MINISTRY OF INDUSTRY AND TRADE
EMBASSY OF DENMARK
Hanoi
Danish Energy Agency

Audit Guideline

Under the Energy Efficiency Incentive Scheme for Energy Intensive Industries in Vietnam

Hanoi, 2025

AUDIT GUIDELINE

Under the Energy Efficiency Incentive Scheme for Energy Intensive Industries in Vietnam

Office/department
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Viegand Maagøe

RCEE-NIRAS

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Contact

Agency for Innovation, Green Transition and Industry Promotion,
Ministry of Industry and Trade

Address: 54 Hai Ba Trung street, Cua Nam ward, Hanoi

INTRODUCTION

The following document serves as an extended guideline for energy audits and is based on the existing regulation in Circular 25 (2020) – see Annex 1.

The document defines additional requirements for energy audits to fulfill – next to Circular 25 – when carried out, funded by the energy efficiency program under the Danish/Vietnamese cooperation.

As such, the guideline does not present issues described in Circular 25 but topics that the auditor shall include in the energy audit to benefit from Danish funding.

The aim of the guideline is by that to secure, that an energy audit will be comparable to international best practices.

The Audit Guideline is part of a document series developed to support the implementation of energy efficiency projects in Vietnam’s industrial sector, including Audit Guideline, Pre-Feasibility Study Guidance, Feasibility Study Guidance, and Loan Application Guidance.

CONTENT

SECTIONS IN ANNOTATED GUIDELINE

This guideline follows the main sections of an energy audit as defined in Circular 25, see table 1 below, which also includes a few requirements described later in the guideline.

Table 1: Checklist of requirements for energy audits

Content of audit report	Requirements
Chapter 1: Summary	
Summary of results from audit	Overall annual energy consumption data and costs should be presented A table with identified energy efficiency projects, related savings and investments, and payback-period The identified energy efficiency projects should be given priority and should be ranked in terms of importance Proposed further steps should be described
Chapter 2: Introduction	
Introduction to the energy audit	Overall company information (name, address, etc.) Breakdown of company structure and production modes Definition of scope and success criteria for the energy audit
Chapter 3: Affairs of the company	
Overall history of the company, their products and operating data	Annual production outputs Overall annual energy consumption (3 years) Overall assessment of focus areas for energy audit and necessary competences and specialists to involve

Content of audit report	Requirements
Chapter 4: Description of procedures in technology processes	
Introduction to manufacturing process and production equipment	Principle diagrams for significant energy users Flow diagrams for production flow and energy usage
Chapter 5: Energy demands and supply capacity	
Mapping of energy consumption and breakdown of energy usage	Equipment lists, significant energy users Breakdown of energy usage by end-use
Chapter 6: Financial – technical obligations	
Economic framework for energy efficient solutions	Energy prices and relevant taxation Legal framework for energy efficiency Fuel and energy data
Chapter 7: Energy-saving solutions	
Assessment of energy efficiency potentials	Technical analysis of saving potentials via a variety of methodologies Technical and financial assessment of relevant investment projects Overview of non-energy benefits Proposal for energy management systems and KPI-structures

The column "Requirements" in the table above is described in detail in relevant sections below.

1 Annotated Energy Audit Report

The following sections provide guidance for development of the Energy Audit Reports:

1. Summary
2. Introduction
3. Affairs of the company
4. Descriptions of procedures in technology processes
5. Energy demands and supply capacity
6. Financial – Technical Obligations
7. Energy saving solutions

In this guideline, mainly methodologies for identifying energy saving solutions (section 7) are expanded, but also in other sections, additional requirements are added.

1.1 Summary

Below, a few additional requirements to the summary of the energy audit report are described.

1.1.1 Annual energy consumption, costs and CO_2 emissions

A table with overall annual production outputs and overall energy usage should be present for the past 3 years so overall trends in energy consumption can be understood. The overall energy consumption should also include any use of biomass.

Also, overall annual costs for energy should be presented as well as annual CO_2 emissions.

1.1.2 Recommended energy efficiency projects

In addition to direct investments projects as stipulated in Circular 25, recommendations from an energy audit can concern other aspects of energy efficiency, by example:

- Further analysis to investigate certain complicated areas in more detail
- Improved maintenance procedures for significant energy users
- Better use of energy management procedures and energy-KPIs
- Etc.

Such recommendations should be considered in the overall assessment of energy efficiency potentials.

It should be stated which CO_2-emission reductions the individual energy efficiency projects can achieve.

It should be described which non-energy benefits that have been identified during the energy audit – if any (see Annex 2 for an overview of non-energy benefits).

1.1.3 Further steps

The report shall describe recommended further steps and conclude for which areas pre-feasibility and feasibility studies is to be elaborated in order to prepare the company management for Final Investment Decisions (FID) for significant energy efficiency projects.

Recommended suppliers to be involved in further work to assess precise investment levels should be identified.

1.2 Introduction

Next to immediate description of the company, the following sections should be added:

1.2.1 Scope of the energy audit

It shall be clearly described which motivation the management of the company has to participate in the energy audit, by example:

- Is CO_2-neutrality an important parameter for success of the energy audit? – does the company have a strategy to reduce CO_2-emissions – is phase out of fossil fuels a key question to look into?
- Are clients to the company requesting action to reduce energy consumptions and CO_2-emissions? – is supply chain question important in the management's priority of investments?
- Are non-energy benefits like increase of production capacity or improved product quality important parameters when assessing benefits from energy efficiency projects?

Such questions are important to clarify and describe in order to secure ownership to the energy audit at management level.

1.3 Affairs of the company

From the description of the company and the products it produces, overall focus areas to improve energy efficiency should be assessed and details of the energy audit planned.

1.3.1 Competences and organisation of the energy audit

For many companies, a majority of the energy saving potentials is to be found inside the production processes and not equally important in related utility systems. The energy audit team must include experts with knowledge and experience of the main energy consuming processes in the enterprise audited. In addition, the people responsible for the processes in the industrial enterprise should be involved in the energy audit.

The relevant experiences of the audit team as well as the inclusion of relevant operation and management staff in the industrial enterprise must be documented in the report.

1.4 Description of procedures in technology processes

The energy audit report must include details of how the production processes takes place in the company as well as the utility systems like steam boilers and compressed air systems. Depending on the context, the description must be supported by diagrams.

1.4.1 Simple process flow diagrams

Flow diagrams can be simple diagrams following the production flow including main components like furnaces, conveyors, silos etc. This will most often be enough for relatively simple production flows in by example cement industry, in brick production etc.

Simple production flow diagrams shall be supplied with illustrations for the main components in the plant, by example for furnaces and driers etc. like illustrated in figure 1 below.

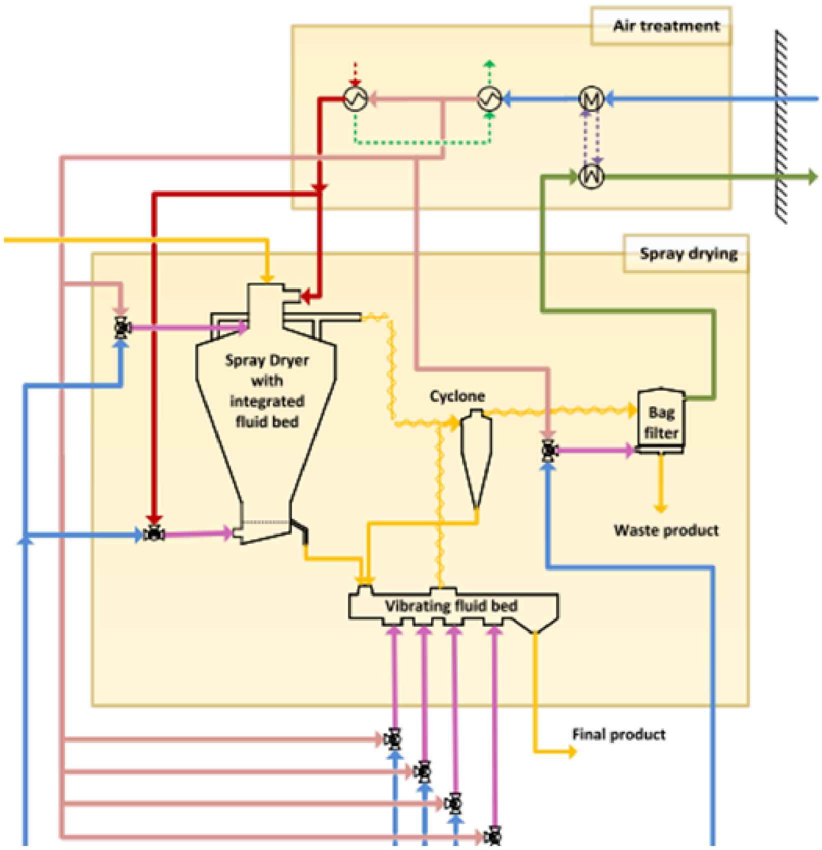


Figure 1. Example of a process flow diagram for an individual process (spray dryer).

Such diagrams provide a good understanding of the energy flows and often also of important process parameters like air flows, temperatures etc.

1.4.2 Advanced process flow diagrams

For sectors like food & beverage, chemical industry and pharmaceuticals etc., the production flow is much more complex, and the energy usage distributed across many different end-users. In such companies the production flow should be described in more detail to provide an understanding of how energy is used at the facility.

Figure 2 below shows a complete production flow diagram for a milk processing plant illustrating all product mass flows and supplied heating and cooling in the individual steps of the process.

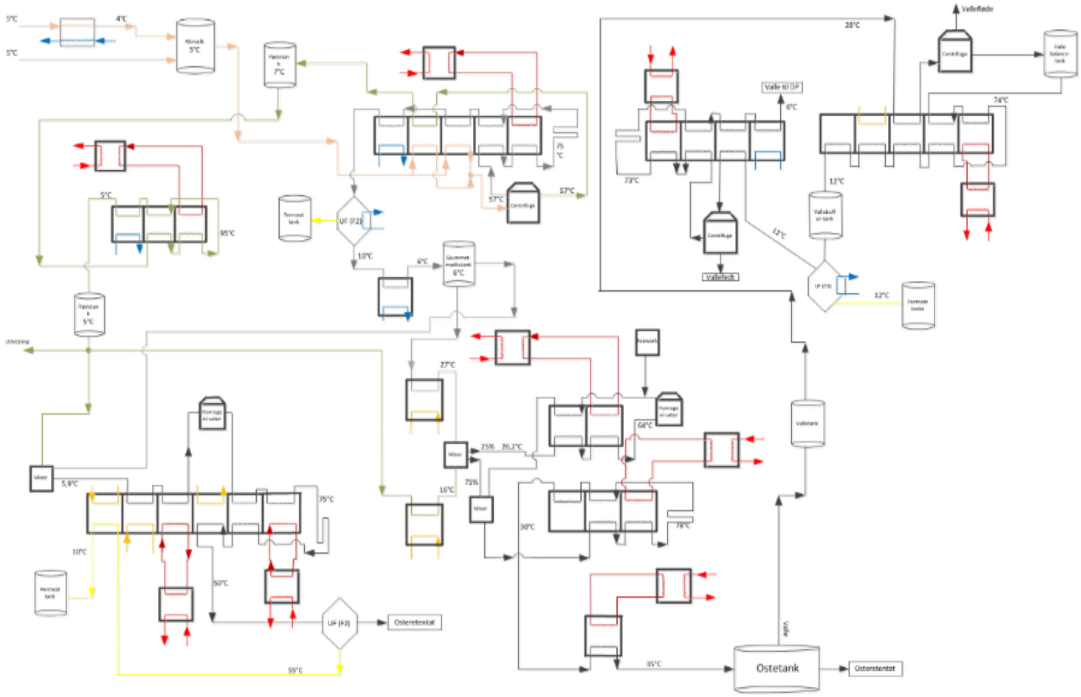


Figure 2. Example of an overall production flow sheet for a dairy plant including hot and cold utility.

Such detail is important to understand the overall energy balance of the facility and assessing potentials for recovering heat between individual process steps.

1.4.3 Screen dumps from control rooms

Often screen dumps from control rooms (process supervision) provides valuable information on specific process parameters, see the example in figure 3 below.

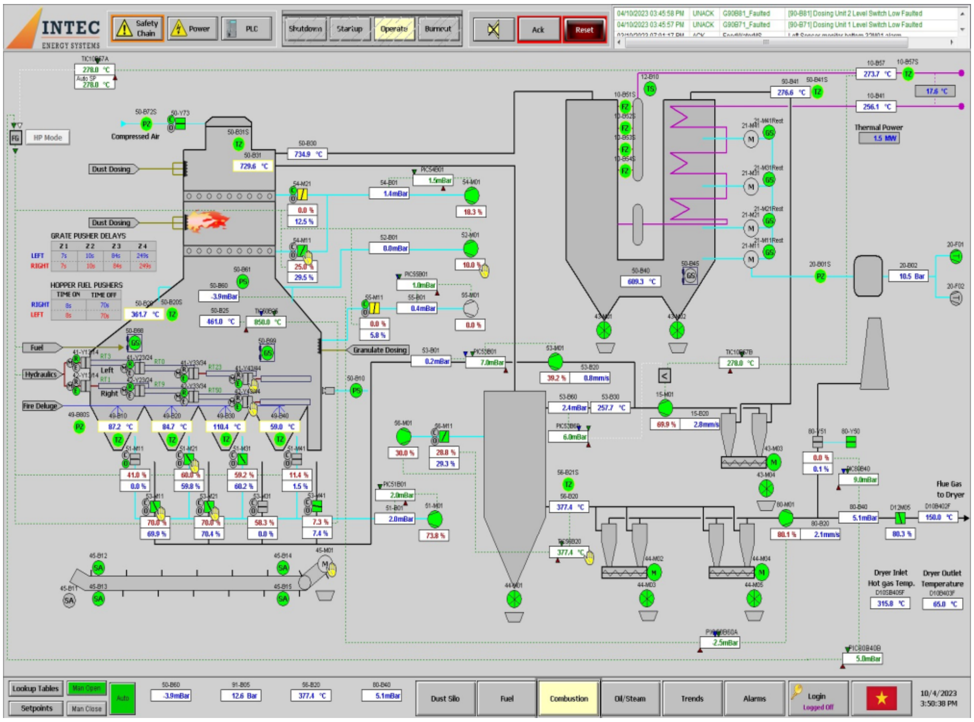


Figure 3. Example screen dump from control room.

Such information shall be included in the energy audit report.

1.5 Energy demands and supply capacity

A good understanding of the present energy usage is crucial for identifying any relevant energy efficiency project.

1.5.1 Equipment lists

As a part of the energy audit, tables with design and capacity data for the most important installations must be prepared, first of all for:

- Boilers
- Refrigeration systems
- Large exhaust fan systems (>25 kW)
- Large air conditioning systems (>25 kW)
- Compressed air systems
- Process equipment and other equipment with installed capacity > 25 kW

For each of such systems, the following data should be provided:

- Installation ID
- Name of manufacturer
- Year of installation
- Design capacity
- Rated efficiency (where relevant)
- Operating parameters (flows, temperatures, pressures etc.)

It is important that this mapping not only targets energy supply systems but also collects data for major processes.

1.5.2 Significant energy users

In addition to requirements set out in Step 4 of Annex III of Circular 25, energy and water consumption must be broken down into categories of significant energy users. A significant user may be one particular installation, a set of installations forming a specific manufacturing process (such as paper machine) or a number of installations of similar category (such as lighting; ventilation etc.)

From the initial mapping of equipment, it should be determined which energy users in the facility that should be considered as "significant". Any installation or category of installations consuming more than 5% of the total energy consumption must be mapped.

Examples of such significant end-users is listed in table 2 below.

Table 2: Examples of significant energy and water users in the industrial sector

Thermal end-users (steam, hot water etc.)	Electrical end-users	Water end-users
- drying - process heating - evaporator lines - boiling - distilling - kilns & furnaces - building heating/HVAC - CIP/SIP	- refrigeration - natural cooling - compressed air - process air - fans/HVAC - air-conditioning - production machinery - pumps	- process (additives) - steam injection (heating) - water for injection (WFI) - RO-plants - humidification of air - cleaning of premises - CIP/SIP

Thermal end-users (steam, hot water etc.)	Electrical end-users	Water end-users
- water heating - conversion losses - distribution losses	- hydraulics - small motors - lighting	- condensate losses - cooling towers - showers - accommodation

For companies with high water usage, also significant water end-users should be identified as much energy usually is bound into heating, cooling and evaporation of water.

1.5.3 Overview of energy consumption by end use

Companies always lack energy meters to monitor a precise distribution of energy usage, both in terms of thermal energy usage, electricity usage and other resources like for example water. Mapping of energy consumption should to the extent possible be based on existing meters. In the absence of meters, a significant element of energy audit work shall therefore be to calculate an estimated distribution of energy end-users.

Assessment of end-uses not covered by the strategic spots of measurements in Step 5.1. of the circular, energy consumption should be assessed from the following parameters:

- Installed capacity (kW)
- Estimated load factor (%)
- Annual run-hours (hours)

From such calculations, the importance of significant end-users of energy (table 2 above) can be assessed and tables or pie-charts for usage of thermal energy, electricity and water can be estimated.

1.6 Financial - technical obligations

For each technical solution proposed, in addition to technological and environmental issues, also other significant non-energy benefits, such as implications on production output capacity, product quality, operational costs etc. must be described. If feasible, the financial implications of these benefits must be quantified, and the value must be included in the financial assessment. A list of frequently observed non-energy benefits is shown in Annex 2.

1.7 Energy saving solutions

The analysis of energy consuming processes should follow the approach illustrated in the below onion diagram. Each step must be considered, and a conclusion of the findings must be reported.

1.7.1 Challenging the energy service

An advanced understanding of the energy consumption in a company can often be described via the “onion diagram” illustrated below.

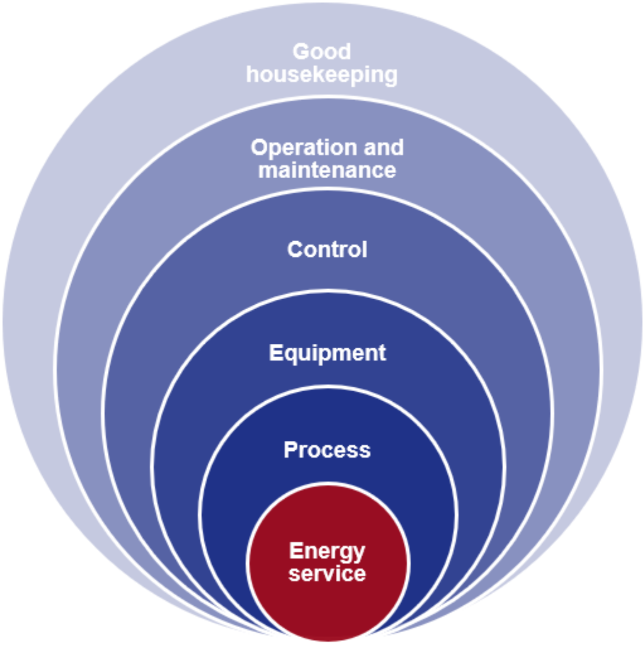


Figure 4. The “Onion diagram” for advanced understanding of energy consumption.

This diagram illustrates, that for any significant energy user there is a reason for why significant amounts of energy is needed, by example:

- For large fan- and ventilations systems, the energy service by example can be:
    - A need for cleaning air in combustion areas via air change and filtration of air

- A need for maintaining a fair working environment in terms of temperature and humidity

- For autoclaves, the energy service by example can be:
    - Sterilization of product
    - Heat treatment of product
- For large furnaces, the energy service by example can be:
    - Drying of a product
    - Chemical processing of a product (by example sintering or calcination)

The basic idea of understanding the energy service is that the need for this sometimes can be challenged – if by example an air change rate is reduced, then the demand for energy is reduced similarly.

An example of such a discussion is illustrated in figure 5 below for the milk reception in a dairy.

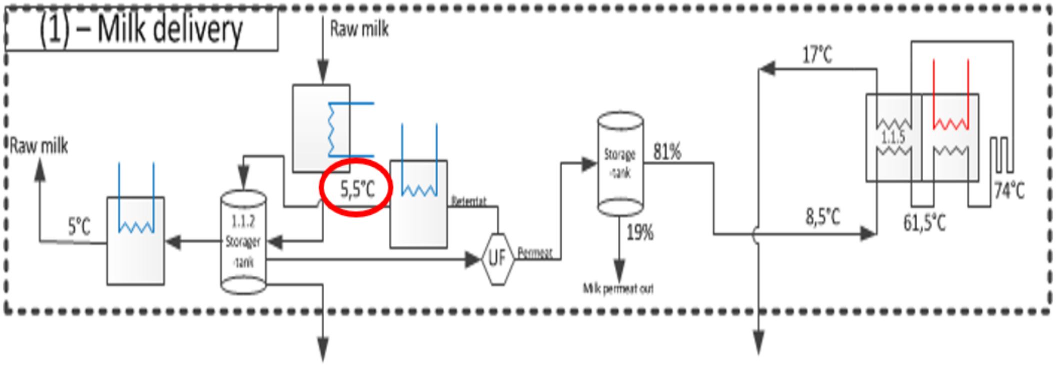


Figure 5. Target temperatures in the milk reception-section of a dairy.

The example shows, that all milk received in the dairy by tradition is cooled down to a target temperature of 5.5°C (or even lower), which can lead to the following questions:

- Is the target temperature the same for all products received?
- Is the target temperature the same for all products to deliver?

Such questions might be difficult to answer and bounded in SOPs (Standard Operational Procedures) and any further dialogue should be taken with key-staff in the company able to make decisions on any change of SOPs. The benefit can best-case be that SOPs can be changed and energy savings achieved without any investment.

The energy auditor shall in the energy audit report present an understanding of these questions, ie. for the most significant energy users it shall be described which overall process parameters that defines the energy consumption. It should further be assessed if these parameters can be challenged and with which benefit.

1.7.2 Energy balances – Sankey diagrams

For the most significant energy users, an energy balance should be established to illustrate the total energy balance and which losses that occur in the operation. The energy balance must quantify all energy and mass flows to and from a certain process. The energy balance should be represented in a diagram such as a Sanky diagram like illustrated below for a drying process in a paper mill.

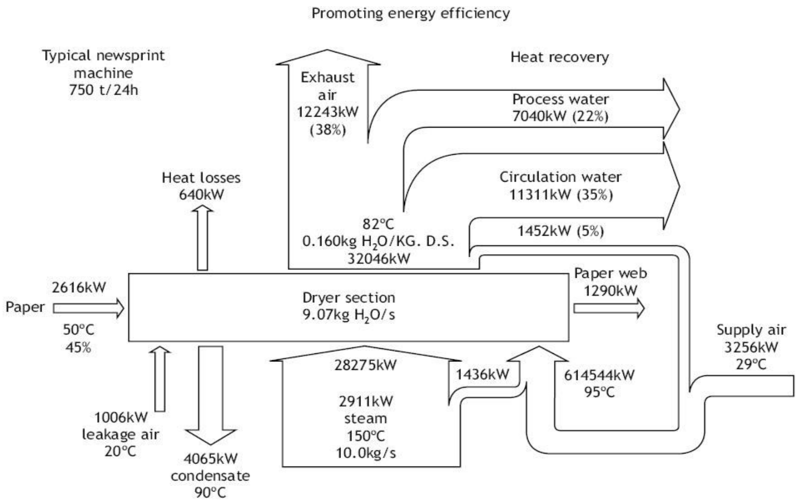


Figure 6. Example of Sankey diagram of the energy balance of a drying process.

The benefit from such an analysis is a throughout understanding of the losses in operation and by that an assessment of the efficiency of the process. The analysis can further identify possible opportunities to recover waste heat into the process in order to reduce energy consumption.

Reduction of losses or opportunities for waste heat recovery should be assessed in the energy audit report.

1.7.3 “Level-2”-mapping

In case of processes, where there can be observed large temperature differences between the source and the sink of heating or cooling (for example the temperature difference between the steam supply and the air heated by the steam), the energy audit must perform a level-2 mapping. The purpose of this is to identify potential energy savings potentials through modification of processes or the energy supply systems.

