eliminate unnecessary steps or consolidate them to reduce energy consumption.
9. Maintain equipment. Equipment that isn't performing at its best wastes energy.
10. Optimize appliances. Adjust the settings of appliances to increase energy savings.

DEFINITIONS

Boiler - A closed vessel in which water is heated, steam is generated, steam is superheated, or any combination thereof, under pressure or vacuum by the application of heat from combustible fuels, electricity, or nuclear energy. The term does not include such facilities of an integral part of a continuous processing unit but does include fired units of heating or vaporizing liquids other than water where these units are separate from processing systems and are complete within themselves.

Blowdown - The drain connection including the pipe and the valve at the lowest practical part of a boiler, or at the normal water level in the case of a surface blowdown. The amount of water that is blown down

Carbon footprint (of product) Sum of greenhouse gas emissions and greenhouse gas removals in a product system expressed as CO_2e based on a lifecycle assessment using the simple impact category of climate change. A carbon footprint can represent the complete lifecycle of a product or a partial lifecycle based on selected lifecycle stages (sometimes referred to as a “partial carbon footprint”)

Carbon dioxide (CO2) - An odorless, colorless gas formed during respiration and by the decomposition of organic substances. Carbon dioxide is also produced when fuel is burned.

Carbon monoxide (CO) - An odorless gas produced when fuel is burned. Carbon monoxide is one of the six criteria pollutants for which the EPA has established National Ambient Air Quality Standards

Chemical product (Chemical product or a material product) - a chemical or material intended for consumers or that is likely -under reasonably foreseeable conditions- to be used by consumers

Combustion The combustion of gas in fuel-burning equipment is not 100% efficient, and some methane emissions occur as a result of uncombusted gas being released via the equipment exhaust stream. The uncombusted proportion of gas varies between internal and external combustion sources (engines, turbines, heaters and boilers); therefore, equipment-specific data or emission factors are typically used for emissions quantification

Condensation – The resulting effect when a vapor or gas is changed into a liquid

Condenser – The segment of a mechanical refrigeration unit that helps passage of cool air. Air forced to pass around the outside of a coil in the condenser removes heat from a gaseous refrigerant that circulates inside of the coil. Lowering the temperature of the gas causes it to change into a cool liquid that is circulated through the system.

Control – The part of a system that manually or automatically regulates the system

Energy – The ability to do work. For example, electrical, mechanical, light, and heat energy

Energy audit – A method by which a person or persons go through a building and identify energy and/or cost savings that would result if energy conservation changes were made in the operation or if modifications could also be called an energy assessment.

Energy conservation - The efficient use of systems that consume energy

Energy Service - The ratio between achieved performance or the profits from services, goods or energy, and the energy used to achieve this.

Energy Management - the predictive, organized and systematic coordination of the procurement, conversion, distribution and use of energy to cover requirements while taking account of eco- logical and economic aims.

Flaring The controlled burning of gas, including associated gas, in the course of oil and gas operations. In many types of operations, including those where gas is sold, reinjected or otherwise utilized, safety flaring can be an important and necessary activity to enable safe operations. The combustion efficiency of a well-designed and -operated flare is generally assumed to be greater than 98%, meaning that less than 2% of the gas passes through the flare stack unburnt. At the individual flare level, local parameters, such as gas content and quality, flare design, flow rates, exit velocities and steam use, contribute to overall combustion efficiency. There are currently no straightforward methods to continuously measure or monitor the actual combustion efficiency or destruction and removal efficiency of a flare

Framework - The rationale and the structure for the identification of sustainability dimensions as well as the way to integrate concepts, parameters, methodologies, methods, models, tools and indicators

Goal - What is specifically sought to be achieved and is determined through the use of measured indicators

Hazard - A substance or activity which has the potential to cause adverse effects to living organisms or environments, Property or set of properties that make a substance dangerous

Heat - Energy in transfer to or from a thermodynamic system, by mechanisms other than thermodynamic work or transfer of matter.

Heater - A heater is any object that emits heat or causes another body to achieve a higher temperature. In a household or domestic setting, heaters are commonly used to generate heating

Heat exchanger - A system used to transfer heat between two or more fluids. Heat exchangers are used in both cooling and heating processes

Heat loss – The amount of heat a building loses due to several sources, such as around doors, windows, through walls, floors, and ceilings

High-pressure - Area, high, or anticyclone, is a region where the atmospheric pressure at the surface of the planet is greater than its surrounding environment.

Impact - The quantified adverse result of a change to the environment caused by human activity

Indicator - A parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon, with a significance extending beyond that directly associated with its value. The indicator could be quantitative or semi- quantitative or qualitative derived from a model, often through a tool or direct measurement

Management - concerned with optimizing and controlling the use of company resources in order to achieve specified objectives. The most important resources are knowledgeable. Main management tasks:

Planning - Deciding on how to use resources in order to achieve given targets.

Coordination - Communication between the company's functional units.

Organization - Organizing people to get the best out of their potential.

Staffing - Hiring, motivating and developing people as the most valuable company resource

Controlling - Supervising, supporting, communicating, motivating and guiding people in order to achieve required performance.

Budgeting - Planning and securing the financial means for company operation

Reporting - Enabling the flow of information and control of policy implementation

Methodology - A collection of individual methods, which together address the different safety, environmental, economic and social issues and the associated effect/ impact

Method - A procedure for measurement or a set of models, tools and indicators that enable the calculation of indicators' values for a certain parameter

Model - A model supporting the quantitative assessment of safety/environmental/social/economic parameters adopted in order to calculate a particular indicator

Optimize - To select the best option from a set of possible alternatives.

Parameter - Refers to a value, a constant, as a mathematical term. In environmental science and particularly in chemistry and microbiology, a parameter is used to describe a discrete chemical or microbiological entity that can be assigned a value

Performance - an ability to complete a task or operation according to a specified standard. The standards may be defined as measures, yardsticks or benchmarks for assessing the deviations of actual performance as compared to preset requirements, as a basis for managerial control

Product - Any goods or services which are supplied for distribution, consumption or use on the Community market whether in return for payment or free of charge

Pump - A pump moves liquid from one area to another by increasing the pressure of the liquid above the amount needed to overcome the combined effects of friction, gravity and system operating pressures.

Reboiler - are heat exchangers typically used to provide heat to the bottom of industrial distillation columns. They boil the liquid from the bottom of a distillation column to generate vapors which are returned to the column to drive the distillation separation

Safety - The responsibility of protecting from harm or other psychophysical dangers

Screening - The use of a model or analytic method designed to select which problems or decisions should be subject to further analysis

Sustainability - The overall dimension integrating safety, economic, environmental, and social dimensions to meet the needs of the present society in a way that does not compromise the ability of future generations to meet their needs.

Sustainability analysis - The identification and analysis of key factors that are likely to have an impact, either positively or negatively, on delivering sustainable benefits

Steam - Water vapor produced by evaporation. Dry saturated steam contains no moisture and is at a specific temperature for every pressure, it is colorless. The white appearance of escaping steam is due to condensation at the lowered temperature, it is the water vapor that shows white.

Steam-generating unit - A unit to which water, fuel, and air or waste heat, are supplied and in which steam is generated. It can consist of a boiler furnace and fuel-burning equipment and may include as component parts waterwalls, superheater, reheater, economizer, air heater or any combinations.

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