Especially in sectors like food & beverage, chemical industry and pharmaceuticals, it is often seen widespread heat and cooling distributions systems supply heating and cooling to many areas of the facility, with widely different requirement for temperatures – by example steam at 8 bars and 160°C can be used for heating of low temperature heat demands – by example heating of cleaning water or process water to 60°C.

Similarly, it is seen that high quality cooling – by example glycol at minus 6°C – is used for cooling of high temperature cooling demands – by example cooling hydraulic oil at 60°C.

It is important to understand that such large differences in delta-T, i.e. differences in process demand-temperature and delivered utility-temperature, can represent significant energy saving potentials.

To enable such an understanding, companies with such energy supply patterns should carry out a “level-2”-mapping, where any thermal energy demand (heating and cooling) should be mapped by energy demand and temperatures like illustrated in table 3 below.

Table 3. Data to collect in a level-2-mapping

Process	Temperature Start (°C)	Temperature Target (°C)	Amount (kg/year)	Heat capacity (KJ/kg/°C)	Heat demand (KJ/year)
1					
2					
3					

Process	Temperature Start (°C)	Temperature Target (°C)	Amount (kg/year)	Heat capacity (KJ/kg/°C)	Heat demand (KJ/year)
4					
5					
Etc.					
Total					

The data collection should further collect data for waste heat ventilated to the surroundings, by example hot exhaust from a furnace or a dryer and categorize these as a cooling demand in table 3 above.

The idea of such a data collection is two-fold:

- To assess whether the current energy supply structures is energy efficient (section 1.7.4 below)
- To assess whether heat recovery relevant option for the company (section 1.7.5 below)

To illustrate such potentials, a temperature vs. load-curve as illustrated in figure 7 below should be established.

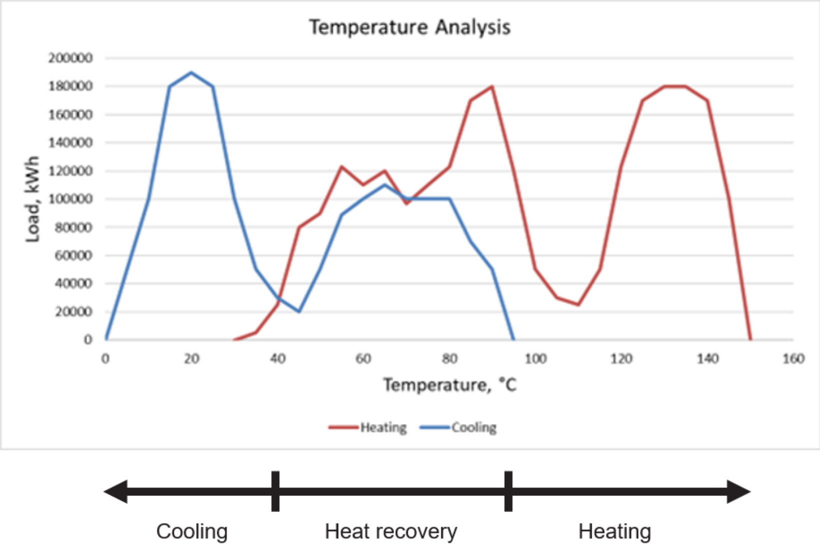


Figure 7. Example temperature/load-curves for cooling demand (blue) and heating demand (red).

This figure shows all heating demands (red) and cooling demands (blue) in a facility integrated into 2 curves by temperature and load. Overlaps in temperatures can be illustrated in such a figure – in this case indicating a significant potential to recovery heat and thus save hot and cold utility.

1.7.4 Utility structures

The understanding of hot utility requirements with the Level-2-mapping can also be illustrated in a diagram like below

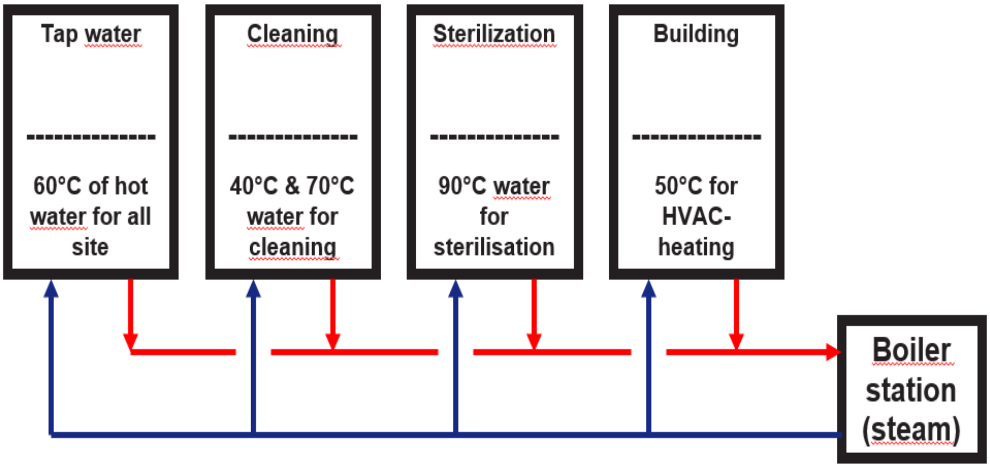


Figure 8. Example how hot utility is supplied across a facility.

In cases where steam is used for many heating demands at low temperatures (<100°C), the following options to save energy shall be considered:

- Will a hot water system be much more efficient to operate?
- Can heat pumps – eventually driven with solar PV – supply hot water to significant energy users?
- Can waste heat be used to cover certain energy demands?

For cooling demand, similar analysis should be performed like illustrated in figure 9 below.

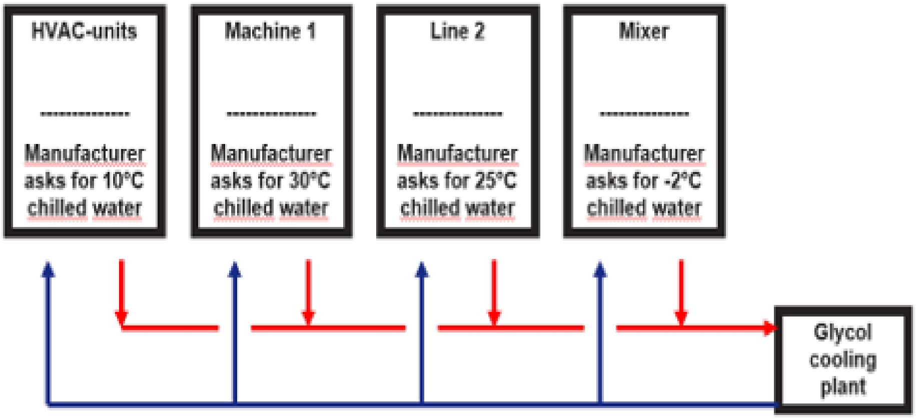


Figure 9. Example how cold utility is supplied across a facility.

In cases, where cooling like brine or glycol at temperatures < 0°C is used for many cooling demands across the facility, the following options to save energy shall be considered:

- Can separate cooling systems at higher temperature – by example +6°C - be applied?
- Can natural cooling (cooling towers) be applied to cover certain cooling demands at high temperature?
- Can internal heat recovery reduce the demand for utility cooling?

Such opportunities are described further below.

1.7.5 Heat recovery schemes

In most facilities heat recovery schemes represent significant energy saving potentials and overall, the following options are to be considered:

- Improved efficiency of already existing heat recovery systems
- Installation of new heat recovery systems internal at significant energy users
- Heat recovery systems across multiple energy consumers

The first of these options address the fact that many existing heat recovery systems have bad performance – either because of fouled heat exchangers with poor heat transfer or because of significant change in operating parameters – by example flows – since the original installation.

The second of these options address the fact that many unit operations/processes have been designed without heat recovery thus impairing the efficiency of the process significantly.

The third option addresses the fact that many industries have waste heat available at many sources across the site and that a collection of these waste heat streams can cover a significant part of the heat demand (heat demands below by example 60°C).

In annex 3, some examples of such solutions are presented.

1.7.6 Large fan and pumping systems

In certain sectors like cement, iron and steel, paper and pulp and chemical industry (fertilizers) comprehensive fan- and cooling water systems are operated. Such systems are often complex and with low efficiency, which shall be assessed carefully. For large fans like the one shown in figure 10 below, the control strategy as well as the total fan efficiency must be assessed – often such fans are old with low design efficiency and often the capacity is controlled with dampers and not efficiently with VSDs.

Figure 10. Large exhaust fan in an iron & steel industry.

Figure 11 below shows the benefit from controlling capacity of fans and pumps with VSD versus damper-control.

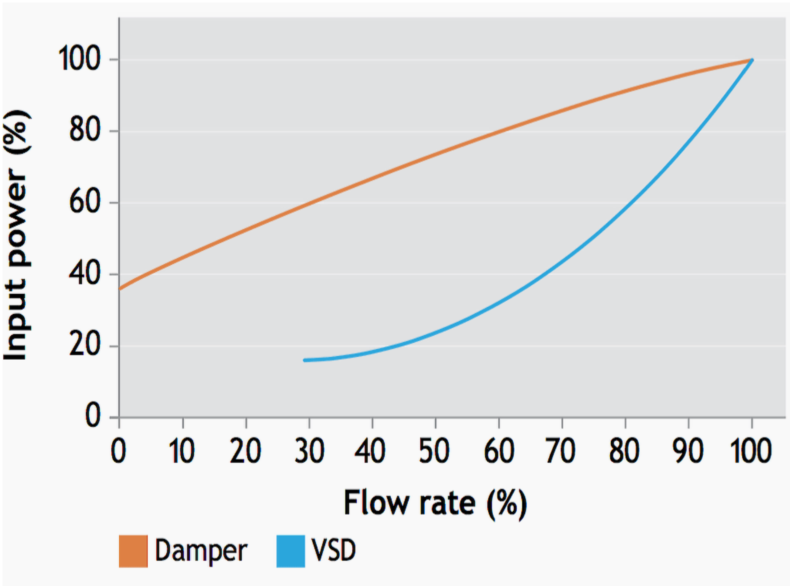


Figure 11. Efficiency of damper- versus VSD-control for large fans and pumps.

For large cooling water systems like the one shown in figure 12 below, the situation is the same.

Figure 12. Cooling water system in an iron and steel industry.

For such large cooling water systems, a careful comparison of delivered cooling and consumed electricity for fans and pumps should be monitored continuously and the COP-system shall be calculated and mapped over longer time-spans as illustrated in figure 13 below.

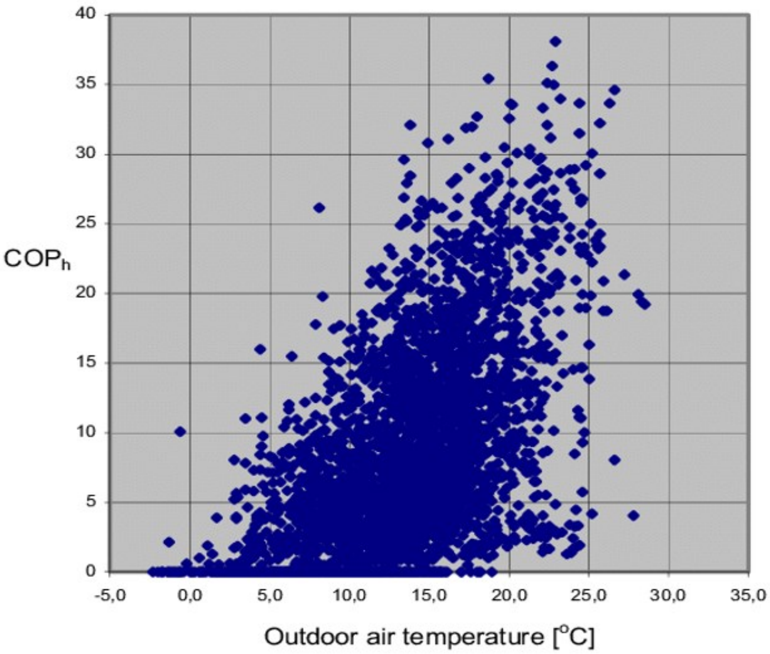


Figure 13. COP monitored for large cooling tower system.

The benefit from such COP-surveillance is that large variations in system efficiency can be discovered thus identifying large potential energy savings via better control of fans and pumps.

1.7.7 BAT-assessments

A throughout understanding of Best Available Technology (BAT) can provide important information on potential energy savings in existing plants.

Detailed information on BAT-solutions can be found in the link to the European Union's BAT-library provided below[1] and illustrated with an example below.

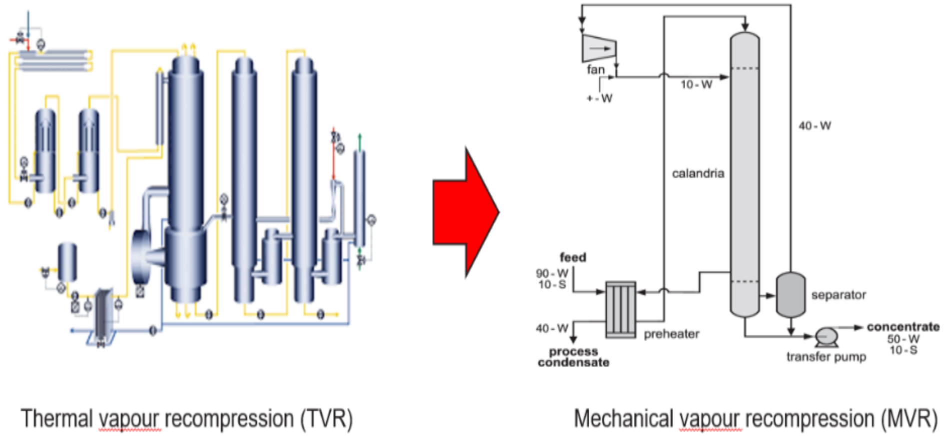


Figure 14. Traditional and BAT-solutions for evaporator systems.

In figure 14, a traditional evaporator system (TVR) is illustrated on the left side and a best-practice MVR-plant is illustrated on the right side – a solution that via electrification might save up to 80% of the supplied energy.

It is important to stress that BAT-solution often will address the core unit operations in a facility and therefore is to be considered as a major and very expensive rehabilitation of these. Such changes are most often only possible if other benefits than energy savings can be achieved, by example increased production capacity, improved product quality, better flexibility of operation etc. (see Annex 2 for an overview of "non-energy"-benefits).

It is requested that the energy auditor during the initial phases of the energy audit identifies any need to address non-energy benefits of the facility and then address opportunities for BAT-solution from conclusions in this area.

[1] https://eippcb.jrc.ec.europa.eu/reference

1.7.8 Maintenance procedures

The sections above have mainly addressed more complex assessments of process energy usage and it should be emphasized that most industries have significant energy saving potentials simply via improving maintenance procedures for the most important energy users, by example:

- Regular control of boiler efficiency (oxygen-percentage and temperature of exhaust gas)
- Repair or installation of missing insulation at all hot surfaces (piping, valves etc.)
- Repair of leaks in compressed air piping systems
- Cleaning of fouled heat exchangers
- Monitoring of water content in ammonia in refrigeration systems
- Removal/purging of air in condensers in freezing plants
- Repair of steam traps in steam distribution systems
- Etc.

The energy audit must assess if such simple improvements will provide significant energy savings in a company.

1.7.9 Operational control and KPIs

During the course of an energy audit, is shall therefore be identified if losses from inefficient operation of processes and utility systems occur and how such losses can be prevented.

It shall further be assessed if technical instrumentation and automation systems can prevent these losses or whether specific groups of personal employed in the facility should be trained, by example:

- Operators in control rooms responsible for daily operation of the processes
- Personal responsible for cleaning of equipment and process installations
- Process people responsible for adjusting process parameters
- Etc.

Figure 15 below show an example of the operating pattern for a large evaporator system with indication of how many hours each day the evaporator is processing product (blue), is under clearing (pink), is operated "water-mode" without product but with full energy consumption (green) etc.

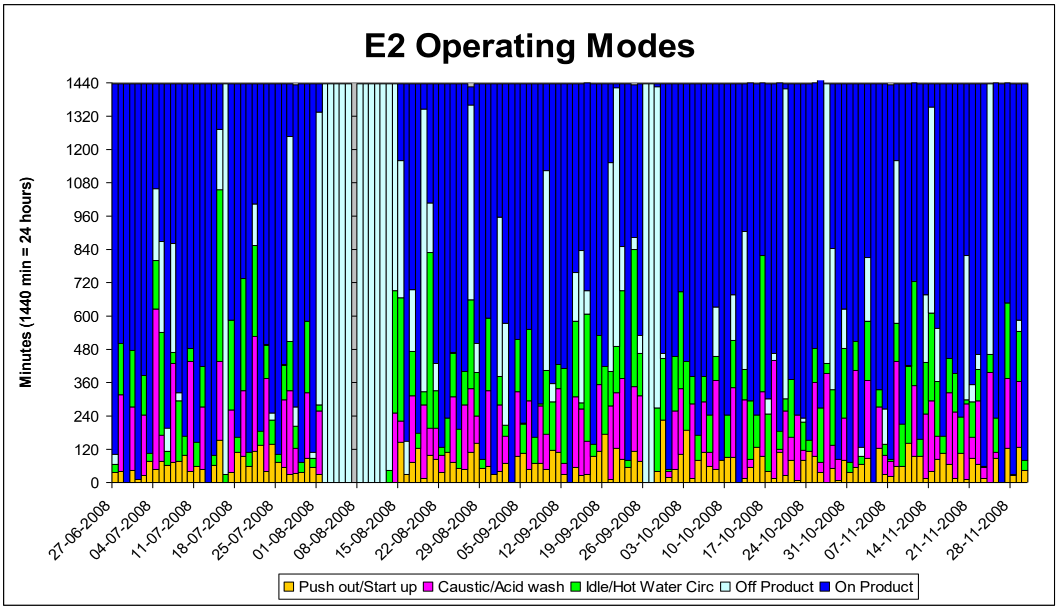


Figure 15. Example of operating modes in large evaporator systems.

A detailed analysis of this diagram shows that operators often clean the evaporator system much to many hours per days and that the evaporator often are operated long hours in "water-mode" – in both cases with significant losses of used energy.

1.7.10 Energy Management Systems

Organization of energy management shall be proposed including identification of relevant staff requirements to cover the necessary positions (e.g. energy managers, boards for energy management).

A proper organisation of an energy management system should further most likely involve different staff at the facility, ie. technical department, process responsibles, QA-department etc. As an integrated part of these assessments, overlaps with other management systems should be identified, first of all:

- ISO50001: Energy Management
- ISO14001: Environmental Management
- ISO9001: Quality Management

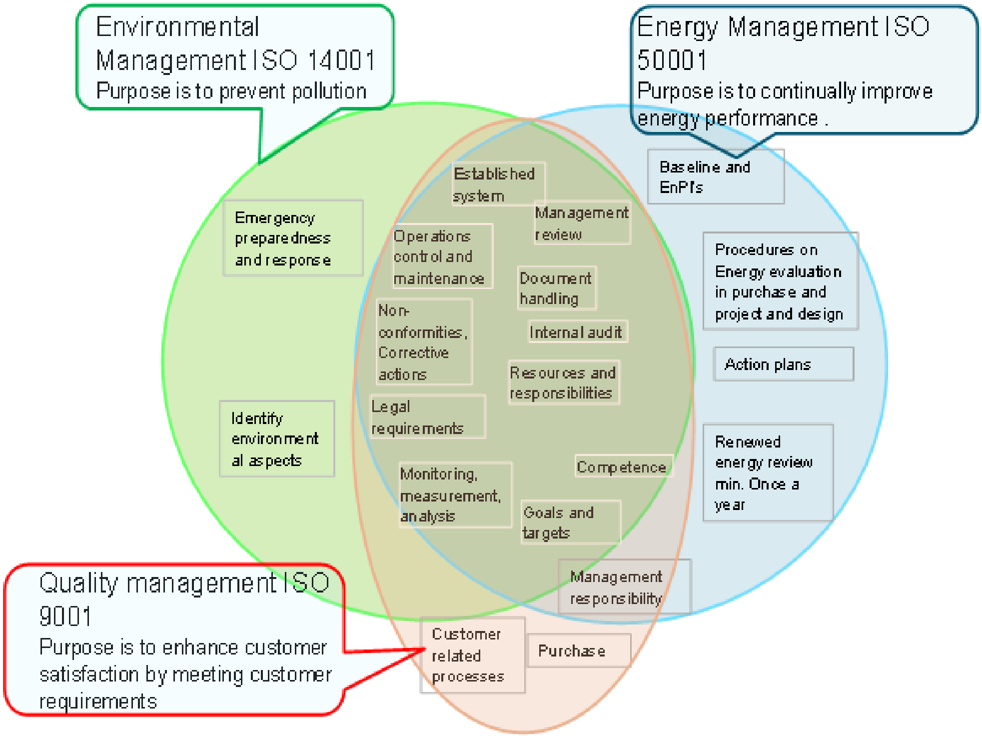


Figure 16. Elements of commonly used management standards.

The energy audit shall describe the expected outcomes of such EMS-systems and define which observations and cornerstones the system should be built on.

Appendix 1. Circular 25

Circular 25 (2020) - Planning and Reporting the Implementation Plans For Energy Efficiency; Implementation Of Energy Audit

Link to UK version (60 pages):
vepg.vn/wp-content/uploads/2020/12/Circular-25-2020_EN.pdf

Scan here to access the document:

Appendix 2. Non-energy benefits

M-Benefits: D2.2 Guidelines for Protocols, Interventions and Evaluations

BENEFITS OF ENERGY-EFFICIENCY PROJECTS *(This list is based on proven benefits of past projects in Europe and the US)*	IMPACT ON RISKS	IMPACT ON COSTS	IMPACT ON VALUE PROPOSITION
Waste			
Reduced waste heat		X	
Reduction hazardous waste	X	X	
Reduced sewage volume	X	X	
Reduced sewage pollution level	X	X	
Reduced product waste	X	X	
Emissions			
Reduced dust emissions	X	X	X
Reduced CO, CO_2, NO_x, SO_x emissions	X	X	X
Reduction of refrigerant gases emissions	X	X	X
Production			
Reduced malfunction or breakdown of machinery and equipment	X	X	X
Improved equipment performance	X	X	X
Longer equipment life (due to reduced wear and tear)		X	
Improved product quality	X	X	X

BENEFITS OF ENERGY-EFFICIENCY PROJECTS *(This list is based on proven benefits of past projects in Europe and the US)*	IMPACT ON RISKS	IMPACT ON COSTS	IMPACT ON VALUE PROPOSITION
Increased production reliability (due to better control)	X	X	X
Larger product range			X
Reduced customer service costs (due to better quality)		X	X
Improved flexibility of production	X	X	X
Improved temperature control	X	X	X
Improved air filtration system	X	X	X
Reduced raw material need	(X)	X	
Reduced water consumption	(X)	X	
Reduced consumables	(X)	X	
Shorter production cycle (shorter process cycle time)		X	X
Increased production yields		X	X
Operations and maintenance			
Reduced maintenance cost		X	
Reduced machinery and equipment wear and tear	X	X	
Reduced engineering control cost		X	
Working Environment			
Reduced noise	X	X	X
Air quality improvement	X	X	X

BENEFITS OF ENERGY-EFFICIENCY PROJECTS *(This list is based on proven benefits of past projects in Europe and the US)*	IMPACT ON RISKS	IMPACT ON COSTS	IMPACT ON VALUE PROPOSITION
Improved temperature control (thermal comfort)	X	X	X
Improved lighting (visual comfort)	X	X	X
Improved workforce comfort	X		X
Improved workforce productivity	X	X	X
Reduced absenteism	X	X	X
Reduction of health costs		X	
Reduced need for protective equipment		X	
Risk Reduction			
Reduced risk of accident and occupational disease	X	X	
Reduced CO_2 and energy price risks	X	X	
Reduced water price risk	X	X	
Reduced commercial risk	X	X	
Reduced legal risk	X	X	
Reduced disruption of energy supply risk	X	X	
Others			
Increased installation safety	X	X	X
Improved staff satisfaction and loyalty	X	X	X

BENEFITS OF ENERGY-EFFICIENCY PROJECTS *(This list is based on proven benefits of past projects in Europe and the US)*	IMPACT ON RISKS	IMPACT ON COSTS	IMPACT ON VALUE PROPOSITION
Reduced staff turnover	X	X	X
Delayed or reduced capital expenditure		X	
Reduced insurance cost		X	
Additional space		X	X
Simplification and automation of customs procedures		X	X
Contribution to company's vision or strategy			X
Improved image or reputation	X		X

Source: Killip, G., Cooremans, C. & Fawcett, T. (2018). M-Benefits: D2.2 Guidelines for Protocols, Interventions and Evaluations.

Report link:
https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bd4f4af7&appId=PPGMS

Scan here to access the document:

Appendix 3. Examples of heat recovery systems

Figure 17 below shows an example of a pasteurizer in a whey processing plant, where efficiency can be improved significantly be re-designing heat transfer area in the individual sections thus saving both hot- and cold utility.

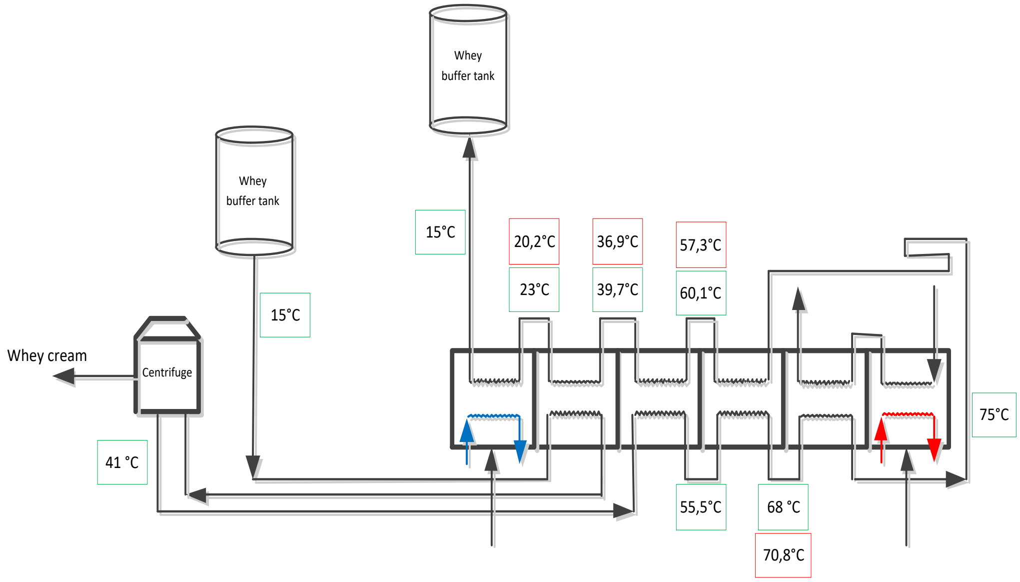


Figure 17. Re-design of pasteurizer in whey-processing plant.

The second of these options address the fact that many process installations like furnaces, kilns and dryers ventilates significant amount of waste heat into the surroundings instead of using the heat to pre-heat inlet to the process like illustrated below for a spray dryer system.

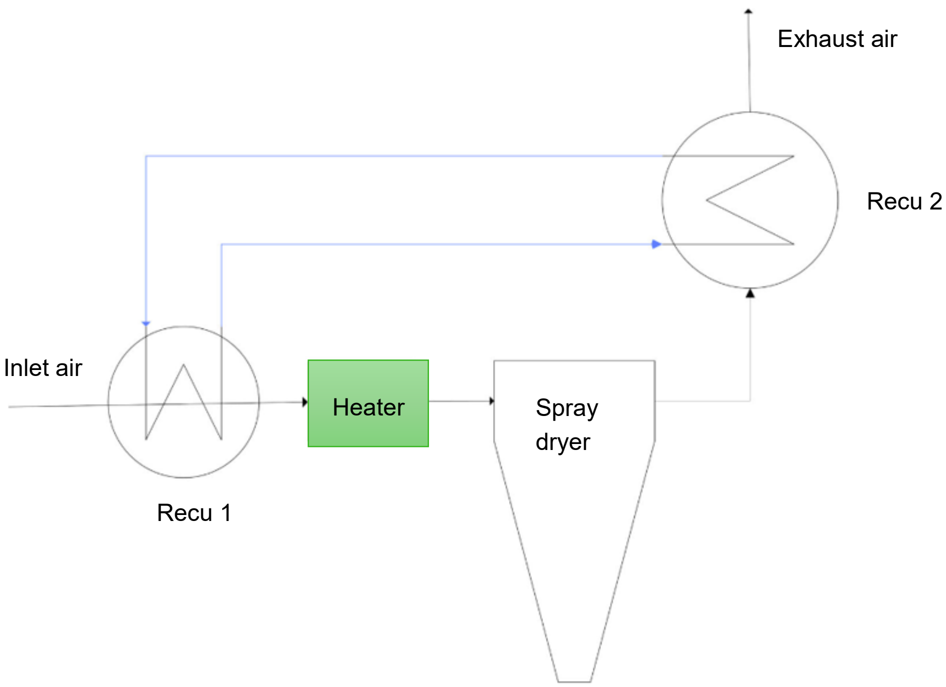


Figure 18. Internal heat recovery outlet-to-inlet in a spray dryer system.

The third of the options listed above address the opportunity to collect waste heat across many sources in a facility, by example from compressed air plants, oil cooling, hot outlets to the surroundings and use this waste heat – eventually boosted with heat pumps – to supply heat to hot water circuits covering certain heating demands in a facility.

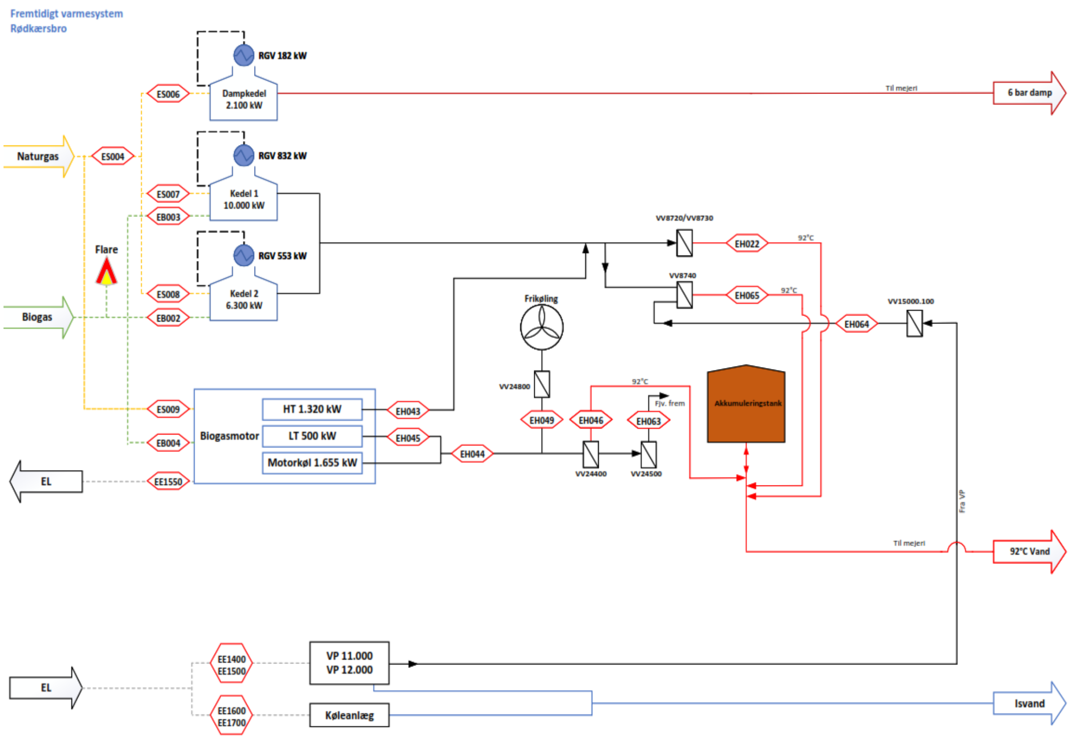


Figure 19. Heat recovery loop with heat pump supplying hot water for certain heating demands.

Such solutions are relevant in food & beverage, in chemical industry and pharmaceuticals and will often cover up to 50% of the total heating demand.

For these sectors such a solution must be considered, while sectors such as cement, paper & pulp and bricks & ceramics only should assess heat recovery options at individual process installations.

In sectors like textile and garments, also heat recovery across energy users should be considered, while mechanics, plastics and electronics most often only can apply waste heat for building heating (seldomly relevant in Vietnam).

Appendix 4. Fertilizer

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

Fertilizer Products

Urea – 800,000 tons/year
NPK – 300,000 tons/year

The letters "NPK" on a fertilizer label stand for nitrogen, phosphorus, and potassium, the three primary nutrients plants need to grow. For example, 5-10-5 of NPK stands for 5% nitrogen, 10% phosphorus, and 5% potassium.

Nitrogen (N) is a building block for growing new stems and leaves, plus it is a necessary part of chlorophyll, which makes the leaves green and helps plants photosynthesize.

Phosphorus (P) is needed for developing flowers, fruits, and root systems.

Potassium (K) keeps roots healthy and also aids flowers and fruits.

Process Plants

This section summarizes a brief understanding of all the process plants. It also mentions the major raw materials along with major process steps. The three plants are described as follows:

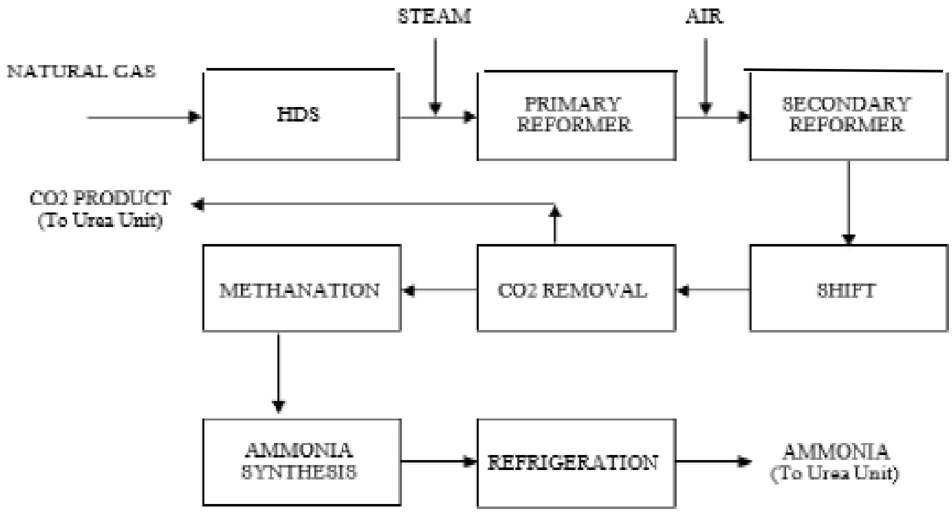
1.1 Ammonia (NH_3)

- Feedstock
  - Natural gas as feed (for Hydrogen in Ammonia (NH_3))
  - Natural Gas as Fuel
  - Ambient Air (for Nitrogen in Ammonia (NH_3))

- Process

  - Step 1: Removal of sulfur compounds *(HDS unit)*
  - Step 2: Catalytic reforming of desulphurization gas to produce synthesis gas *(Reforming Unit)*
  - Step 3: Conversion of Carbon Dioxide CO2 to Carbon Monoxide (CO) *(Shift reaction Unit)*
  - Step 4: Removal of Carbon Dioxide -Goes to Urea Plant- *(Absorber & Strip- ping unit)*
  - Step 5: Carbon oxides are converted to Methane *(Methanation Unit)*
  - Step 6: Synthesizing ammonia from hydrogen and nitrogen *(Ammonia Con- verter)*
  - Step 7: Cooling of Ammonia *(Refrigeration Unit)*

Ammonia Unit:



1.2 Urea (46% nitrogen)

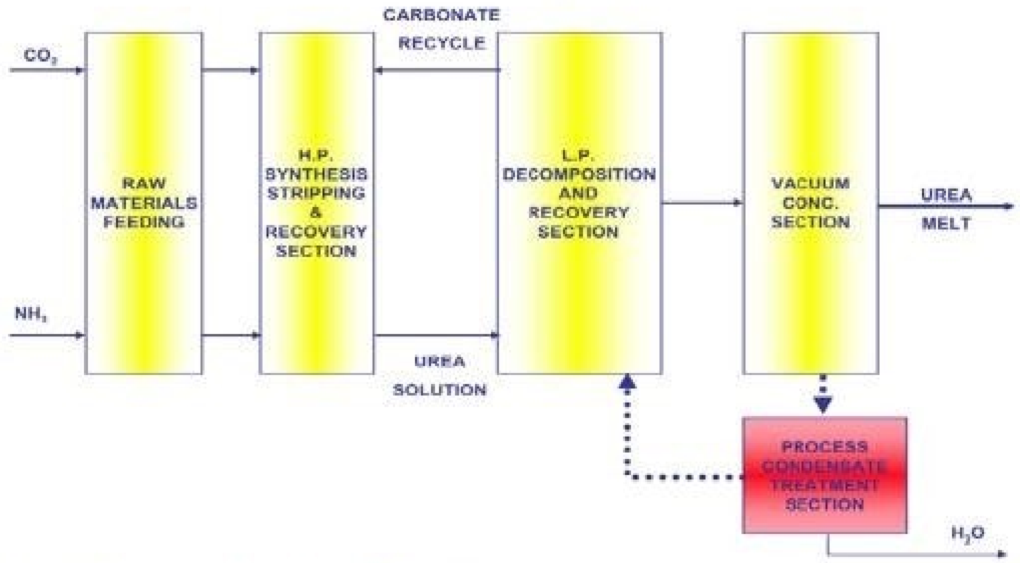
- Feedstock

  - Carbon Dioxide from Step 4 in Ammonia Plant
  - Ammonia from Step 7 in Ammonia Plant

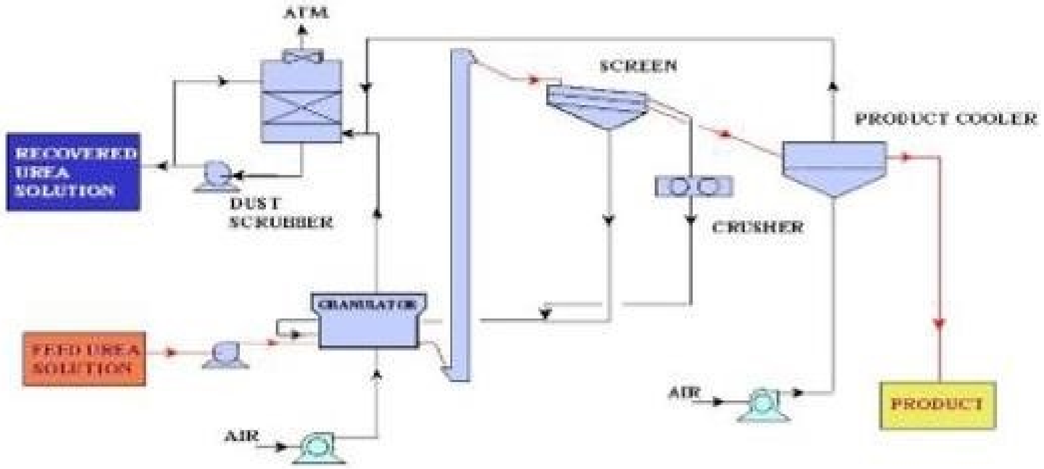
- Process

  - Step 1: Mixing of Ammonia & Carbon Dioxide *(High Pressure -Urea synthesis unit)*
  - Step 2: Purification & Recovery of Urea *(Medium Pressure)*
  - Step 2: Purification & Recovery of Urea *(Low Pressure)*
  - Step 3: Concentrating the urea molten liquid *(Concentration Unit)*
  - Step 4: Solidifying the urea liquid - *(Grain Generation Unit- Separate Plant)*

Urea: Snamprogretti - Italy, 2385 MTPD



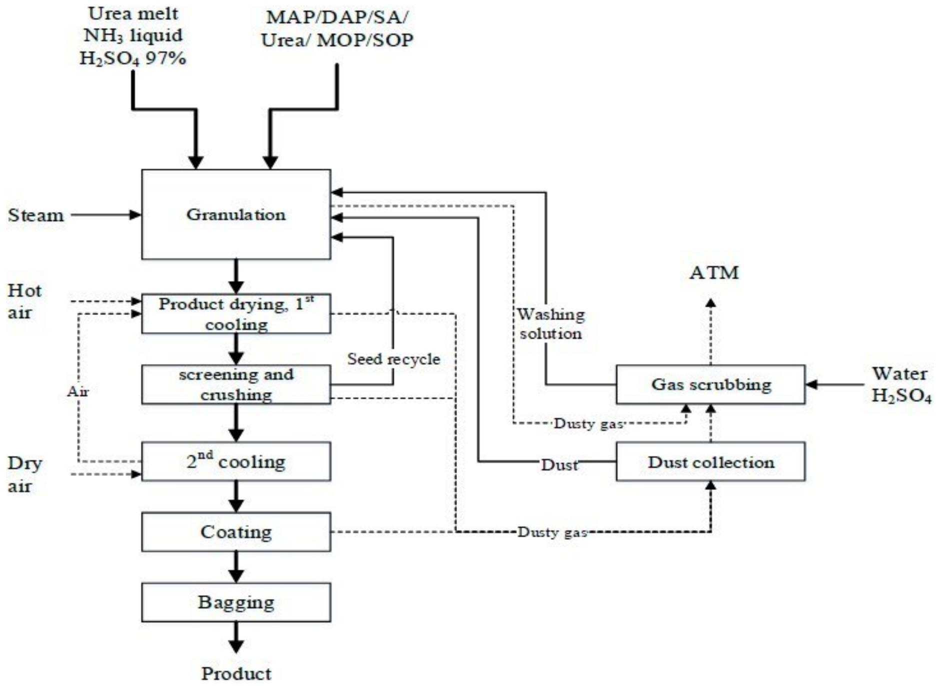
Grain Generation: TOYO, Japan



1.3 NPK

- Feedstock
  - Depending on the ratio of NPK, the feedstock changes
  - Urea/Ammonia/Sulphuric Acid/ MOP or SOP (Potash compounds)/MAP or DAP (Ammonium Phosphates compounds)
  - Feedstock can be imported into the facility.

- Process
  - Step 1: Handling of Solids
  - Step 2: Handling of Liquids
  - Step 3: Mixing of Solids and Liquids in the granulator *(Granulation Unit)*
  - Step 4: Drying of Granulated NPK *(Drying & Cooling Unit)*
  - Step 5: Classification of NPK particles *(Screening and crushing unit)*
  - Step 6: Secondary Cooling of NPK *(Air conditioning unit)*
  - Step 7: Final cooling of NPK *(Cooling and coating Unit)*
  - Step 8: Packaging & Delivery of fertilizer *(Bagging Unit)*
  - Step 9: Recovery of fertilizer dust collection *(Cyclones Unit)*
  - Step 10: Scrubbing of the process gas *(Scrubbing Unit)*
  - Step 11: Collection of condensates from the process *(Collecting Unit)*



Annual Energy Consumption – Based on available Data

This section presents an overall energy mapping of the entire facility based on the two available documents. Table 1 and Figure 1 (left) present the annual consumption of three major types of energy types used in the facility. The most dominant energy type was Natural gas, which comprised of 95% of the total energy consumption. It should be pointed out that out of this 95%, a significant portion is used a feedstock (approx. 65%-70%), while the rest is used as a fuel. It was followed by Electricity and Permeate gas, representing the remaining consumption. The numbers are based on average annual numbers from 2018-2022.

Table 1: Annual Consumption of Energy Types in the facility (based on average numbers from 2018-2022)

Energy Type	Units	Annual Consumption (Average of 2018-2022)
Electricity	(GWh)	174
Natural Gas	(GWh)	5200
Permeate Gas	(GWh)	108
Total	(GWh)	5682

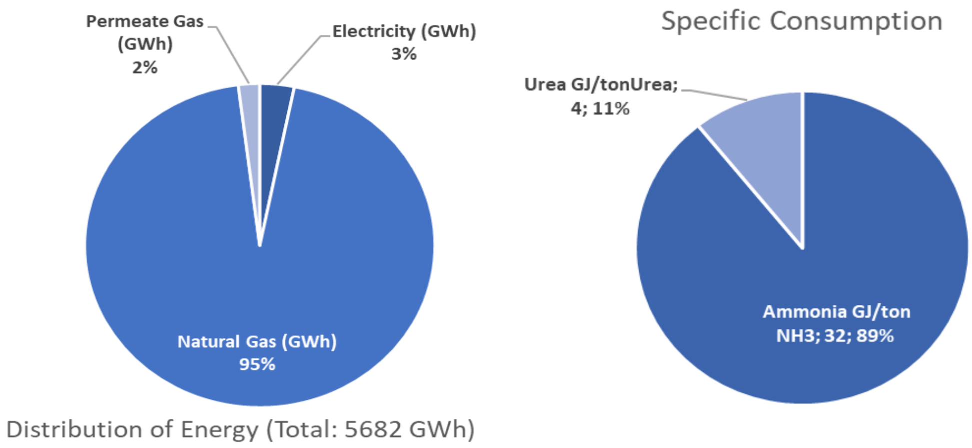


Figure 1: Distribution of Energy Type at the entire facility (2018-2022) (Left); Specific Energy Consumption for Ammonia & Urea (2018-2020) (Right).

Having known the total energy consumption of the site, the energy division of the process plants are described. Figure 1 (right) describes the energy required to produce 1 ton of ammonia and urea. The data was only available for ammonia and urea. It is expected that some energy consumption should also correspond to NPK, but that data was not available.

Figure 2 presents the design capacities – based on Natural Gas flow rate. The maximum energy consumers are the combustion chambers and reformers.

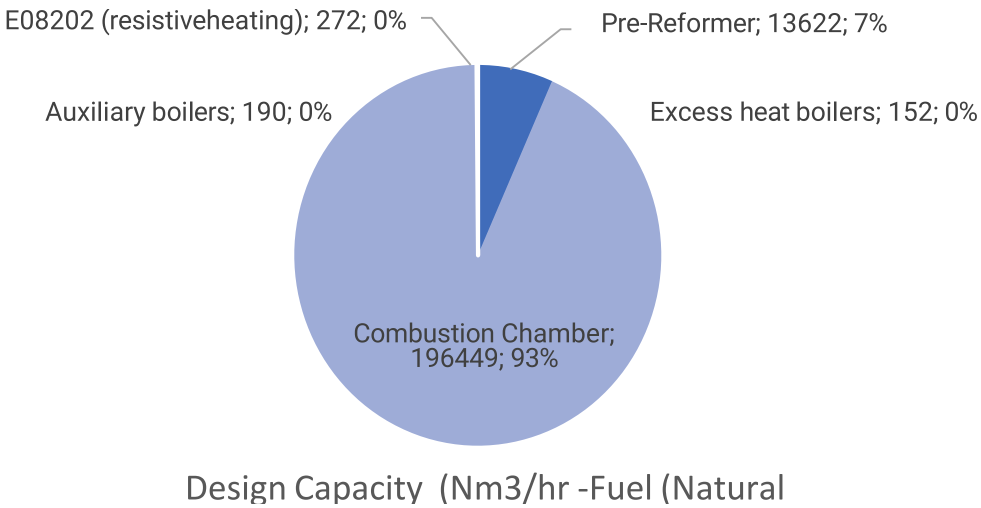


Figure 2: Distribution of Natural Gas Consumption - Based on design capacities.

1.4 Benchmarking

The International Energy Agency (IEA) showed the world's best available technology (BAT) for ammonia production is 28 GJ/t ammonia, which corresponds to a carbon footprint of 1.6 t/t ammonia[2]. This shows that the Vietnam Ammonia plant presently has a scope of increasing the energy efficiency by 14%. A study monitoring the efficiencies of 50 ammonia plants showed the best plants in each group (lower, medium, and higher capacity) have energy efficiency rates ranging from 29.5 GJ/t NH_3 to 30.6 GJ/t NH_3[3]. This again shows that the present ammonia plant has a scope for improvement when compared with other ammonia plants of around 6-7%.

Major Energy Savings Observations & Potentials

1.5 Process

a. Part of the steam produced in the ammonia plant is used for electricity production, while part of it is for process heating.

b. Natural Gas Reforming is a super energy intensive process. The impact of delta P (change of pressure) across the reformer determines the specific energy consumption of ammonia should be optimised.

c. Steam to carbon ratio also gives a good measurement of energy efficiency, which should be checked. Most of the steam reforming ammonia plants maintain S/C ratio of 3.3 to 3.5 but excess steam requires energy and later steam condensate has to be treated. Therefore, lowering the S/C ratio to 3.0 or even lower has the benefit of saving of steam and thus energy.

d. Ammonia Convertors delta T (change of temperature) across the beds has to be optimised for an optimum specific energy consumption.

e. The saturation of natural gas using hot condensates upstream of the primary reformer can be assessed. This measure leads to a reduction of steam injection demanded by steam reforming and thus the possibility of reducing steam generation of the auxiliary boiler.

f. Recovery of residual heat from the stacks – Urea Plant Scrubber

g. Monitoring of vacuum technology

[2] Ammonia Production Processes from Energy and Emissions Perspectives: A Technical Brief

[3] https://www.ajer.org/papers/v2(7)/N027116123.pdf

1.6 Equipment

Heat Exchangers

a. There is a high possibility that energy is lost due to heat exchange (exergy loss) in several heat exchangers because the heat flow in the heat exchangers is not flowing as per the 2nd law of thermo- dynamics. Therefore, a PINCH ANALYSIS makes a lot of sense for the most optimum heat

b. integration, if this has not been done in the last several years.

c. Fouling of heat exchangers is a common occurrence and should be checked.

d. In the primary reformer convection section better design (plate type) heat exchanger with a larger sur- face resulted in higher heat recovery and its utilisation needs to be explored.

Boilers

a. Preheating of boiler feed water is to be checked for optimum energy utilization.

b. The efficiency of the auxiliary and excess heat boilers should be monitored and checked with the design numbers.

c. Complete recovery of heat from flue gases of the boiler.

d. Recover waste heat from cooling systems of the boiler.

Combustion chambers

a. The efficiency of the combustion chambers should be monitored and checked with the design numbers.

b. Air to-fuel ratio can be checked in the combustion chambers for monitoring efficiency.

c. Preheating of combustion air

d. Combustion control can be checked, if it is operated manually. An automatic control system can be proposed for the combustion equipment in the auxiliary boiler and primary reformer.

Compressors

a. Monitoring of efficiency on ammonia refrigeration compressors – Driven by steam turbines

b. Air Compressor unit to be checked for energy efficiency.

c. Recovery of heat from compressor Unit.

d. Variable frequency Drive control when operating at part loads.

Wet Bulb Cooling towers

a. Fans run mostly at fixed speeds. A variable frequency drive might be necessary.

b. Check for the range, approach, and effectiveness of the cooling tower. The effectiveness should be around 75%.

c. The cycles of concentration, which is also known as concentration ratio, is a ratio of the total dissolved solids in the circulating water of a cooling tower to the total dissolved solids in the makeup water.

d. Depending on the temperature of the return water, a part load of the same can be diverted to dry cooling towers.

Pumps

a. There are huge pumps that might be installed at the site up to (3-5 MW).

b. Trimming the size of large pumps to meet the low load requirement, installing variable frequency drives (VFDs) and changing the drive of some small capacity steam-driven pumps to motor drive have improved efficiency. It has been established that smaller pumps and turbines are more efficient if driven by power than steam.

c. Air Compressor unit to be checked for energy efficiency.

d. Recovery of heat from the compressor Unit.

Rotary Drier

a. Heat losses are generally very significant in a rotary drier because of large exergetic destruction.

b. The process parameters like air flow rate, water content, drier rotation speed etc. should be monitored.

c. Studies have revealed that a dryer inclination of 1°, heat flow rate of 180 m^3/h, and dryer rotation speed at 10 rpm were the most optimal drying conditions.

Miscellaneous:

a. There would be a large number of steam traps in the plant – whose working should be checked.

b. Collection of condensates from the steam traps- for both heat and water recovery. Generally, this condensate is pure and can be used as boiler-feed water.

c. Thermal losses, caused by insulation conditions, mainly located in the reformer, furnace and main pipelines, including ammonia refrigerated pipelines can be evaluated.

d. In general, there would be a lot of low- temperature heat sources that would be going to the cooling tower. A potential heat pump solution could be explored for lifting the temperature and its probable use in the process heating. Also, potential could be explored for making electricity out of it via organic Rankine cycle or Kalina cycle.

e. Monitoring of energy and process performance indicators can be first identified, and then proper digital sensor technology could be installed for better management of energy performance.

1.7 Future Potentials

a. Green ammonia: besides the fossil-fuel based pathways currently in use, ammonia can also be synthesized using renewable electricity and water electrolysis (TRL – 7-9) and/or electro- chemical-route (TRL – 1-3) and/or biomass gasification (TRL – 6-8) to produce syngas for the Haber-Bosch process.

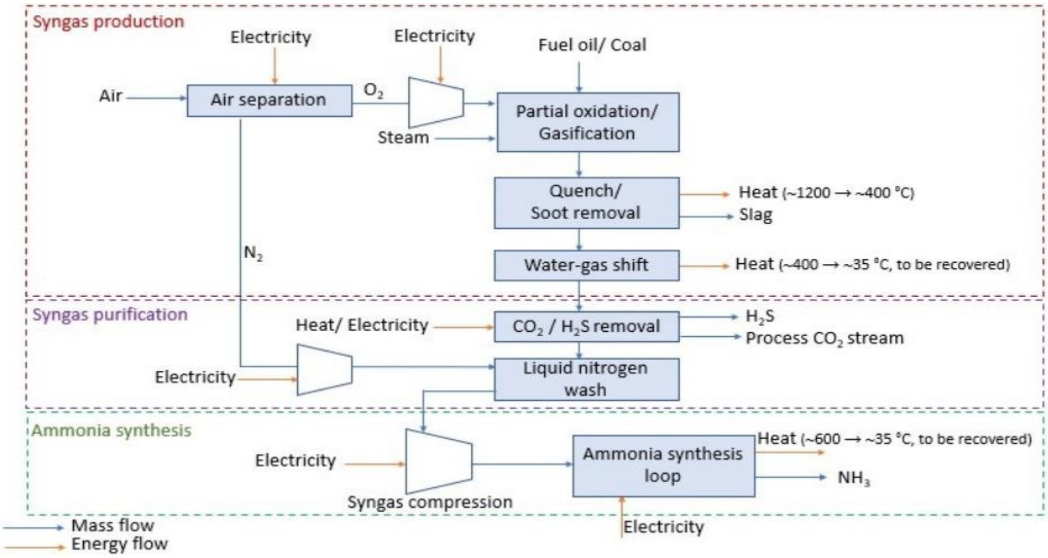
b. Potential of carbon capture solutions after the CO_2 unit.

1.8 Important information- Ammonia energy & Process

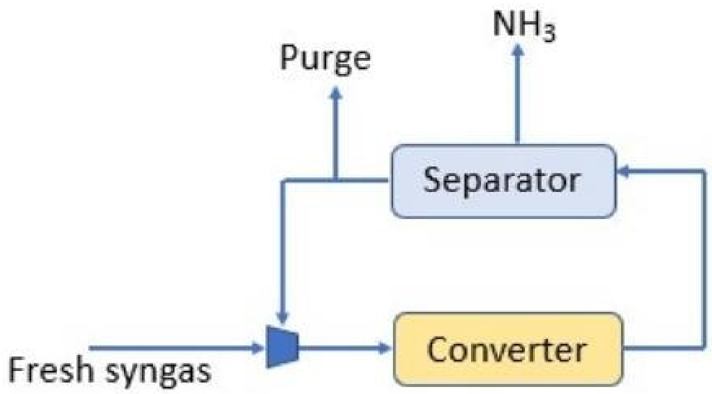
Breakdown of energy use for a typical natural gas-based ammonia plant

Technology	Natural gas GJ/t-NH_3	Heat input/output GJ/t-NH_3
Primary reformer feed	20.4 – 22.3	
Primary reformer fuel	7.2 – 9	3 – 4.5
Waste heat boiler		-5 – -6
Shift and CO_2 removal		0.8 –1.2
Synthesis loop		-2.5 – -3
Auxiliary boiler	0.3 – 3.5	-0.2 – -3
Turbines/compressors		3.9 – 6.3
Others (e.g., flare)	0.2 – 0.7	
Total	28.1 – 35.5	0

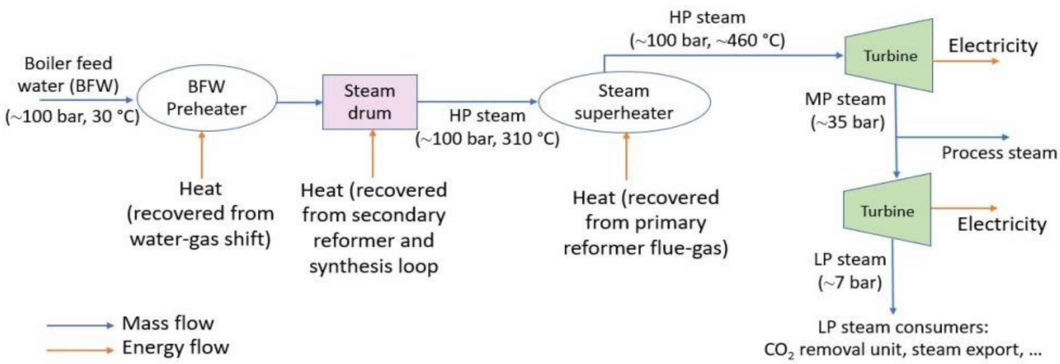
*Negative values represent net steam generation



Typical process flowsheet for partial oxidation/gasification of heavy feedstocks



Typical ammonia synthesis loop configuration



Typical steam system flowsheet of the steam reforming process

Appendix 5. Beer and beverage

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the beer and beverage sector are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

- **Mashing and wort boiling** is the process of heating water, malt, and additives to release sugars for fermentation from the malt. Subsequently, the beer is cooled to avoid contamination.
- **Pasteurization** is the process in which the finished product is gradually heated and subsequently gradually cooled to ensure a longer shelf life of the product.
- **Bottle- and keg-washing** is the process where used bottles are returned to the company and are cleaned and washed before re-filled with products.
- **Refrigeration:** Cooling is typically produced centrally at breweries and distributed to cooling consumers throughout the plant. Cooling is typically produced using ammonia chillers and distributed through either a glycol media or as ice water.
- **Clean-in-place (CIP) systems** require significant amounts of energy to heat water, as the chemicals used for cleaning are most effective at a certain temperature (between 60 – 80˚C)
- **Steam boilers and distribution** are used to deliver heat for heat requiring processes across the facilities.

- **Compressed air** is used to power the machinery of the facilities and is therefore applicable to all processes powered by heavy machinery.
- **Heat recovery systems** are applied to recover heat either at individual processes or to supply waste heat across several heat users.

Heat recovery is applicable to most of the key technologies individually, while overall systemic mapping of heat recovery is also important, as energy recovered from one technological process may be used in another.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Mashing and wort boiling	• Hot water for the mashing processes is to be heated using heat from waste heat recovery systems. • Preheating of wort to the cooking process can partly be covered via waste heat. • Heat in vapour from the wort boiling can be recovered (solution is named a Phaduco-system). • Mechanical Vapor Recompression (MVR) can be applied for the wort boiling process. • Cooling of wort after the boiling process shall not be done via cooling from compressor systems but via cold water, where heat is recovered when producing hot water for the mashing process etc.

No.	Technology	Energy efficiency measures
		• All steam piping, valves and tanks are to be insulated. • Investigate and optimize delta-T in all plate heat exchangers.
2	Pasteurization	• Regenerative heating and cooling are to be applied. • Investigate and optimize delta-T in all plate heat exchangers. • Optimal heat source is to be selected – preferably hot water partly heated via waste heat recovery systems. • Optimal cooling source is to be selected – cooling brine should only be 2°C colder than the target temperature. • Piping, valves, and the pasteurizer unit itself should be insulated.
3	Bottle and keg-washing	• Heat is to be recovered and circulated across the different zones in the washing system. • Optimal heat source is to be selected – preferably hot water partly heated via waste heat recovery systems. • Optimal cooling source is to be selected – cooling brine should only be 2°C colder than the target temperature. • Investigate and optimize delta-T in all plate heat exchangers. • Piping and valves should be insulated.

No.	Technology	Energy efficiency measures
4	Refrigeration	• See Technology Catalogue for refrigeration systems.
5	CIP-Systems	• Water reused from last rinse to first flush etc. • No "once-through" cleaning to be applied, i.e., cleaning water can be used more than once until too polluted. • Measurement of quality of cleaning water (conductivity). • Heat recovery from wastewater to fresh water. • Optimal heat source is to be selected – preferably hot water partly heated via waste heat recovery systems. • Minimization of cleaning periods.
6	Steam boilers and distribution	• See Technology Catalogue for boiler and heating systems.
7	Heat recovery	• Heat can be recovered from other areas than the beer processing equipment above, by example: - From refrigeration plants o De-superheating. o Oil cooling. - Heat from compressed air. - Heat from flue gas (boilers). - CO_2-regeneration plant. - Additional process heat sources.

Appendix 6. Brick and ceramics

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the brick and ceramics sector are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

1. **Raw materials** for the ceramics are clay, kaolin, clayey materials, feldspar and quartz. The raw materials are stored in open stockpiles, warehouses which are subdivided into boxes, large volume feeders, tempering silos, ageing silos, souring silos or dry silos

2. **Preparation of raw material** involves a number of processes depending on the product e.g. mixing, pre-drying, blending, watering, crushing, grinding and screening all to get a specific characteristic and uniform product. Some ceramic raw materials are also pre-fired, usually in rotary kilns, tunnel kilns or shaft kilns, to improve their properties.

3. **Shaping** can be done in different ways depending on the product and type of production. The shaping can be done by molding and casting techniques, afterwards applying different dewatering techniques e.g., various forms of pressing.

4. **Drying** of the ceramics is thermally done in chambers or tunnels. The temperature and speed depend of the product. But the drying is often done with hot air. Electrical (inferred or microwaves) dryers are emerging but not widely used.

5. **Surface treatment** of ceramics varies from function to decorating. The treatment can create a texture in the surface for e.g., providing non-slippery floors or it can for coloring.

6. **Firing** is a key process in the manufacture of ceramic products, as it controls many important properties of the finished ware. These include mechanical strength, abrasion resistance, dimensional stability, resistance to water and chemicals, and fire resistance. During the firing process a number of physico-chemical processes take place as the temperature increases. The temperature of the firing process varies from 800ºC (pottery) up 1,300ºC (bricks).

7. **Finishing, Sorting and pancaking** involves a final shaping by grinding, drilling, sawing and polishing. After the finishing the products are sorted and packed.

8. **Waste handling** covers both waste products from different stages but also resources as water and energy.

9. **Heat recovery systems** are applied to recover heat either at individual processes or to supply waste heat across several heat users. Heat recovery is applicable to most of the key technologies individually, while overall systemic mapping of heat recovery is also important, as energy recovered from one technological process may be used in another.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Raw material	• Avoid any watering during storages.
2	Preparation of raw material	• Pre-drying could be done by waste heat from the firing or drying process itself.
3	Drying	• Is automated drying control applied? The control should be based on humidity and temperature. • Is the thermal load distributed evenly in the dryer?
4	Firing	• Is the kiln proper sealed and well insulated? • Is the refractory material in the kiln optimal and in good conditions to minimize heat losses and downtime? • The use of high velocity burners to improve combustion efficiency and heat transfer. • Alternative fuels should be considered e.g. oxygen. • The heating curve should be optimized, with focus on reducing the rate of heating in the low temperature range (up to 400°C). • Is there an efficient combustion control on the kiln to make sure that combustion is operated at the optimal operation point? • Minimize the passage between dryer and kiln and also using the preheating zone of the kiln for finishing the drying process – avoid unnecessary cooling of the dried ware before the firing process. • A surplus of air in the kiln will increase the energy consumption. The air flow should be minimized.

No.	Technology	Energy efficiency measures
5	Waste handling	• Sludges can be reused to avoid the disposal and it substitutes water and other raw material.
6	Heat recovery	• Heat can be recovered from other areas than processing equipment above, by example. - From cooling zone in the firing process to the drying process. - Heat recovery can also be done in cogeneration with a gas engine.

Appendix 7. Cement

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the cement sector are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

1. **Storage** is the first part of the process on site where the raw materials are being gathered on site from the quarry and/or different suppliers. At the storage a pre-blending process can take place.

2. **Raw mill** is the process in which the raw materials are grinded and dried into homogeneous compositions of fine powder.

3. **Cyclone Preheater/calcinator** is a process where fine raw meal is partly calcined and preheated to approximately 850°C. Pre-heater chamber consists of series of vertical cyclones from where the raw meal passes before entering the kiln. Pre-heating chamber utilizes the emitting hot gases from kiln.

   The cyclone also acts as a dust collector.

4. **Rotary kiln** is a process where the pre-calcined raw meal (or raw meal slurry in the wet process) is dried, pre-heated, calcined and sintered to produce cement clinker.

5. **Cement mill** is a milling process where the clinker, gypsum and other additives are milled into the final cement.

6. **Fuel and combustion systems:** the primary fuels are used in the rotary kiln, which uses coal, petcoke, natural gas and waste. Coal and petcoke are crushed in a mill to get a fineness that secures an optimal combustion when used in the rotary kiln.

7. **Cooling systems** are used to cool the cement clinker after the rotary kiln. Cooling of the clinker heats up air which is often used for preheating purposes.

8. **Compressed air** is used to power the machinery of the facilities and is therefore applicable to all processes powered by heavy machinery.

9. **Generation of electricity** is often done in an ORC power plant utilizing the waste heat leaving the cyclones.

10. **Heat recovery systems** are applied to recover heat either at individual processes or to supply waste heat across several heat users.

Heat recovery is applicable to most of the key technologies individually, while overall systemic mapping of heat recovery is also important, as energy recovered from one technological process may be used in another.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Storage	• Optimizing the storage décor, to avoid any redundant handling of raw material. • Covering raw material, to avoid an increase of the moisture content, which must be removed afterwards.

No.	Technology	Energy efficiency measures
		• Optimizing transport systems e.g. using gravity conveyer, with the potential for electricity production. • Optimizing transports control to minimizing standby consumption and operating at optimal speed.
2	Raw mill	• Heat recovery on raw mill can be made by utilizing the hot exhaust air for preheating the raw material. See also item number 10 for heat recovery. • Milling should be controlled based on the content of the air and raw material. The energy performance can be optimized by adjusting the feed, grinding pressure, air flow, as well a rotary and table speed. • Is the drying control designed in a way making sure that over or under drying does not take place? The drying should be controlled by the moisture content in the raw material and by the moisture content of the drying air. • Several new emerging grinding mill technologies are under development, which all reduces the specific energy consumption: - Contact-free grinding systems. - Ultrasonic comminution. - High voltage power pulse fragmentation. - Low temperature comminution.
3	Cyclone preheater and calcinator	• The number of cyclones has a direct influence on the system efficiency. The financial optimal number is 4-6 cyclones. The moisture content also has an influence on the number of cyclones.

No.	Technology	Energy efficiency measures
		• Insulation of air ducts at the cyclones and calcinator (also in the Kiln) can reduce thermal losses and increase efficiency.
4	Rotary kiln	• Improving the brick insulation of the kiln. Better brick material will reduce thermal losses, need for cooling, and increase the production time. • Making sure the refractory lining is not allowing significant heat losses. To identify refractory issues, routine inspections should be conducted, checking for temperature hotspots. • Improving the combustion by controlling the oxygen, fuel and moisture content. • The heat from cooling the kiln should be recovered elsewhere in the system such as preheating air for combustion. • Optimizing process controls can reduce heat consumption, improve clinker quality, and increase the lifetime of the equipment. Relevant process parameters include homogenization of raw material, uniform coal dosing and optimal operation of the cooler. • Introducing a gas bypass can reduce the build-up of different substances originating from alternative fuels. The build-up reduces the performance of the kiln, calcinatory and preheater. A gas bypass that removes a part of the process gas can secure stable conditions.
5	Cement mill	• Reducing the clinker content by adding fillers like, sand, slag, limestone, fly ash and pozzolana will reduce the specific energy consumption.

No.	Technology	Energy efficiency measures
6	Fuel and combustion system	• The characteristic of the fuel has an influence of the specific consumption e.g. the moisture content of the lignite influences the energy efficiency of the combustion process. To improve the combustion process, the lignite could be pre-dried before use. • See Technology Catalogue for boiler and heating systems.
7	Cooling system	• Excess heat from the Clinker cooling can be recovered – see item number 10. • The air intake for the clinker cooling must be taken from a "cold" location and not from a hot environment to increase the efficiency of the clinker cooler. • The cooling air flow must be controlled according to the cooling demand and the control must not be done by dampers it should be done by a combination of on/off and frequency control. • Use cooler grate plates to provide a more uniform cooling distribution. • The cooling air must be controlled to the individual sections.
8	Compressed air	• See Technology Catalogue for compressed air systems.
9	Generation of electricity	• Electricity can be generated on the waste heat from the preheater by an ORC (Organic Rankine Cycle). The ORC has a power efficiency in the range of 10-20%. • Alternative methods of producing electricity locally should be considered by:

No.	Technology	Energy efficiency measures
		- Waste incineration. - Gas motors. - Combined heat and power. The methods must be evaluated against the electricity costs from the public grid.
10	Heat recovery	• Large quantities of waste heat are often available from the clinker cooler and preheater. • The hot air can be used for: - Combustion air both in the calcinatory and in the kiln. - Drying of raw material e.g. pozzolan. - Preheating for the raw mill. - Drying of fuel. - Electricity production by ORC. - Producing district heat for external usages.

Appendix 8. Mechanical industry

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the mechanics industry are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

- **Heating** is the process of heating the billets before cutting to soften them, after cutting for incubation and after machining for hardening. Focusing idling and heat losses is very important.

- **Cutting, forging, and machining** is the process of cutting rebar into billets, shaping the billets into bearings and subsequent machining and polishing. The focus should be on efficiency of motors.

- **Painting and galvanizing** are the surface treatment of the product to create an anti-rust coating by dipping it into a molten zinc solution.

- **Transforming** is the transforming of the electricity to the voltage and frequency used in furnace. Transformation losses can be reduced significantly when comparing old equipment with BAT.

Auxiliary equipment:

- **Motors** are required for many applications in the mechanics industry like the rolling mill and general for pumps, fans etc.

- **Pumps** are required in hydraulic systems, water circulation, process air and gases.

- **Compressors** are required for pneumatics air supply, air separation processes, which use very large compressor motors.

- **Fans** are required for ventilation, extraction systems and material handling.

- **Water treatment** is required for reuse of water from cooling, descaling and dust scrubbing.

Below, important energy efficiency measures for each of these areas are described.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Heating	• The billet furnace can be heated by electricity or fuel; and it can be operated batch wise or continuously. The main energy losses to consider are: - Electricity transformation losses. - Radiation losses. - Losses due to openings. • Is the furnace and lid construction well insulated? • Is idle time and alloy shifting reduced as much as possible?

No.	Technology	Energy efficiency measures
		• Is the heat from the exhaust gasses reused? • Is the furnace combustion process optimized with the correct excess air ratio?
2	Cutting, forging, and machining	• Are motors highly efficient and with optimized drives? • Are VSD's and the control system capable of handling quickly changing loads and wide torque ranges in an energy efficient way? • W.A.G.E.S. (water, air, gases, electricity, steam) utilities represent a large share of energy consumption. - Is the cooling water system efficient? Can the water reuse be increased? - Are the descaling pumps and water circulation pumps efficient? - Are furnace combustion and fume extraction fans efficient?
3	Painting and galvanizing	• Is the temperature of the zinc bath controlled to minimize energy consumption and heat loss? • Is idle time reduced as much as possible? • Are zinc elements to zinc bath sized for an efficient melting process?
4	Transforming	• Are transformer losses higher than BAT?
5	Auxiliary equipment	• Are VSD's used where relevant? • Is motor efficiency similar to IE4 or IE5 requirements?

No.	Technology	Energy efficiency measures
		• Are pumps and fans designed for the actual working conditions and is the total pump / fan efficiency high? • Are hydraulic systems designed to minimize losses during idle operation? • Are compressor systems designed to be energy efficient in the actual working range?
6	Heat recovery	• Heat can be recovered from furnaces, exhaust air, hydraulic systems, compressed air, cooling water, and generators. With very high temperatures the potential for heat recovery is large, but the challenge is to find good usage. - Assessment of internal possibilities. - Assessment of possible export to neighboring enterprises.
7	Water reuse	• Increasing water reuse will also have an impact on energy consumption. Is a high percentage of the water cleaned, cooled, and returned to the source? • Are the water flows controlled according to the actual need? • Is unnecessary pumping prevented?

Appendix 9. Paper

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the pulp and paper sector are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

1. **Raw material** for paper making varies depending on the type of paper produced. However, the main component in paper is cellulose fibers. The prime source of cellulose is trees, especially pine, spruce, birch, and eucalyptus. Modern papermaking uses both virgin and recycled fibers, depending on the requirements of the final products.

2. **Transport of raw material** covers in principle both internal and external transport of raw material, depending on the origin of the material and boundary of the specific site. External transport covers transport from where the raw material is collected/made to the site, and the internal transport covers the transportation from the onsite storages to the pretreatment.

3. **Storage** is the process steps in between the incoming raw material, pretreatment, pulping, drying and final product. The storages are binding each process steps together and therefore the efficiency of the storages have a direct effect on the capacity and efficiency of each process steps.

4. **Pretreatment** of the raw material depends on the type of material. The pretreatment can consist of sorting, washing, debarking, chorusing, drying of virgin and fibers.

5. **Pulping** is a process where the fiber structure of the raw material is broken down into a liquid solution. There are several pulping methods, but the most common are chemical and mechanical pulping. Chemical pulping separates the fibers into the raw material by dissolving the lignin bonds that hold these fibers together, often at elevated temperatures and pressures. Mechanical pulp is made by subjecting the raw material to an abrading action, either by pressing the wood against a revolving grinding stone or by passing the raw material through a mill.

   The pulping can also involve a bleaching process to make with paper.

   Some factories have their own pulping process while others source in pulp from pulping factories and then only re-pulp as a part of the paper making process.

6. **Papermaking** process can be divided into the following areas: wet end, wet press, drying section end and operational finishing and coating. The purpose of the papermaking process is to remove water by pressing, draining and evaporation. The dewatering is done by various gravity, vacuum, pressing, steam, and ventilation systems. This part of the paper process is the most energy intensive part of the process, being most energy intensive towards the dry end of the paper process.

7. **Steam boilers and distribution systems** are used to deliver heat for heat requiring processes across the facilities. An integrated part of the steam systems, co-generation and waste incineration systems are integrated to produce electricity and contribute to waste disposal respectively.

8. **Compressed air** is used to power the machinery of the facilities and is therefore applicable to all processes powered by heavy machinery.

9. **Reuse of raw material**: there are several options for reusing raw material in the process. The reuse of raw material will have a positive effect on the use of new raw material, plant efficiency and load on the waste treatment systems and plants.

10. **Heat recovery systems** are applied to recover heat either at individual processes or to supply waste heat across several heat users.

11. **Water treatment systems**: A large part of the paper making process involves water as a solvent, homogenization, and transportation agent. To support the water systems, fresh water, wastewater and water recovery systems are an integrated part of the paper making process.

12. **Electrical systems:** Electrical systems serve to support the paper making process. The main components of the electrical systems are motors, pumps, air compressors, vacuum systems, hydraulic systems and lighting systems.

Heat recovery is applicable to most of the key technologies individually, while overall systemic mapping of heat recovery is also important, as energy recovered from one technological process may be used in another.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Raw material	• Balancing the input of raw material to the production capacity (this goes both for virgin and recycled) to reduce bottlenecks that have a negative influence on the production KPIs. • Are there efficient cleaning and screening procedures, to ensure high quality and to avoid losses?
2	Transport systems	• Are high-efficient transport systems used e.g. belts or gravity conveyers as an alternative to pneumatic systems?
3	Storage	• Balancing the input of raw material to the production capacity (this goes both for virgin and recycled) to reduce bottlenecks that have a negative influence on the production KPIs. • Are the storages facilities organized to avoid any unnecessary handling procedures?

No.	Technology	Energy efficiency measures
4	Pretreatment	• Is the water recycled from the washing process? • Are efficient debarking and crushing methods used? • Are the chips being conditioned for improving the pulping process?
5	Pulping	• Are pulping aids used in the pulping process to increase liquor penetration and promote more even cooking? • Are raw materials, water, chemicals and energy recovered in all steps of the process? • Are efficient mixing methods applied?
6	Papermaking	• Is the water removal process optimized with the focus of removing water upstream in the process? • Are the process steps monitored to ensure that each step continuously performs optimally? • Is a steam box used for unifying the paper humidity and draining? • Is the hood of the dryer tight? • Is the dew point that levels in paper drying hoods measured and controlled to optimize the drying process? • Is heat recovered internally from the high-pressure dryers to the low-pressure dryers (cascade system)? • Is the drying controlled to make sure that under and over drying is prevented?

No.	Technology	Energy efficiency measures
		• Are all precautions taken to prevent downtime? Downtime on the paper machine increases the specific energy consumption and reduces the throughput.
7	Steam boilers and distribution	• See Technology Catalogue for boiler and heating systems. • Is solid waste being used as an energy source for producing steam?
8	Compressed air	• See Technology Catalogue for compressed air systems.
9	Reuse of raw material	• Is water (and temperature) reused from the vacuum system, or does it end up in the wastewater treatment? • Treated wastewater can be used for seals and water hose instead of fresh water. • Is the retention share high enough? Higher retention will have a positive impact on the raw material cost and wastewater treatment? • Are the steam and process condensate being recovered and reused? • Are the fibers and fines captured (e.g., using a DAF unit), to prevent ending up in the wastewater treatment?
10	Heat recovery	• Heat can be recovered from various parts of the process and reused on the process itself or in a recovery system serving other processes. • In the papermaking process there are a number of heat recovery solutions that can be or are applied to the processes. When optimizing the heat

No.	Technology	Energy efficiency measures
		recovery systems some of the following questions can be asked: - Is the recovery system in balance? - Does the heat recovery design and control support the full recovery potential? - Can the surplus heat be recovered for other purposes? • Some of the most common heat recovery solutions in the paper making process are: - Reuse of flash steam. - Reuse of exhaust air for the process itself or for other heat demands e.g. pulp water heating.
11	Water treatment	• In the water and wastewater treatment processes a long range of electrical components are used – i.e., electrical systems. • The maintenance level of filters, blowers, agitators etc. has a significant effect on energy consumption. • Speed, time and frequency of the operation of the different parts of the systems also have a significant impact on energy consumption, e.g. is the air blower adjusted to the actual demand or is it running at full speed? • In the wastewater treatment process the sludge contains biological material which can be utilized to produce bio methane. Bio methane can be used as a contribution to the thermal energy supply system.

No.	Technology	Energy efficiency measures
12	Electrical systems	• The paper making process involves several electrical components and systems, which can be optimized, considering: - Are motors controlled by inverters instead of gears and belts? - Are systems operating without products or activities? e.g. conveyers without products, lighting without human activities. - Is highly efficient equipment used? e.g. motors, pumps, light, etc. - Is internal transport minimized? - Are switchboards maintained? Maintenance minimizes thermal losses and the risk of failure.

Appendix 10. Power generation

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the power generation industry are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

- **Combustion** is the transformation of energy from fuel to steam.
- **Generation** is the transformation of energy from steam to electricity.
- **Insulation:** all surfaces of equipment, pipes and valves must be at a low temperature.
- **Water:** good water quality is essential for energy efficient operation.

Auxiliary equipment:

- **Motors** are required for many applications in power generation industry like pumps, fans etc.
- **Fans** are required to establish fluid bed circulation and for ventilation and extraction system.
- **Pumps** are required in hydraulic systems, water circulation, etc.
- **Compressed air** is required for machine operation.

Below, important energy efficiency measures for each of these areas are described.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Combustion	• Is the plant running with the fuel quality that it is designed for and is it operated according to the original parameters? • Does the combustion process achieve full combustion of the fuel? • Is the combustion air monitored and controlled to achieve proper combustion? • Is combustion stable? Are there fluctuations in steam temperature and/or pressure? • Is the combustion system and fuel feeding system maintained regularly to avoid build-up of residues in the combustion chambers? • Is the burning control capable of controlling the temperature so slag adhesion is avoided? • Is an efficient system for removing residues under operation installed? • What is the oxygen percentage (O_2) of the flue gas?

No.	Technology	Energy efficiency measures
		• What is the temperature of the flue gas out of the chimney? • Is the combustion system designed for condensation and if so, is condensation achieved? • Are de-NOx and SOx removal included?
2	Generation	• Generation efficiency, is the share of electricity output maximized? (min. 45% for super-critical technology) • Is the steam pressure utilized for power generation to as low as possible? • Is the energy in the turbine exhaust steam utilized? • Can water droplets be avoided? • Is the vacuum in the condenser maintained within the designed parameters?
3	Insulation	• Are all surfaces of the combustion system and related ducts insulated properly? • Are all pipes, valves and fittings properly insulated?
4	Water	• Is the feed water quality as high as possible to lower the maintenance on the turbine? • Is the loss of water / condensate minimized?
5	Auxiliary equipment	• Are VSD’s used where relevant? • Is motor efficiency similar to IE4 or IE5 requirements? • Are pumps and fans designed for the actual working conditions and is the total pump / fan efficiency high?

No.	Technology	Energy efficiency measures
		• Are compressor systems designed to be energy efficient in the actual working range?
6	Fans	• Do fans have high efficiency? • Are VSD’s used and operation optimized according to variation in loads?
7	Compressed air	• Is the electricity consumption per m^3 low? • Is compressor set-up optimal with a mixture of direct drive and VSD control? • Is the heat reused from the compressors?
8	Heat recovery	• Heat can be recovered from flue gas, compressors, cooling systems and reused to a higher degree? The potential in heat recovery is large, but the challenge is to find good usage. - Assessment of internal possibilities. - Assessment of possible export to neighboring enterprises.
9	Cooling water system	• Is the circulating water pump system operating optimally?
10	Fuel handling system (coal, fuel oil, gas)	• Is the fuel handling system operating optimally? • Do coal mills operate effectively (coal fineness, air leakage, power consumption, etc.)?

Appendix 11. Seafood industry

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the seafood industry are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

- **Freezer** is the process of freezing the seafood products immediately after cleaning and processing them, often including ice-glazing.
- **Ice production** is the process of producing ice for packaging seafood products.
- **Air conditioning** is the process of keeping a certain low temperature in the production areas so as the seafood products can be kept at a low temperature during all stages of production.
- **Cold storage** is the process of storing raw materials and final products at a low temperature to maintain a high product quality.
- **Chilled water** is the process of producing cold water for cleaning and washing of seafood products.
- **Refrigeration:** Cooling is typically produced in a number of cooling plants matching specific temperature requirements in the production.
- **Compressed air** is used to power the machinery of the facilities and is therefore applicable to all processes powered by heavy machinery.

- **Heat recovery systems** are applied to recover heat from central refrigeration plants to supply waste heat across to any heat user.

Below, important energy efficiency measures for each of these areas are described.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Freezers	• Is the right set-point for air temperature applied in the freezer? – according to product type (fat fish vs. lean fish), belt speed and target temperature? • Is a matching evaporator temperature applied in the refrigeration plant supplying brine/glycol etc. to the freezer? • Are 2-stage evaporators used to supply the freezer with cooling in matching temperature zones of the freezer? • Are inlet and outlet to the freezers properly designed not allowing ambient and humid air to enter the freezer? • Are doors to freezers (blast freezers) closed while freezing and the freezers loaded/on-loaded fast? • Is a proper de-frosting procedure applied for the freezer and with a proper sequence?

No.	Technology	Energy efficiency measures
		• Can fan speed in freezers be reduced (VSD) to match the actual products freezed? • Is the right freezer used for the right purpose? – is a freezer for large products by example used for small products?
2	Ice production	• Is cooling for the ice production produced at a separate cooling plant with an evaporator temperature matching the temperature demands in the ice machine? • Is the amount of ice produced measured on a daily basis or is production exceeding the demand for ice in production?
3	Air conditioning	• Are the set-points for inlet air to production areas properly set according to the requirements in the room? • Are the set-point for inlet air adjusted outside working hours not to keep the premises at too low temperature? • Are the production areas properly closed with doors, fast gates and curtains so that outside air is prevented from entering the rooms? • Is cooling for air conditioning produced at a separate cooling plant with an evaporator temperature matching the temperature demands in the production areas?
4	Cold storage	• Is the cold storage installation properly insulated? • Are doors sealed so as no humidity enters the cold storage? – or are fast curtains used to avoid ambient air to enter the rooms?

<table>
<tr><th>No.</th><th>Technology</th><th>Energy efficiency measures</th></tr>
<tr><td></td><td></td><td>Is a proper de-frosting procedure applied for the evaporators in the cold storage rooms and with a proper sequence?
Is low energy lighting (LED) applied in the storage rooms?
Is cooling for the cold storage rooms produced at a separate cooling plant with an evaporator temperature matching the temperature demands in the rooms?</td></tr>
<tr><td>5</td><td>Chilled water</td><td>Is chilled water produced by cooling of water (and not as water mixed with ice)?
Is cooling for chilled water produced at a separate cooling plant with an evaporator temperature matching the temperature demands of the chilled water?</td></tr>
<tr><td>6</td><td>Refrigeration</td><td>See Technology Catalogue for refrigeration systems.
For freezing plants special attention shall be paid to:
- Air purging to remove air from condensers etc.
- Water purging to remove water from refrigerant.</td></tr>
<tr><td>7</td><td>Compressed air</td><td>See Technology Catalogue for compressed air systems.</td></tr>
<tr><td>8</td><td>Heat recovery</td><td>Heat can be recovered from refrigeration plants
- De-superheating.</td></tr>
</table>

No.	Technology	Energy efficiency measures
		- Oil cooling. • Heat can also be recovered from compressed air plants. • Any hot water demand can be covered this way and not with a boiler.

Appendix 12. Steel industry

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the steel industry are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

- **Preparation** is the process of preparation of the recycled items before melting. It is important to have a good filling of the furnace, and no items must prevent the lid from closing.

- **Transforming** is the transforming of the electricity to the voltage and frequency used in furnace. Transformation losses can be reduced significantly comparing old equipment with BAT.

- **Melting & casting** is the process of melting the scrap and iron, transport of the melt and casting of billets. Focusing on reducing idling is very important.

- **Rolling mill** is the process of shaping billets into finish profiles. Due to the high loads and temperatures that these applications handle, they are very energy intensive.

Auxiliary equipment:

- **Motors** are required for many applications in the steel industry like the rolling mill and general for pumps, fans etc.

- **Pumps** are required in hydraulic systems, water circulation, process air and gases.

- **Compressors** are required for pneumatics air supply, air separation processes, which use very large compressor motors.

- **Fans** are required for ventilation, extraction systems and material handling.

- **Water treatment** is required for reuse of water from cooling, descaling and dust scrubbing.

Below, important energy efficiency measures for each of these areas are described.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

No.	Technology	Energy efficiency measures
1	Preparation	• Are scrap items prepared for an efficient melting process by cutting into pieces? • Can a shredder be used to minimize the size of raw materials so as a smooth and efficient feeding of furnaces is achieved?
2	Transforming	• Are transformer losses higher than BAT?
3	Melting & casting	• Are the melting furnaces operated with electricity consumption similar to international benchmarks? • Can the power unit perform an uninterrupted melting procedure and a precise temperature control for holding?

No.	Technology	Energy efficiency measures
		• Can the melting control system manage preheating, sintering, melting, and holding in an energy efficient way? • Is the furnace and lid construction well insulated? • Is idle time and alloy shifting reduced as much as possible? • Are hydraulic support systems operated efficiently during on-loaded periods and when idling?
4	Pressure Recovery Turbine	• Pressure Recovery Turbine for Power Generation at the Top of the Blast Furnace • Can a turbine be used in the blast furnace of a steel factory, with the function of controlling pressure at the top of the blast furnace and also generating electricity by rotating the turbine with blast furnace gas generated at the furnace?
5	Rolling mill	• The rolling steel reheating furnace can be electric or with combustion and batch or continuous. In all cases is the question; is the total efficiency high? - Efficient energy transformation. - Radiation losses. - Losses due to openings. • Are roller and roller table motors highly efficient and with optimized drives? • Are hydraulic support systems operated efficiently during on-loaded periods and when idling? – can DC-motors be applied?

No.	Technology	Energy efficiency measures
		• Are VSD's and the control system capable of handling quickly changing loads and wide torque ranges in an energy efficient way? • W.A.G.E.S. (water, air, gases, electricity, steam) utilities represent a large share of energy consumption. - Is the cooling water system efficient? Can the water reuse be increased? - Are the descaling pumps and water circulation pumps efficient? - Are furnace combustion and fume extraction fans efficient?
6	Auxiliary equipment	• Are VSD's used where relevant? • Is motor efficiency similar to IE4 or IE5 requirements? • Are pumps and fans designed for the actual working conditions and is the total pump / fan efficiency high? • Are compressor systems designed to be energy efficient in the actual working range?
7	Heat recovery	• Heat can be recovered from furnaces, exhaust air, hydraulic systems, cooling water. With very high temperatures the potential for heat recovery is large, but the challenge is to find good usage. - Assessment of internal possibilities. - Assessment of possible export to neighboring enterprises.

No.	Technology	Energy efficiency measures
8	Water reuse	• Increasing water reuse will also have an impact on the energy consumption. Is a high percentage of the water cleaned, cooled, and returned to the source? • Are the water flows controlled according to the actual need? • Is unnecessary pumping prevented?

Appendix 13. Textile

Sector Specific Annex to Audit Guideline under the EE Incentive Scheme for energy intensive industries in Vietnam

1 Introduction

The purpose of this annex is to secure that the most important opportunities for energy efficiency improvements in the textile sector are investigated.

The annex is prepared to provide more sector-specific guidance than what is presented in the general energy audit guideline prepared under the Danish/Vietnamese cooperation.

As such, the guideline describes the most important focus areas within the key technologies of:

1. The **Harvesting, Spinning and Yarn** process consists of several steps, harvesting, ginning/cleaning, carding/formation, spinning and winding. The raw material for the yarn process can be virgin/synthetic cotton or recycled fibers. The spinning process takes the textile fibers and filaments and makes then into yarn. The processes are primarily mechanical processes driven by electricity – some cleaning process include thermal input for heating water.

2. The **Weaving** process is a process where two distinct sets of yarns or threads are interlaced at right angles to form a fabric or cloth. Alternative to the weaving knitting, tufting, needle-felting etc. Printing is an alternative to the weaving process. The weaving process is a mechanical process driven by electricity.

3. **Dyeing** of textiles is a process in which color is transferred to a finished textile or textile material (like fibers and yarns) to add permanent and long-lasting color. The dying permanent can both by natural or synthetic. The dyeing process depends very much on the raw material and application. The dying process is both mechanical and thermal (heating up water for dying and bleaching).

4. **Washing** is normally carried out in hot water (40-100 °C) in the presence of a wetting agent and a detergent. The detergent emulsifies the mineral oils and disperses the undissolved pigments. The choice of the surfactants may also vary depending on the type of fibre. Mixtures of anionic and non-ionic surfactants are commonly used. An important factor in the selection of a surfactant is its effectiveness in strong alkaline conditions. Washing always involves a final rinsing step to remove the emulsified impurities.

   Dry cleaning is an alternative to using a wetting agent.

5. **Drying** is necessary to eliminate or reduce the water content of the fibres, yarns and fabrics following wet processes. Drying is highly energy intensive. Drying is often done both mechanical and thermal.

   The thermal removal of water is done by evaporation. Heat for the evaporation can be transferred by:

   - Convection
   - Inferred radiation
   - Direct contact
   - Radio frequency

6. **Cutting, sewing and ironing** is a part of transforming the textile into readymade garments by cutting them into shapes and joining the shapes together to form the final garments. The joining can be done by sewing with needle and thread or by other means e.g. “gluing”.

7. From the garments process there are several **Wastewater** streams, mainly from dying, washing and drying process.

8. **Steam or hot water boilers and distribution** are used to convert energy and distribute the energy for specific processes across the facilities.

9. **Compressed air** is used to power the machinery of the facilities and is therefore applicable to all processes powered by heavy machinery.

10. **Heat recovery systems** are applied to recover heat either at individual processes or to supply waste heat across several heat users. Heat recovery can be applicable to some of the key technologies individually, while overall

systemic mapping of heat recovery is also important, as energy recovered from one process may be used in another.

11. **Electrical systems** are applied to all parts of the production and for a long range of different supporting functions, where some of them are mentioned in the above section, e.g. compressed air. Besides the systems mentioned then there at motors, pumps, fans/ventilation, and lighting that must also be addressed.

2 Technology review compared with Best Current Practice

In the table below, best practice energy efficiency projects are listed for each of the technologies above. The energy audit should consider the possible viability of each of the measures in the specific context.

The energy audit report should document how these potential measures have been considered. For each measure it should be stated whether it is practically relevant for the specific enterprise. If it could be relevant, the report must make a pre-assessment of the technical and financial viability.

In the textile production several production methods are applied depending on the specific product. Therefore, it must be emphasized that the recommendations below do not apply for all the process steps.

No.	Technology	Energy efficiency measures
1	Harvesting, Spinning and Yarn	• Electricity is the main energy consumer in this process step. Therefore, the recommendations made with regard to Electrical systems (number 11) also apply for this step. • There are several methods applied for these processes. Ther energy efficiency primarily depends on the production type, technology and maintenance. Some examples are: - Using optimal spindle oil in the ring frame. - Using light spindles. - Optimizing ring diameter.

No.	Technology	Energy efficiency measures
		• The yarn polisher used thermal energy – evaluating the best source of energy (steam/electricity). • Poor waste (e.g. fluff) management impacts production quality and therefore the specific consumption. By removing waste (machine cleaning and in process (OHTC) incurs best fabric quality. • Overhead Traveling cleaner (OHTC) can be optimized both in terms of controlling time and demand by sensors, securing that cleaning is adjusted to the demand.
2	Weaving	• Electricity is the main energy consumer in the weaving process. Therefor the recommendations made with regard to electrical systems (number 11) also apply for the weaving process. • The weaving machines themselves account for 50-60% of the consumption in the weaving process, the remaining part involves dehumidifier, compressed air and lighting. • The dehumidifier can be optimized by proper control by VFD, that controls the spray nozzles and fans.
3	Dyeing	• Dying directly on wet fabric, thus avoiding the intermediate dyeing step. • Securing even and rapid absorption of water, by total removal of cotton seed husks, and - the ability to absorb dyes and chemicals uniformly. This will reduce product losses.

No.	Technology	Energy efficiency measures
		• Dyeing water can be preheated from the process itself or by other surplus heat sources – to secure timing then buffer systems could be introduced.
4	Washing	• Washing water can be preheated from the process itself or by other surplus heat sources – to secure timing then buffer systems could be introduced. • Reusing washing water directly or by first filtering in membrane systems, thus recovering both heat and washing enzymes.
5	Drying	• Use of mechanical dewatering to minimize thermal dewatering. • Controlling the drying to make sure that the textile is not dried below their natural moister content. • Optimizing the drying control by controlling based on: - Humidity and temperature of the inlet air. - Temperature of the textile and air in the dryer. - Humidity and temperature of the exhaust air. • Considering alternative drying methods e.g. microwave or radio frequency dryers. • Preheating the drying air e.g. waste heat from the dryer itself or other waste heat sources. • Flash steam recovery could be considered on inline drying processes. • Vapor recovery can also be considered in the inline drying process, where the vapor from one step is used to dry other process steps.

No.	Technology	Energy efficiency measures
6	Cutting, sewing and ironing	• Continuous running sewing machines can be replaced by servo motor-based machines that only operate when sewing takes place. • Blowing through losses in steam ironing can cause flash problems. This can be solved by better system control and maintenance.
7	Wastewater	• Is the wastewater properly sized – no bypass. • Are the air blowers properly controlled? • Are the blowers used the most efficient. E.g. using turbo blowers. • Is there a potential for producing biogas on the wastewater?
8	Steam boilers and distribution	• See Technology Catalogue for boiler and heating systems. Here are some additional recommendations: • Heat recovery on exhaust pipe from the boiler. The recovered heat can be used for: - Air preheating. - Feed and makeup water preheating. - Other hot water demands. • Introducing combustion control to reduce the thermal losses. This can be done by automated control or by periodic trimming. • Improving thermal insulation in boilers, pipes, valves, etc. • Reducing starts and stops to reduce blow through.

No.	Technology	Energy efficiency measures
		• Reducing convective losses during standby by installing a damper in the exhaust pipe. • Improving blow down control by conductivity control instead of manual or timer-based blow down. The need for blow- down can also be reduced by improving the makeup water quality. • Heat can be recovered from blow-down and used for heating e.g. the makeup water. • Reducing the condensate losses by improving insulation and steam traps and optimizing the condensate return pipe.
9	Compressed air	• See Technology Catalogue for compressed air systems. Here are some additional recommendations: • Challenging the pressure level – 7-8% saving per bar reduced. • Investigating if the compressed air system can be operated at different pressure levels and/or if any of the users can be decentralized. • Optimizing compressor control (master/slave in the case of several compressors). • Optimizing the compressed air buffer (if there is any). • Recovering surplus heat. • Evaluating alternative methods to compressed air for single users.

No.	Technology	Energy efficiency measures
		• Having routines for leak detection and repair (consumption outside production is a good indication of the magnitude of leakages).
10	Heat recovery	• Heat can be recovered from several areas: - Heat from compressed air. - Heat from flue gas (boilers). - Dyeing process. - Washing process. - Steaming process. - Wastewater plant. - Other specific heat sources can be present. In all cases the surplus heat can either be reused on the process itself or used across the processes. The recovered heat can be used for low temperature purposes or upgraded by heat pumps for higher temperature processes. To balance heat demand and supply then buffer systems can be considered to improve the utilization of surplus heat.
11	Electrical systems	• Using energy efficient light e.g. LED. • Introducing light control systems e.g. sectioning, motion sensors, timers, daylight control etc. • Using highly efficient motors. • Replacing all mechanical drives with variable speed drives (VSD).

Appendix 14. Energy mapping user guide

Under the Energy Efficiency Incentive Scheme for Energy Intensive Industries in Vietnam

1 Introduction

A careful mapping and understanding of the energy usage in an industrial company is a crucial baseline in project development.

However, in numerous international projects it has been observed that energy auditors face severe challenges in such important work, partly because the work is not very well structured and well defined in terms of outputs, and partly because energy auditors are reluctant to build conclusions on other than detailed and precisely measured data.

With this background, this guide aims to establish a well-defined mapping methodology, that delivers clear outputs phase by phase and supports and instructs energy auditors on specific activities to be carried out.

The guide consists of an energy mapping template in Excel format which is accompanied by the present user guide which describes how to set-up such a mapping in practice and how to utilize the results for developing projects. The data and process flow within the energy mapping template are only for illustrative purposes and do not represent actual data from an actual production site.

Figure 1 shows a flow chart of the overall energy mapping process which can be used to keep track of the steps in the energy mapping process. It also highlights the iterative process of setting up the energy balance, where the mapping degree is used as an indicator for when to move on to analyse the results. This simplified approach can save auditors a lot of time on carrying out many very time-consuming measuring programs on all equipment and instead focuses on first getting a full overview of the actual energy demands based on available information and assumptions. This enables the auditor to prioritize the more time-consuming analyses and measuring programs on the processes and equipment that is initially shown to have the greatest saving potentials. Having set up energy- and mass balances for a process will often also be a necessary step for identifying which parameters to measure.

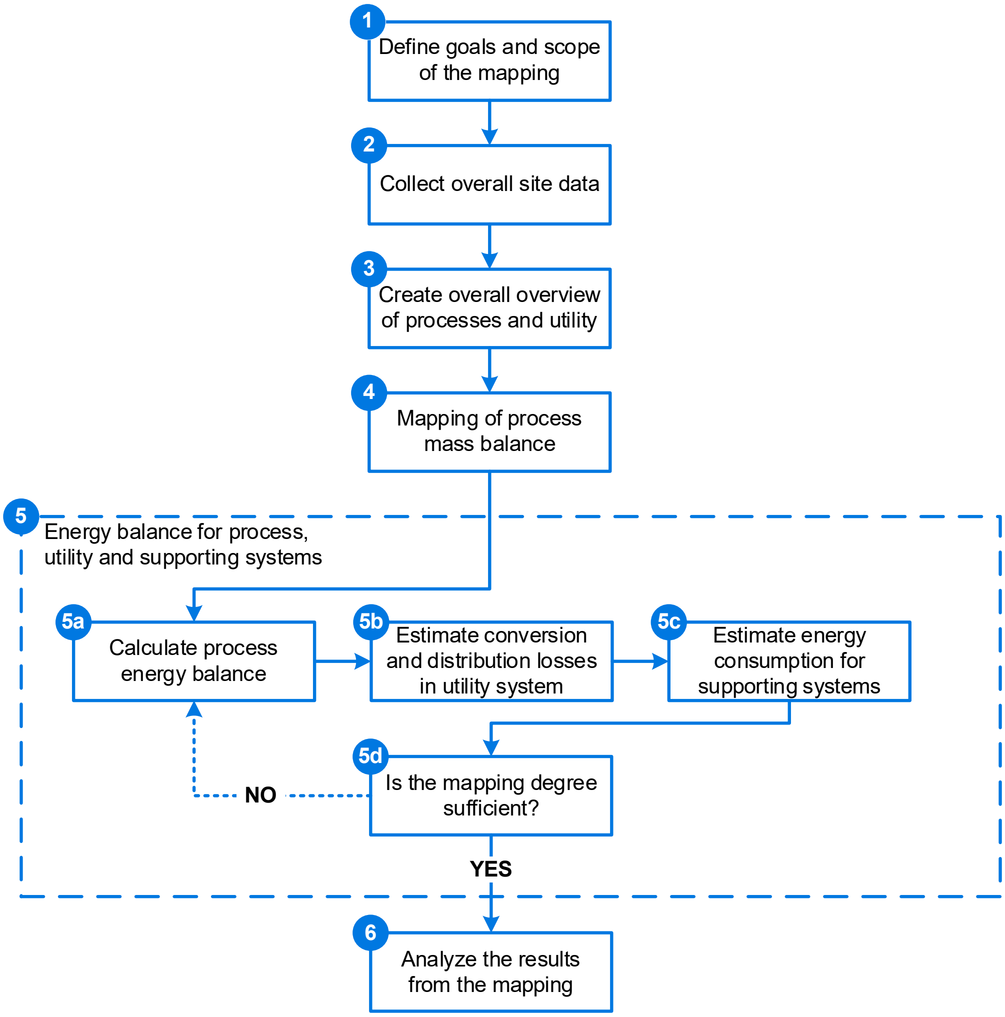


Figure 1: Flow chart of the energy mapping process

2 Defining a scope and goal

This first step of the energy mapping is to clearly define a scope and purpose for the energy mapping. Depending on the size of the company and timeline for the energy mapping and the overall strategy of the company which is being mapped, the scope and goals of the mapping could vary. The following questions should therefore be considered before starting the energy mapping:

- Is the goal to map the entire facility or should the mapping focus on certain areas?
    - Geographic areas?

    - Certain production areas of higher interest?
- What level of detail can be achieved with the given timeline for the energy mapping?
- What is the main driver for conducting the energy mapping?
    - Is it only to achieve a detailed overview of the energy consumption?
    - Is it economical? Should the model be prepared to handle economic evaluations?
    - Is it environmental? Should the model be prepared to handle CO_2 savings as well?

3 Overall site data

When the scope is defined, the next step of the energy mapping is to get an overview of the overall site data. This data should be easily available at most sites. The overall site data covers all purchased primary energy consumption and the amount of production output. In addition to the outputs the main inputs (i.e. raw materials) to the production process should also be achieved at this step. In the Energy mapping template, an example of such overall data collection is shown in the sheet "Yearly data".

This sheet will function as an input sheet for the mass balance and utility mapping sheets later on. Therefore, all unit conversions should be carried out in this sheet to avoid unnecessary calculations in the later sheets. It is important to secure consistency of the units within all data types. For time, energy and mass, the recommended units are:

1. Time: Year
2. Mass: Tons
3. Energy: kWh

Being consistent about all units will ease further work and comparisons.

The overall site data should be collected as soon as possible and many times even before an actual site visit, in order to give a better understanding of the size of the production company and their overall energy demands.

Yearly data

Energy Data	Year	
Purchased Electricity	20.000.000	kWh/y
Purchased Natural Gas Steam boiler	20.000.000	kWh/y
Purchased Coal	18.000.000	kWh/y
Total Purchased Energy	**58.000.000**	**kWh/y**
Production data		
Material X	160.000	Ton/y
Material Y	20.000	Ton/y
Material Z	40.000	Ton/y
Material W	5.000	Ton/y
Material V	10.000	Ton/y
Material Q	15.000	Ton/y
Total Raw materials	**250.000**	**Ton/y**
Additives production line 1	10.000	Ton/y
Additives production line 2	-	Ton/y
Total Additives	**10.000**	Ton/y
Final product data		
Final product 1	100.000	Ton/y
Final product 2	80.000	Ton/y
Total final product	**180.000**	**Ton/y**

Figure 2: Overview of collection of overall site data. See sheet "Yearly data" in the Excel template.

Creating an overview of process, utilities and supporting systems

Once the overall site data has been gathered and goals and scope have been defined, an overall overview of the production processes, utilities and supporting systems should be created. These are essentially the first drafts of what will become the mass flow balance and utility mapping in the Excel template.

The overviews should be made on the basis of screenshots, flow diagrams, previous audits, production trends, site walks, etc. This first overview can also be carried out on paper or a drawing program such as Visio to then later be carried over to the Excel spreadsheets. An example of a simple Visio sketch of the example from the Excel template is shown in Figure 3.

For the production processes the goal is to create a basic overview of the entire production flow at the site. At this step, the focus is to include all processes in the right order in relation to each other, but not necessarily to get numbers on inputs and outputs of each step. Every process should be labelled and each process stream should be numbered to keep a good overview of the system. The production flows are mapped in the sheet "Mass flow balance" in the Excel template.

In addition to creating an overview of the production processes, an overview of the utility structures at the site should also be prepared. Once again focus at this stage is more to qualitatively achieve the full overview rather than quantifying losses and efficiencies. This should be done for all utility systems at the site (i.e. heating, cooling, compressed air, etc.). The utility structures are mapped in the sheet "Utility mapping" in the Excel template.

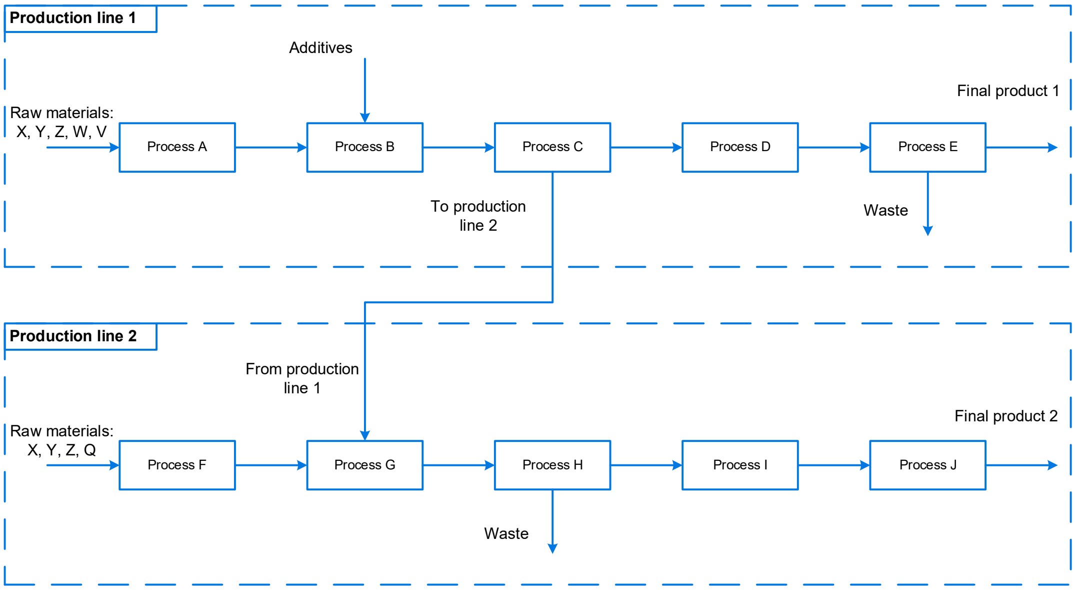


Figure 3: Simple Process flow overview of the template example.

4 Process mass balance

The next step is to set up the process mass balance based on the previously created process flow diagram. This is shown in Figure 4 below and is done in the "Mass flow balance" sheet in the mapping template. Each process step is indicated by a box. The example shows a site with two different production lines that are creating two different products from a list of raw materials. Each production line consists of 5 processes with varying inputs of additives and energy. It is also seen that a biproduct from production line 1 is used directly in production line 2. To carry out the mass balance the following steps should be followed:

1. The yearly data for raw materials are imported from the "Yearly data" sheet.
2. For each process it is evaluated whether there is any addition or extraction of material.
3. If any product or additive is added or removed during a process, data should either be collected from the company if possible or it should be estimated.
   a. Estimation can often be done by consulting the operating personnel at the site.
   b. For some processes calculating the mass balance could require more information about the product. In the energy mapping template such an example is given for production line 2, where the mass balance is set up from knowing the Dry Matter percentage between process steps.

c. This process can require a more detailed understanding of the process than the auditor has and it can therefore be an advantage to involve operational or production personnel with extensive knowledge on the process in this step.

4. All streams with additions or removal of product are numbered.

   a. It is important remember to include waste streams since these might become interesting for later analysis.

5. It is important to keep progressing with the energy mapping and not get stuck in trying to achieve a value in a very detailed way that takes too long at this stage. If the uncertainty of a value is deemed very high this should be noted by the energy auditor as a potential focus point for later analysis.

6. When all processes have been mapped, the calculated amount of final product can be compared to the actual data for final production. This can be used to indicate if there are significant errors in the mass balance.

   a. In addition to this, a check should also be done for each production line on all incoming materials and outgoing products, making sure it equals out (In the Excel template this is carried out in cells T25 and T52 for the two production lines respectively).

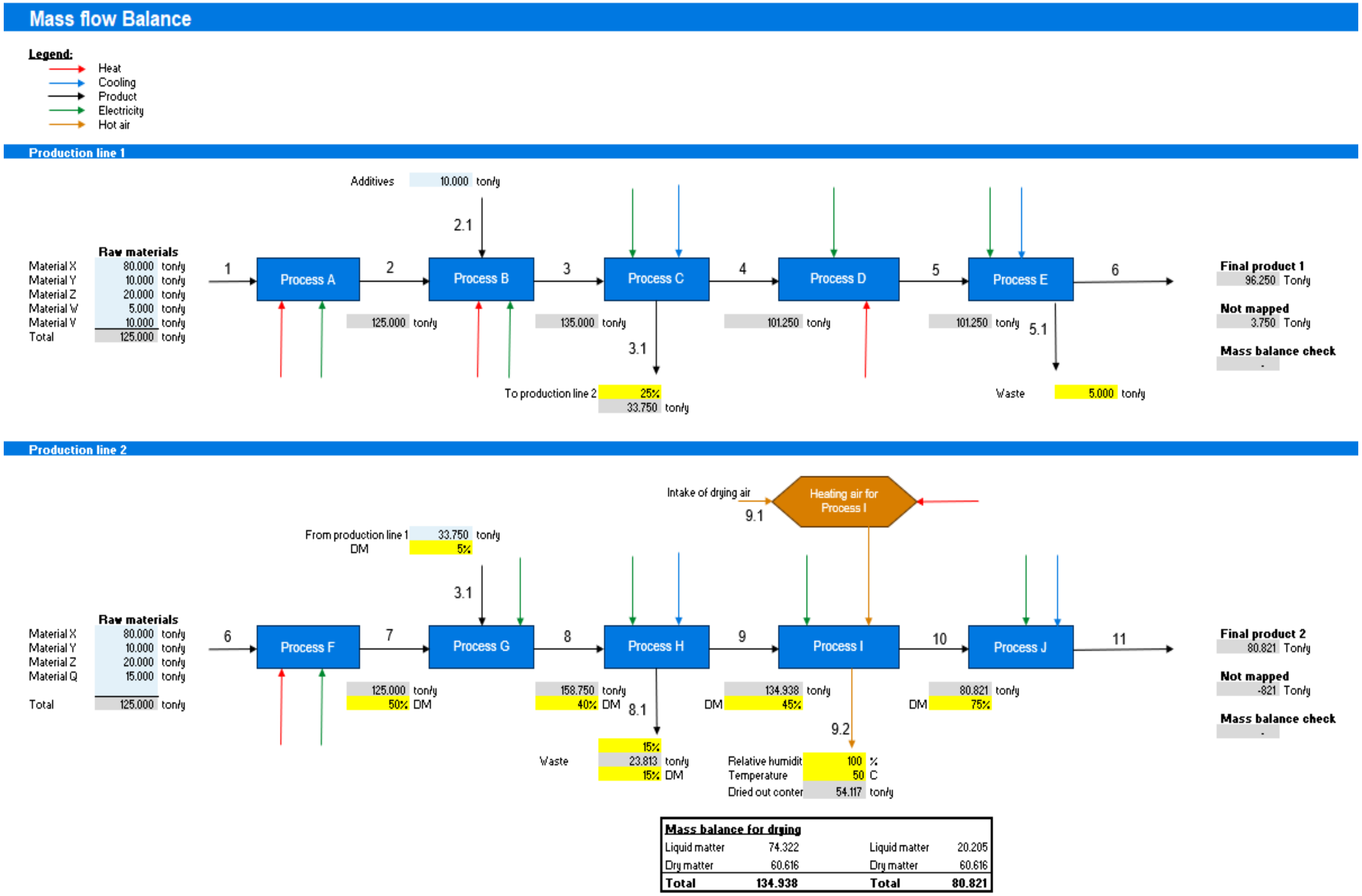


Figure 4: Overview of the process mass flow balance. See sheet "Mass flow balance" in Excel template.

5 Energy balance for process, utility and supporting systems

In addition to the mass flow balance, energy balances for process, utility and supporting systems should be set up. The goal is to set up tables for each utility type where all the energy consumers are listed. This is shown in Figure 5 and can be seen in sheet “Process mapping” in the Excel template. Starting with the process energy balances the recommended approach is described below:

1. The first step is to evaluate the energy inputs for each process on a qualitative level, considering both the thermal and electrical energy consumption. This is most easily done by drawing ingoing energy flows on the previously created mass balance. This can also be seen in Figure 4.
2. After this, the specific energy consumption in each process step should be calculated. Each process is listed in the respective energy consumption tables and some basic information on “Section”, “Media” and “Stream No.” is noted for easy reference later.
3. For thermal energy mapping additional information on the process stream might be required. In any case temperature information is needed and, in some cases, pressure and heat capacity or enthalpy could also be needed. The mapping itself can be carried out with three different approaches (examples of all three approaches are given in the Excel template):

   - **Flow**: With the flow approach, the energy demand is calculated with the following equation. This approach is based on information of the mass flow and temperature difference over a specific unit.

$$(T_{out} - T_{in})\ [K] \times c_p \left[\frac{kJ}{kg * K}\right] \times \dot{m}_{in} \left[\frac{ton}{year}\right] \times 1000 \left[\frac{kg}{ton}\right] \times \frac{1}{3600} \left[\frac{h}{s}\right] = \dot{Q} \left[\frac{kWh}{year}\right]$$

   - **KPI**: With the KPI approach, the energy demand is calculated based on a KPI for the specific unit, if such information exists.

$$KPI \left[\frac{kWh}{ton}\right] \times \dot{m} \left[\frac{ton}{year}\right] = \dot{Q} \left[\frac{kWh}{year}\right]$$

   - **Measurement**: With measurement approach, the energy demand from a component will be measured over a period of time and the measured value will be extrapolated to a yearly consumption. It can also be that the energy consumption for a given process is logged by the production company.

4. It is important to keep in mind that the potential energy content of the process waste streams should also be mapped during the thermal energy mapping.

5. For the electrical energy mapping, the electricity consumption of the process equipment is calculated. This calculation can also be based on three different approaches (examples of all three are once again shown in the Excel template):

   - **Power**: with the power approach then the electricity demand is calculated by the knowledge of the power capacity, the operating hours and a load estimate.

$$\gamma[-] \times t\,[h] \times p[kW] = \dot{P}_{unit}\left[\frac{kWh}{year}\right]$$

t = annual operational time in hours [h]

γ = Load factor

p = effect in kW [kW]

   - **KPI**: This approach is the same as for the thermal part.

$$[KPI]\left[\frac{kWh}{ton}\right] \times \dot{m}\left[\frac{ton}{year}\right] = \dot{P}_{unit}\left[\frac{kWh}{year}\right]$$

   - **Measured**: This approach is the same as for the thermal part.

$$\dot{P}_{unit}\left[\frac{kWh}{year}\right] = measured$$

6. The template is set up with conditional formatting to indicate the largest consumers in each energy type. Cell E6 can furthermore be utilized to define a threshold for Significant Energy Users. This can vary depending on the size of the facility and the number of process streams.

7. In column CO to MK a temperature analysis is set up for analyzing results in the later stage.

8. Once again it is important to keep progressing with the energy mapping and not get stuck in trying to achieve a value in a very detailed way that takes too long at this stage. If the uncertainty of a value is deemed very high this should be noted by the energy auditor as a potential focus point for later analysis

9. The tables in the Excel template are set up to be able to handle up to 100 processes within each category. Most of these are hidden to keep a better overview. For a guide on how to unhide a number of rows Appendix 0 should be reviewed.

Process Mapping

NB: See Appendix in User guide for help on how to add additional rows to the tables

Definition of Significant Energy User:	15%

Heating consumption

Section	Proces	Medium	Stream no	Utility system	Temp. In °C	Temp. Out °C	Mass flow t/yr	Dry matter %	Cp kJ/KgK	KPI kWh/ton	Flow approach kWh	KPI approach kWh	Measurement kWh	Total kWh	Share of total
Production line 1	Process A	Product	1	Steam	20	50	125.000	5,0%	4,06		4.228.440			4.228.440	14,6%
Production line 1	Process B	Product	2	Steam	50	100	135.000	5,0%	4,08	100,00		13.500.000		13.500.000	46,6%
Production line 1	Process D	Product	4	Hot water	45	50	101.250	5,0%	4,07				800.000	800.000	2,8%
Production line 2	Process F	Product	6	Steam	20	60	125.000	50,0%	3,00		4.168.389			4.168.389	14,4%
Production line 2	Heating air for Process I	Product	9.1	Steam	20	80	134.938	44,9%	3,17	40,00		5.397.500		5.397.500	18,6%
Support system 1	Support system 1	Water	11	Hot water	20	50	26.000	0,0%	4,18		905.667			905.667	3,1%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
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									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
	TOTAL										9.302.496	18.897.500	800.000	**28.999.996**	100%

Cooling consumption															
Section	Proces	Medium	Stream no	Utility system	Temp. In	Temp. Out	Mass flow	Dry matter	Cp	KPI	Flow approach	KPI approach	Measurement	Total	Share of total
					°C	°C	t/yr	%	kJ/KgK	kWh/ton	kWh	kWh	kWh	kWh	
Production line 1	Process C	Product	3	Glycol	75	20	135.000	5,0%	4,07		8.386.860			8.386.860	37,7%
Production line 1	Process E	Product	5	Glycol	30	12	101.250	5,0%	4,05	30,00		3.037.500		3.037.500	13,6%
Production line 2	Process H	Product	8	Glycol	55	15	158.750	5,0%	4,06				9.000.000	9.000.000	40,4%
Production line 2	Process J	Product	10	Glycol	50	15	80.821	75,0%	2,35		1.845.256			1.845.256	8,3%
									4,18					-	0,0%
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									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
	TOTAL										10.232.115	3.037.500	9.000.000	22.269.615	100%

Waste heat potential															
Section	Proces	Medium	Stream no		Temp. In	Temp. Out	Mass flow	Dry matter	Cp	KPI	Flow approach	KPI approach	Measurement	Total	Share of total
					°C	°C	t/yr	%	kJ/KgK	kWh/ton	kWh	kWh	kWh	kWh	
Production line 1	Process E	Product	5.1		50	20	5.000	0,0%	4,18		174.167			174.167	6,4%
Production line 2	Process H	Product	8.1		40	20	23.813	0,0%	4,18		552.979			552.979	20,3%
Production line 2	Process I	Air	9.2		50	20	54.117	0,0%	1,01				2.000.000	2.000.000	73,3%
									4,18					-	0,0%
									4,18					-	0,0%
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									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
	TOTAL										727.146	-	2.000.000	2.727.146	100%

Electricity consumption															
Section	Proces	Medium	Stream no		Effect	Operation hours	Mass flow	Load factor		KPI	Flow approach	KPI approach	Measurement	Total	Share of total
					kW	h/y	t/yr	%		kWh/ton	kWh	kWh	kWh	kWh	
Production line 1	Process A	Product	1		500	6.500	125.000	90,0%			2.925.000			2.925.000	24,8%
Production line 1	Process B	Product	2		300	6.500	135.000	50,0%		8,00		1.080.000		1.080.000	9,1%
Production line 1	Process C	Product	3		100	7.000	135.000	60,0%			420.000			420.000	3,6%
Production line 1	Process D	Product	4		300	6.500	101.250	70,0%		3,00		303.750		303.750	2,6%
Production line 1	Process E	Product	5		50	7.000	135.000	75,0%					400.000	400.000	3,4%
Production line 2	Process F	Product	6		400	6.500	125.000	90,0%			2.340.000			2.340.000	19,8%
Production line 2	Process G	Product	7		400	6.500	125.000	50,0%		20,00		2.500.000		2.500.000	21,2%
Production line 2	Process H	Product	8		200	7.000	158.750	60,0%			840.000			840.000	7,1%
Production line 2	Process I	Product	9		300	6.500	134.938	70,0%		3,00		404.813		404.813	3,4%
Production line 2	Process J	Product	10		50	7.000	80.821	75,0%					600.000	600.000	5,1%
														-	0,0%
														-	0,0%
														-	0,0%
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														-	0,0%
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														-	0,0%
														-	0,0%
														-	0,0%
	TOTAL										6.525.000	4.288.563	1.000.000	**11.813.563**	100%

Figure 5: Overview of the process energy mapping. See sheet "Process mapping" in Excel template.

When the process level energy balances are set-up, the utility level energy balance can be set-up. The utility mapping covers all the utility systems that support the process energy demand. The utility systems can be boilers, coolers, chillers, air compressors, wastewater etc. The scope is to cover the purchased energy, conversion of energy, distribution of energy and finally the process energy. An example is shown in Figure 6 and can furthermore be seen in the Excel template. This system consists of two steam boilers using coal and natural gas to supply the main heating consumption, while a small hot water boiler and waste heat from air compressors is used in a 60°C system to supply hot water for supporting systems and one low temperature heating process. Cooling is supplied by one central chiller. The Excel template is prepared to handle up to three heating and cooling systems respectively. If more systems are present, the later results will have to be expanded by the user. The utility mapping can be carried out by the following steps:

1. All purchased energy is imported into the “Purchased” column
2. All major utility equipment is added to the “Conversion” column e.g. in the example the system consists of two steam boilers, chillers and air compressors.
3. For each type of equipment, the efficiency is estimated, and energy losses are calculated.
   - In the example losses are estimated for the boilers and air compressors
   - For chillers a Coefficient-of-Performance (COP) and known electricity consumption is used to estimate the amount of cooling that is produced. The COP value is not always known by the site in which case it might have to be estimated based on an assessment of the present equipment.
4. Next, the distribution losses are estimated in the “Distribution” column based on an overall assessment of the distribution system (level of maintenance, insulation, steam traps etc.)
5. Then the utility is connected to the end-users in the “Consumption” column.
6. Finally, the overall mapping degree can be calculated. As shown in Figure 1 in the beginning, the mapping degree is now used to evaluate whether the mapping is done to a sufficient degree or whether an extra iteration is required to.
   - If the mapping degree is deemed too low the energy balances are reevaluated.
   - If the mapping degree is deemed sufficient the auditor can move on to setting up and analyzing the results.

- The sufficient level can vary a lot depending on the size of the facility and level of detail. Based on international experience a mapping degree of at least 90% is most often considered sufficient. However, no matter the degree it is very important to critically reflect on the reasons why it is not exact and what the potential consequences can be.

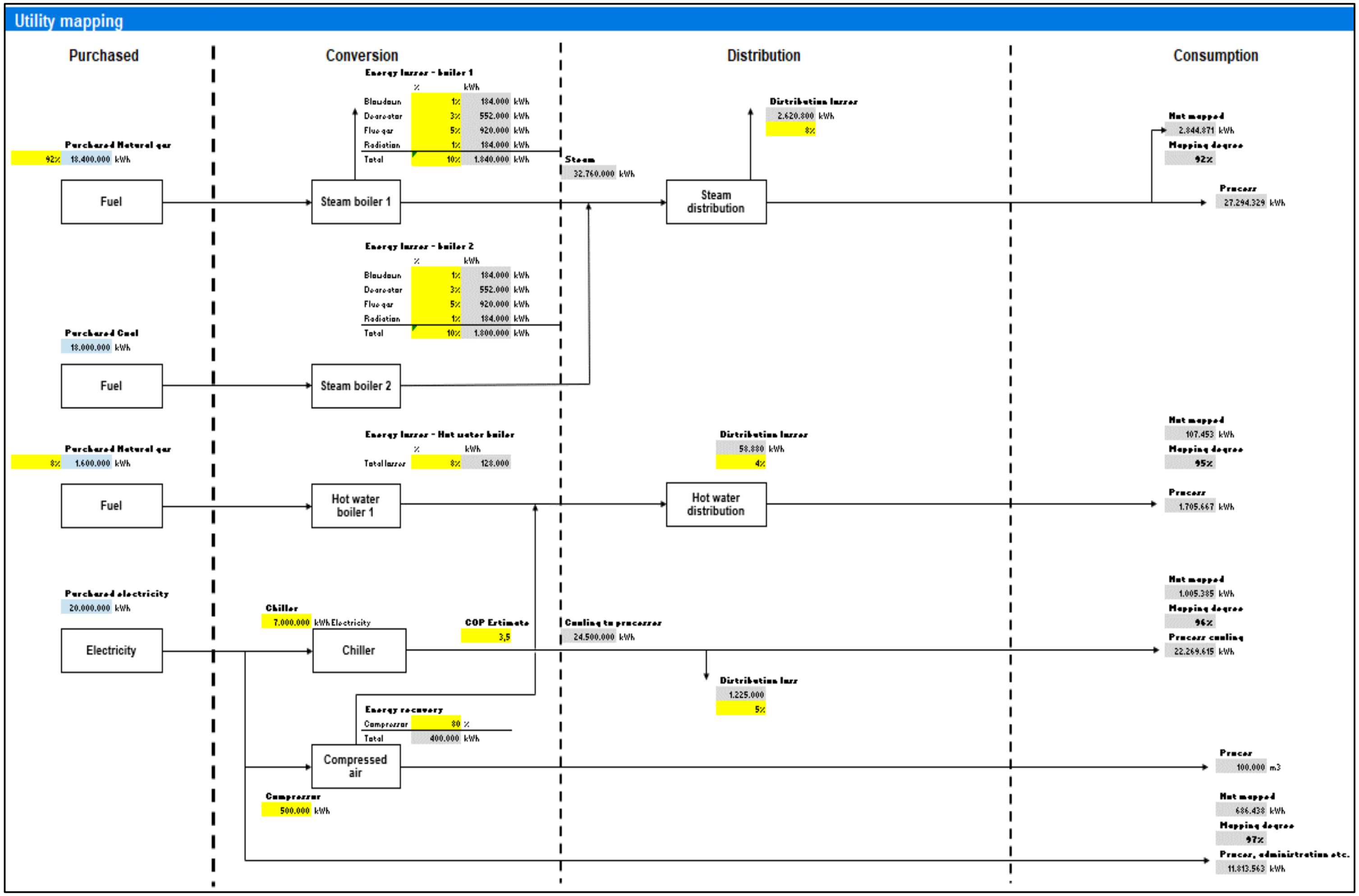


Figure 6: Overview of the utility mapping. See Excel template sheet "Utility mapping".

In addition to process and utility level energy balances, many production facilities also have several supporting systems. These systems are also required to be mapped, to get the full overview of energy consumption at a site. Examples could be, Cleaning-In-Place, washers (containers, boxes, bottles etc.), ventilation, packaging units etc. Since these will not be visible in the process flow, a separate sheet in the Excel template is kept for handling of these systems “Supporting systems”. In the Excel template oe example is given which is shown in Figure 7 below. In this example steam is used for heating up water for a washing machine at the site. This energy consumption is also carried over to the process mapping overview tables.

Supporting systems

Support system 1

An example of a common support system could be a washing machine. An example of such calculation is given below:

Supply water temperature	Forward temperature to washer	Weekly water consumption	Annual water consumption	Specific heat
[C]	[C]	[m3/week]	[m3/y]	[kJ/kgK]
20	50	500	26.000	4,18

Energy consumption for support system 1

905.667 **kWh**

Stream 11

Temperature levels

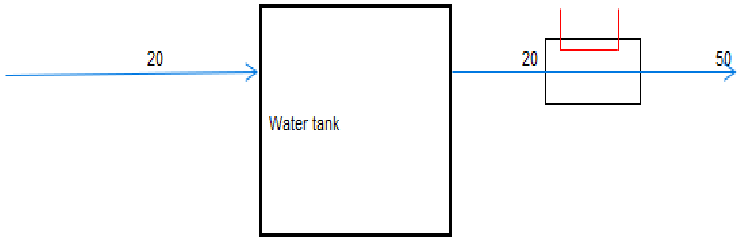
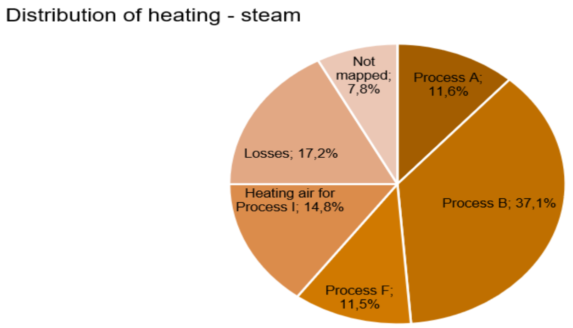


Figure 7: Overview of the supporting systems. See the sheet "Supporting systems" in the Excel template

6 Analyzing and understanding the results

When a sufficient mapping degree is achieved, the next step is to set up the results in an easily understandable way. To use the energy mapping properly it is important to consider how to present the results and how to use the results efficiently develop energy saving projects. It is emphasized that the development of projects should start by understanding the energy consumption of the processes before moving on to the utility systems. A full understanding of the actual energy service or purpose of using energy in the specific processes is therefore required.

To easily get a full overview of the entire facility pie charts and bar charts are made for each utility type at the site. As an example, an overview of the heating consumption for the given example is shown in
Figure *8*. These plots provide a good overview of the distribution of heat consumption for the entire site and make it easy to identify the main energy consumers at the site. In the example these are only created on site level, but for larger sites they can also be created on a production line level or section level, to have an even more detailed overview of where the energy is consumed. The overviews are created for each utility system at the site.



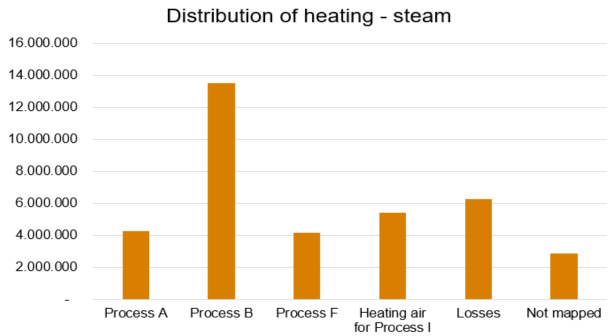


Figure 8: Charts for presenting the results of overall heat consumption. See Excel template sheet "Result Overview".

In addition to the overall overviews, it is often also useful to connect the consumption to temperature. This can help assess the potential for heat recovery and integration of, for example heat pumps. The graphs help give a good overview of what temperature levels the heating is utilized at. An example from the template is shown in

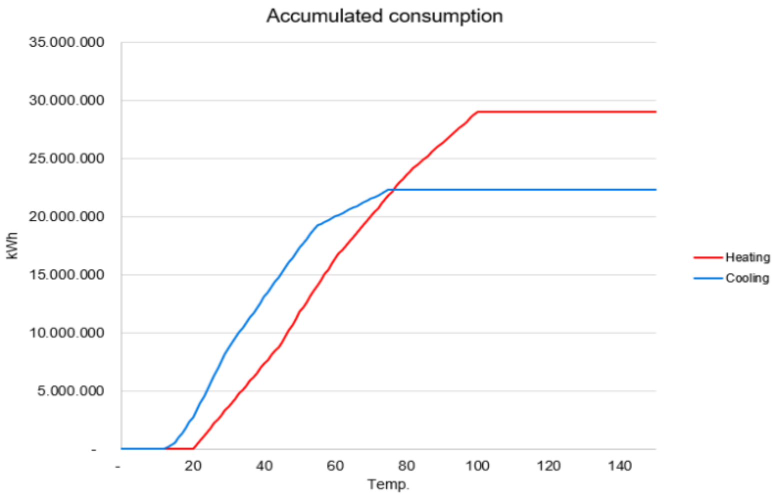


Figure 9. Conclusions from these plots could for example be that:

- 80% of the heating is used for processes below 80°C (about 23 GWh) and all heating is below 100°C.
    - Can hot water be used instead of steam?
    - Any good heat sources for heat pumps?
- 20% of the cooling is used above 50°C (about 4 GWh).
    - Are there any potentials for heat recovery?

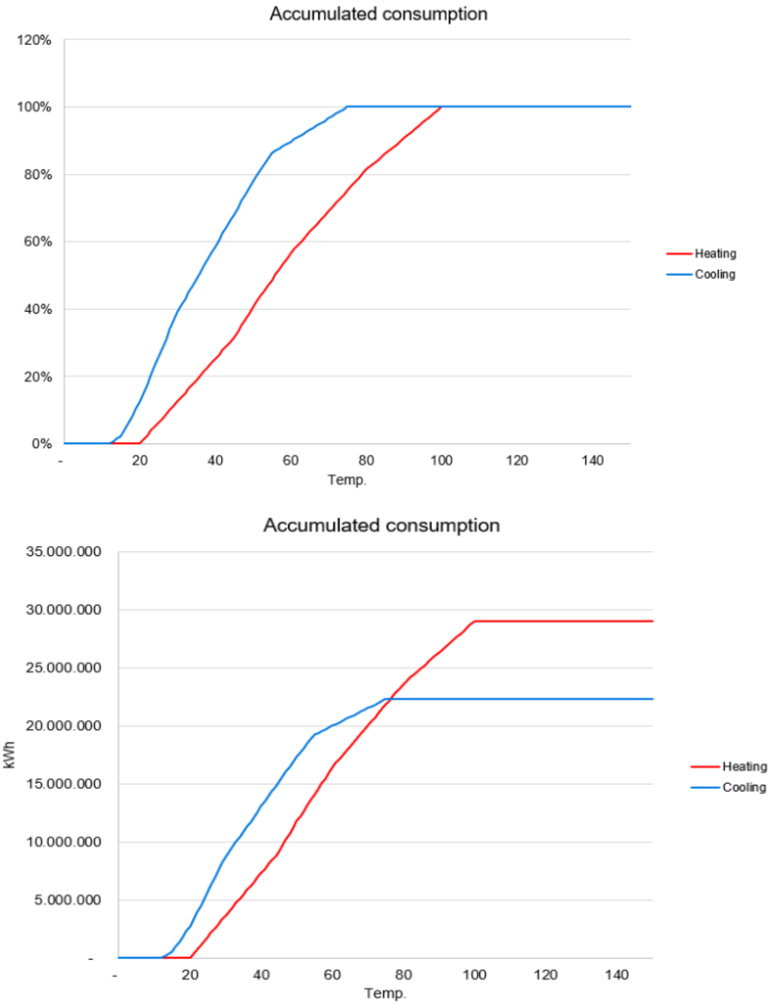


Figure 9: Accumulated thermal energy consumption. See Excel template sheet "Result Overview".

To gain a better overview of the relations between heating and cooling temperature levels, composite curves can be plotted for each. This is shown for the Excel template and in Figure 10 below, where the mapped waste heat streams have also been added. This analysis shows the amount of energy that is consumed at each degree of temperature. It can therefore be used to identify heat recovery potentials. The graph has four distinct areas.

- Orange area: theoretically minimum required heating utility
- Blue area: theoretically minimum required cooling utility
- Yellow area: Available waste heat from the processes

- Overlapping grey area: maximum potential for direct heat recovery between processes

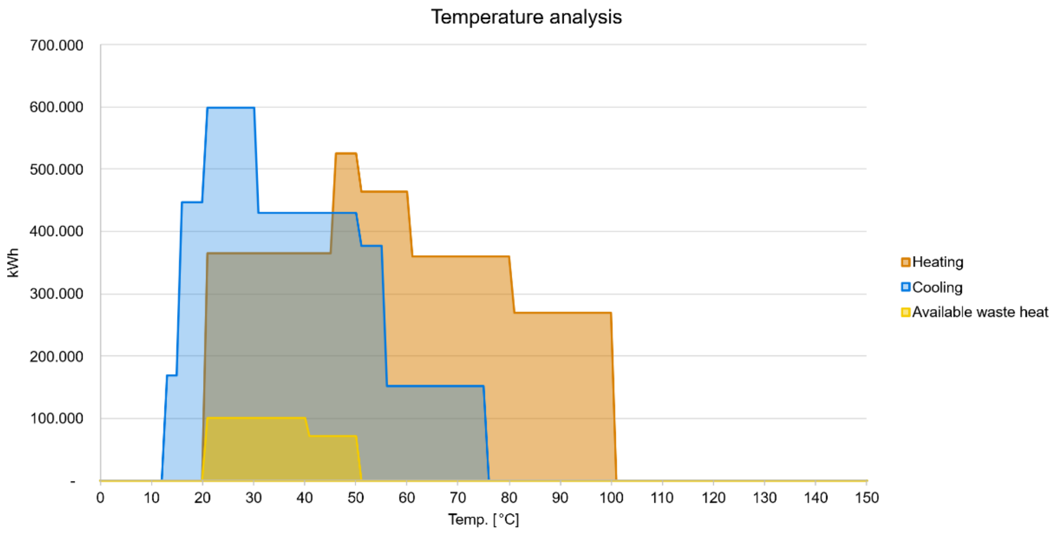


Figure 10: Example of a temperature analysis. See Excel template sheet "Result Overview".

In the example from the Excel template, it is seen that there is a high potential for implementing heat recovery between 20-75°C. Next step is to identify processes from the "Process mapping" tables with overlapping temperature requirements. In this example it can be seen that Process C for example can be matched with Process A and F:

Table 2: Potential heat recovery opportunities

Process	Temperature in [°C]	Temperature out [°C]	Energy consumption [MWh]
Process A	20	50	4.228
Process F	20	60	4.168
Process C	75	20	8.387

In terms of energy these streams almost match exactly, however, it will not be possible to cool Process C all the way to 20°C. A pinch temperature should therefore be introduced to reflect the physical limitations. Assuming a pinch temperature of 5°C, this means that process C can be cooled to 25°C and that 7.627 MWh can be recovered for heating. Cooling and heating utility will therefore still have to be used in both ends.

It should be noted that the above exercise is fully theoretical. In the real world there are many more elements to consider when analysing the heat recovery potentials such as:

- **Matching operation times**: Are the processes running at the same time or are they batch controlled? Do we need a buffer tank?
- **Geographical location**: How far away are the processes from each other? Do the potential energy savings justify the piping investments?

It is therefore necessary to make a techno-economical analysis, estimating full investment costs and calculating payback times.

Once the energy consumption has been optimized, the utility system should be evaluated. From the utility mapping sheet, it should be evaluated whether the energy losses from the equipment can be minimized or recovered. In the Excel template, it is seen that waste heat from air compressors is already utilized in a 60°C hot water system. However, no heat is recovered from the chillers. There is a possibility to install an oil cooler or de-superheater on the chillers to supply more energy to the 60°C system. A lot of heat is also lost in the condensers of the chillers which could potentially be upgraded to higher temperatures with a heat pump. For the boilers it is seen that both boilers have an estimated flue gas loss of 5%. Recovering this in an economizer should therefore also be considered.

7 Appendix

Adding additional rows in Process mapping tables

The following describes how to practically add extra rows to the Excel template. Each Process mapping table contains 100 rows of which most are left empty for the user to fill in if required. To add rows for the energy mapping the following steps should be followed:

1. Click on the “+” sign to the left of the table to open up the empty rows:

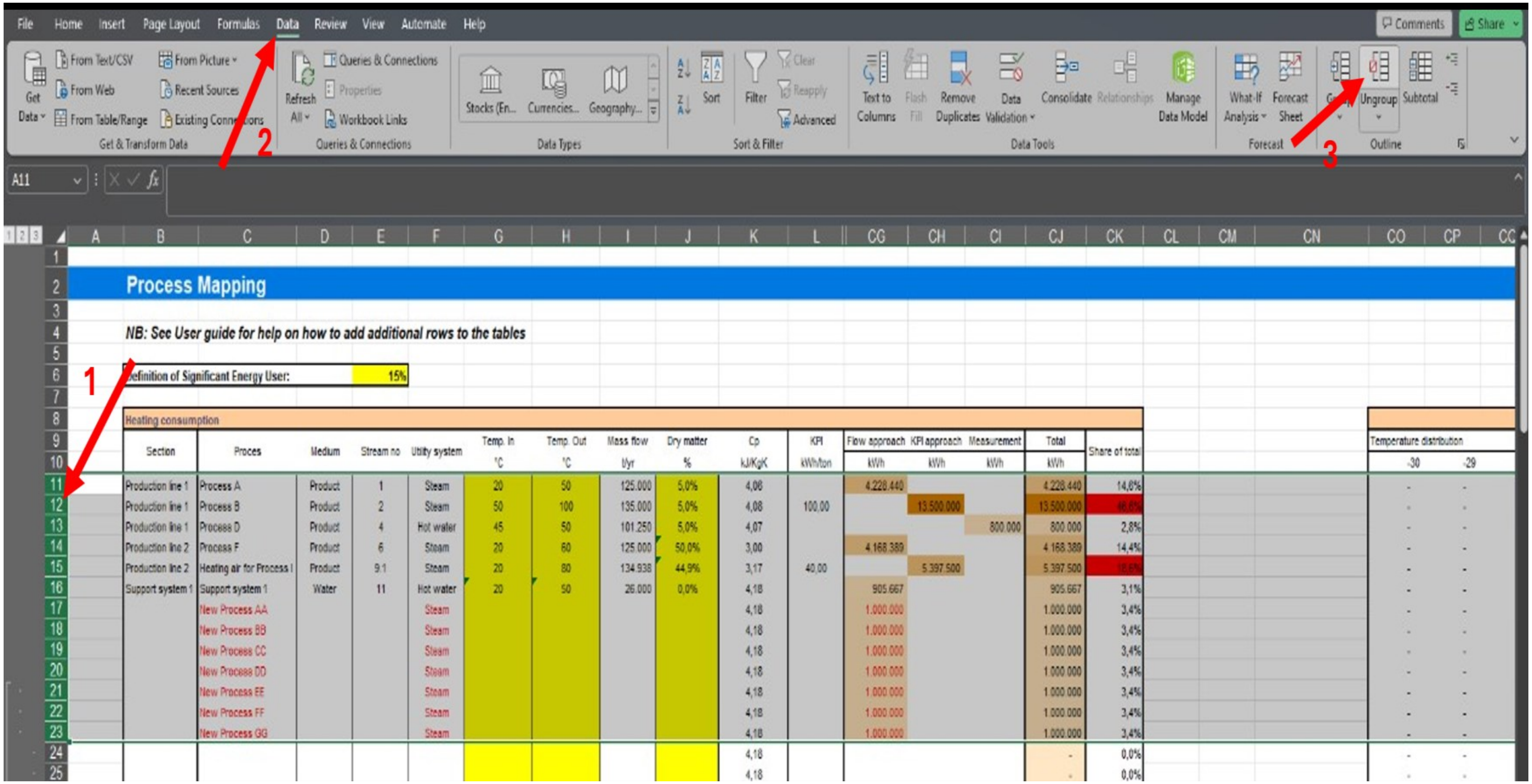
Heating consumption															
Section	Proces	Medium	Stream no	Utility system	Temp. In °C	Temp. Out °C	Mass flow t/yr	Dry matter %	Cp kJ/KgK	KPI kWh/ton	Flow approach kWh	KPI approach kWh	Measurement kWh	Total kWh	Share of total
Production line 1	Process A	Product	1	Steam	20	50	125.000	5,0%	4,06		4.228.440			4.228.440	14,6%
Production line 1	Process B	Product	2	Steam	50	100	135.000	5,0%	4,08	100,00		13.500.000		13.500.000	46,6%
Production line 1	Process D	Product	4	Hot water	45	50	101.250	5,0%	4,07				800.000	800.000	2,8%
Production line 2	Process F	Product	6	Steam	20	60	125.000	50,0%	3,00		4.168.389			4.168.389	14,4%
Production line 2	Heating air for Process I	Product	9.1	Steam	20	80	134.938	44,9%	3,17	40,00		5.397.500		5.397.500	18,6%
Support system 1	Support system 1	Water	11	Hot water	20	50	26.000	0,0%	4,18		905.667			905.667	3,1%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
	TOTAL										9.302.496	18.897.500	800.000	28.999.996	100%

Cooling consumption															
Section	Proces	Medium	Stream no	Utility system	Temp. In °C	Temp. Out °C	Mass flow t/yr	Dry matter %	Cp kJ/KgK	KPI kWh/ton	Flow approach kWh	KPI approach kWh	Measurement kWh	Total kWh	Share of total
Production line 1	Process C	Product	3	Chillers	75	20	135.000	5,0%	4,07		8.386.860			8.386.860	37,7%
Production line 1	Process E	Product	5	Chillers	30	12	101.250	5,0%	4,05	30,00		3.037.500		3.037.500	13,6%
Production line 2	Process H	Product	8	Chillers	55	15	158.750	5,0%	4,06				9.000.000	9.000.000	40,4%
Production line 2	Process J	Product	10	Chillers	50	15	80.821	75,0%	2,35		1.845.256			1.845.256	8,3%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
									4,18					-	0,0%
	TOTAL										10.232.115	3.037.500	9.000.000	22.269.615	100%

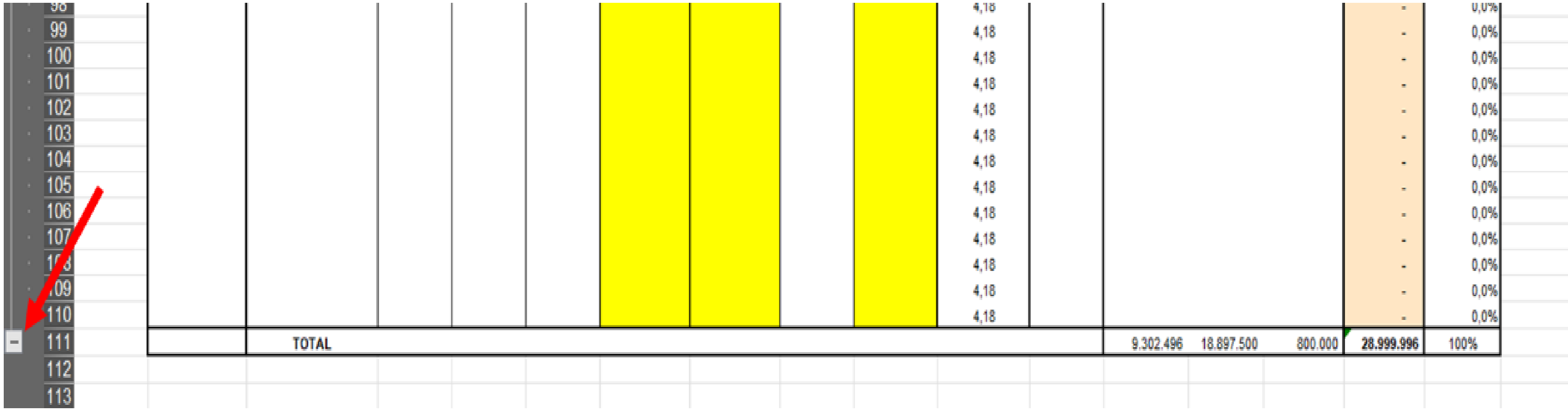
2. Add the new processes to the table:

	Heating consumption								
9–10	Section	Proces	Medium	Stream no	Utility system	Temp. In °C	Temp. Out °C	Mass flow t/yr	Dry matter %
11	Production line 1	Process A	Product	1	Steam	20	50	125.000	5,0%
12	Production line 1	Process B	Product	2	Steam	50	100	135.000	5,0%
13	Production line 1	Process D	Product	4	Hot water	45	50	101.250	5,0%
14	Production line 2	Process F	Product	6	Steam	20	60	125.000	50,0%
15	Production line 2	Heating air for Process I	Product	9.1	Steam	20	80	134.938	44,9%
16	Support system 1	Support system 1	Water	11	Hot water	20	50	26.000	0,0%
17		New Process AA							
18		New Process BB							
19		New Process CC							
20		New Process DD							
21		New Process EE							
22		New Process FF							
23		New Process GG							
24									
25									
26									
27									
28									

3. When the new processes have been added, all the rows that have been filled out are marked. From the top ribbon navigate to “Data”, and click the “Ungroup” button to the right side:



4. All the filled-out rows are now ungrouped and the remaining empty rows can be hidden again by scrolling to the bottom of the table and clicking the "-" sign to the left:

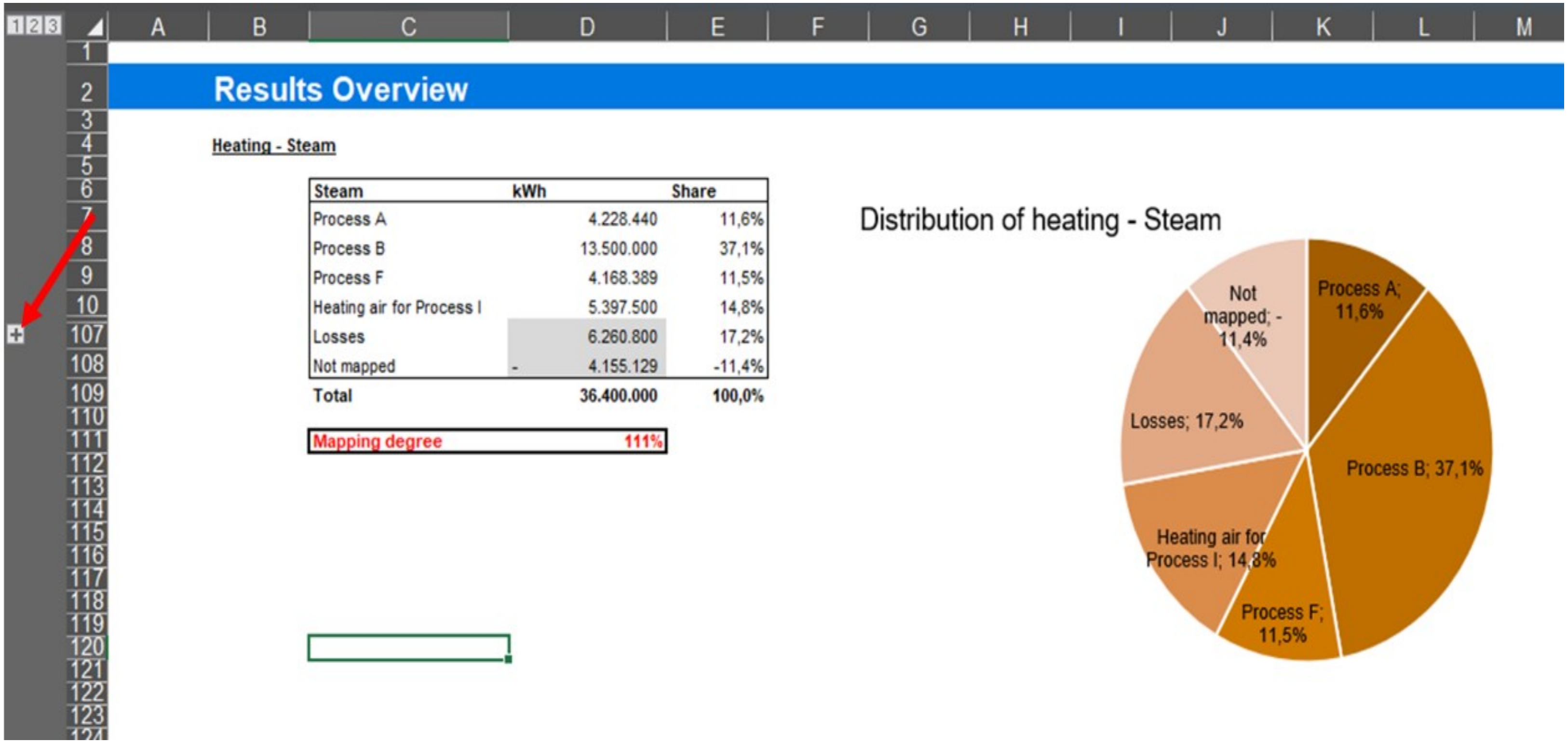


5. You are now left with a table containing all the new processes:

	Section	Proces	Medium	Stream no	Utility system	Temp. In °C	Temp. Out °C	Mass flow t/yr	Dry matter %	Cp kJ/KgK	KPI kWh/ton	Flow approach kWh	KPI approach kWh	Measurement kWh	Total kWh	Share of total
8	Heating consumption															
11	Production line 1	Process A	Product	1	Steam	20	50	125.000	5,0%	4,06		4.228.440			4.228.440	14,6%
12	Production line 1	Process B	Product	2	Steam	50	100	135.000	5,0%	4,08	100,00		13.500.000		13.500.000	46,6%
13	Production line 1	Process D	Product	4	Hot water	45	50	101.250	5,0%	4,07				800.000	800.000	2,8%
14	Production line 2	Process F	Product	6	Steam	20	60	125.000	50,0%	3,00		4.168.389			4.168.389	14,4%
15	Production line 2	Heating air for Process I	Product	9.1	Steam	20	80	134.938	44,9%	3,17	40,00		5.397.500		5.397.500	18,6%
16	Support system 1	Support system 1	Water	11	Hot water	20	50	26.000	0,0%	4,18		905.667			905.667	3,1%
17		New Process AA			Steam					4,18		1.000.000			1.000.000	3,4%
18		New Process BB			Steam					4,18		1.000.000			1.000.000	3,4%
19		New Process CC			Steam					4,18		1.000.000			1.000.000	3,4%
20		New Process DD			Steam					4,18		1.000.000			1.000.000	3,4%
21		New Process EE			Steam					4,18		1.000.000			1.000.000	3,4%
22		New Process FF			Steam					4,18		1.000.000			1.000.000	3,4%
23		New Process GG			Steam					4,18		1.000.000			1.000.000	3,4%
111		TOTAL										9.302.496	18.897.500	800.000	28.999.996	100%
112																

Next, the same procedure should be carried out in the "Result Overview" sheet. The formulas in the tables update automatically, but to make the plots show the correct values the new processes have to be unhidden.

1. Click on the "+" sign to the left of the table to open up the empty rows:



2. Scroll up to the top of the table and check that the new processes have been imported correctly:

Results Overview

Heating - Steam

Steam	kWh	Share
Process A	4.228.440	11,6%
Process B	13.500.000	37,1%
Process F	4.168.389	11,5%
Heating air for Process I	5.397.500	14,8%
New Process AA	1.000.000	2,7%
New Process BB	1.000.000	2,7%
New Process CC	1.000.000	2,7%
New Process DD	1.000.000	2,7%
New Process EE	1.000.000	2,7%
New Process FF	1.000.000	2,7%
New Process GG	1.000.000	2,7%
		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
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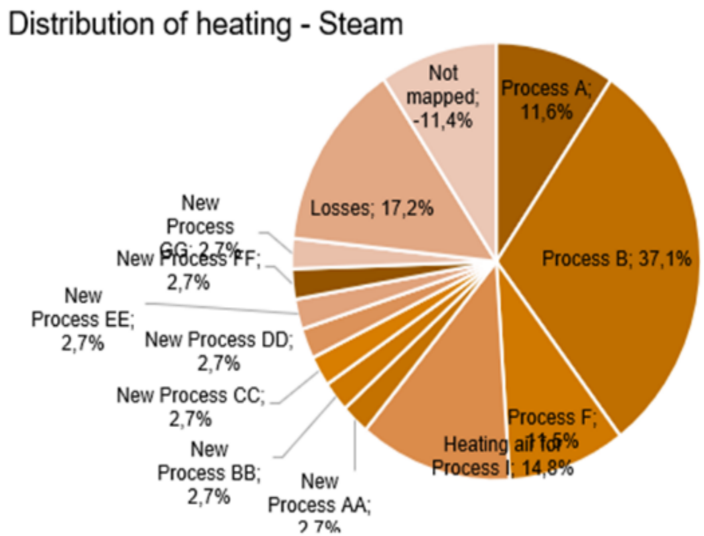
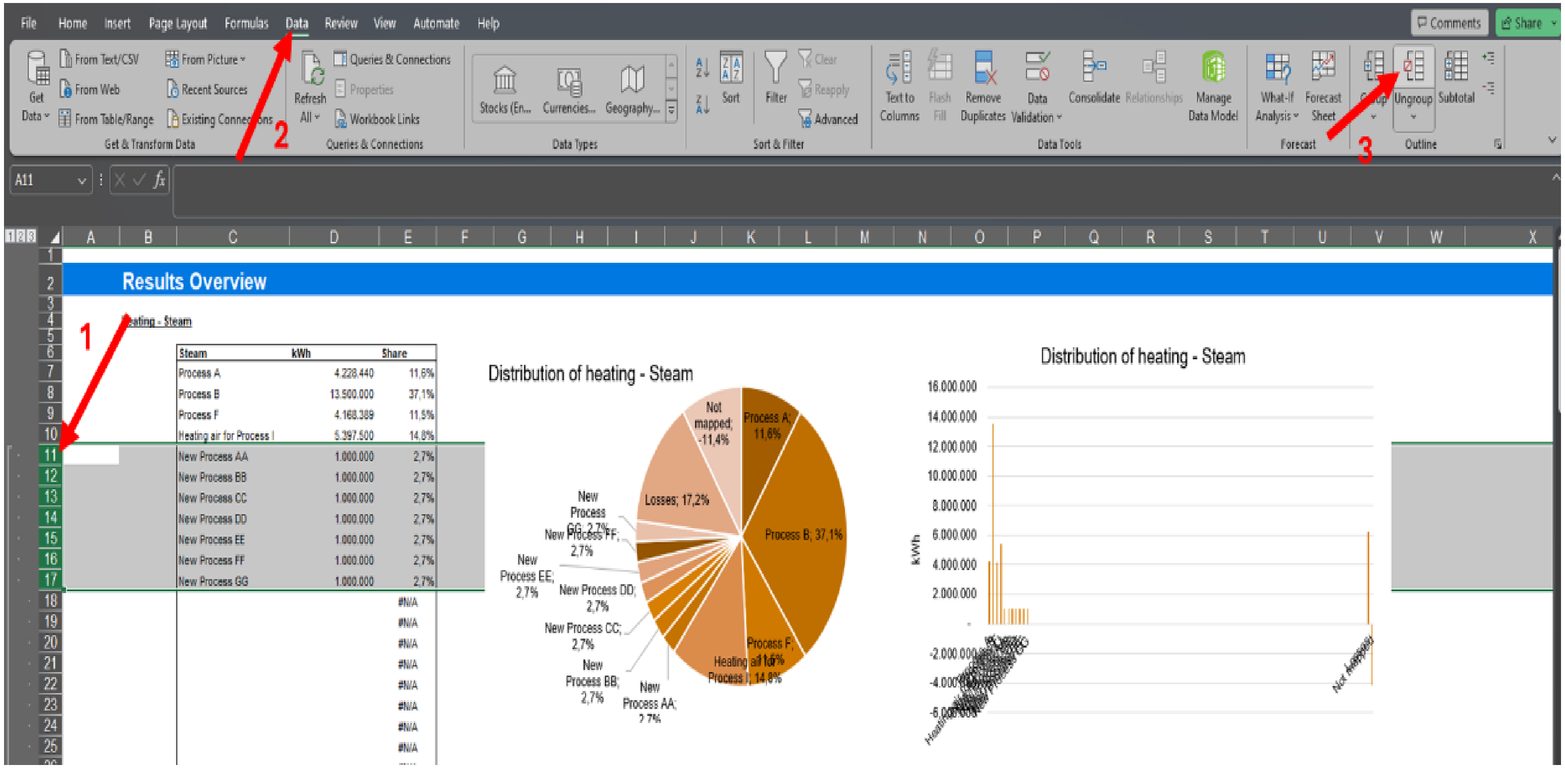
		#N/A

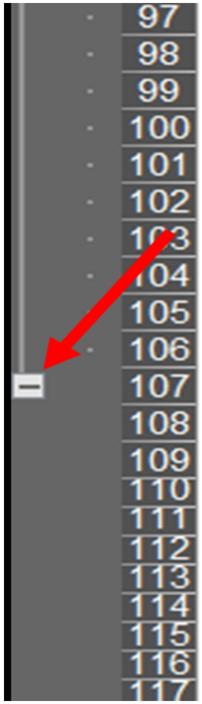


3. Similar as for the process mapping – mark all the new process rows. From the top ribbon navigate to "Data", and click the "Ungroup" button to the right side.

(NB: The bar chart will show all the unhidden empty cells during this step, but will become normal once the empty cells are hidden again.)

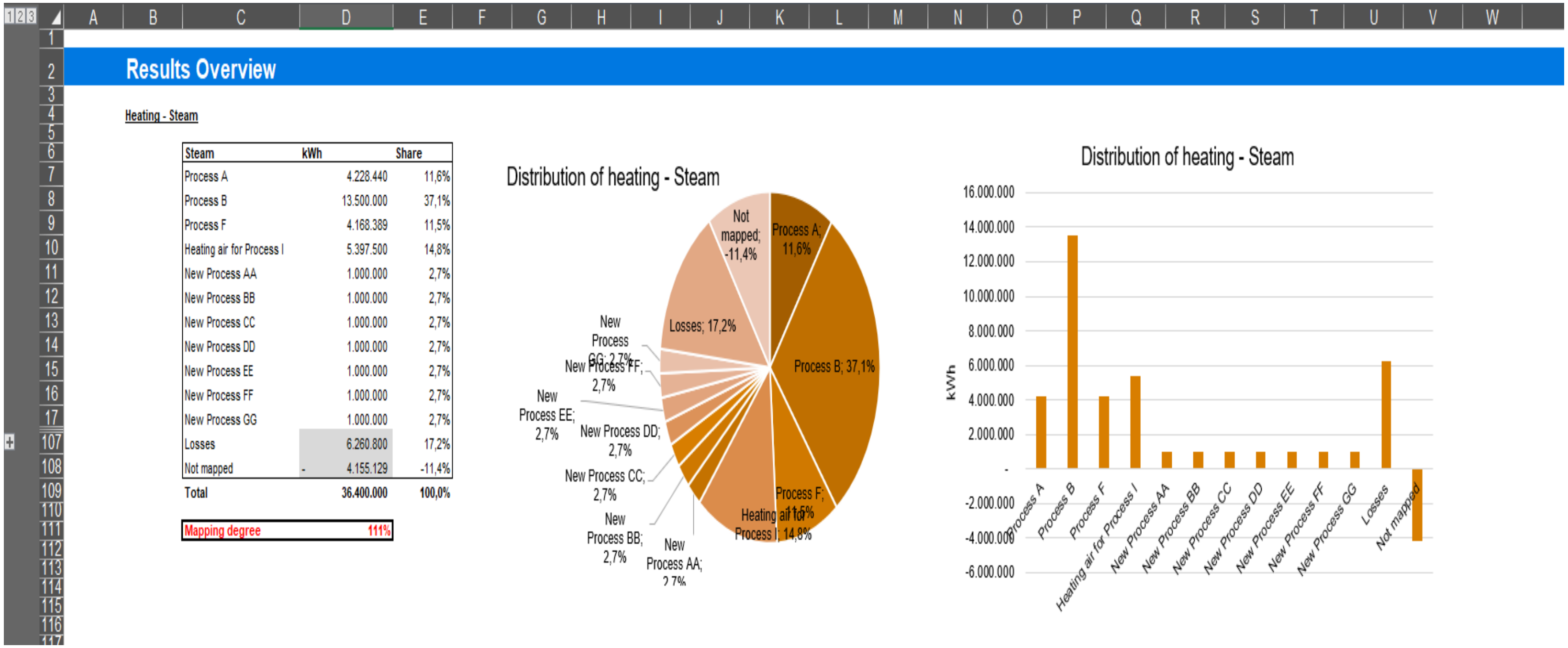


4. All the filled-out rows are now ungrouped and the remaining empty rows can be hidden again by scrolling to the bottom of the table and clicking the "-" sign to the left:



		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
		#N/A
Losses	6.260.800	17,2%
Not mapped	- 4.155.129	-11,4%
Total	**36.400.000**	**100,0%**
Mapping degree	111%	

5. You are now left with a table containing all the new processes. This can be repeated for the remaining utility systems where processes have been added to the tables.



Steam	kWh	Share
Process A	4.228.440	11,6%
Process B	13.500.000	37,1%
Process F	4.168.389	11,5%
Heating air for Process I	5.397.500	14,8%
New Process AA	1.000.000	2,7%
New Process BB	1.000.000	2,7%
New Process CC	1.000.000	2,7%
New Process DD	1.000.000	2,7%
New Process EE	1.000.000	2,7%
New Process FF	1.000.000	2,7%
New Process GG	1.000.000	2,7%
Losses	6.260.800	17,2%
Not mapped	- 4.155.129	-11,4%
Total	36.400.000	100,0%

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54 Hai Ba Trung, Cua Nam ward, Hanoi, Viet Nam
024. 2220 5528