PULP AND PAPER

Vietnam September 2015

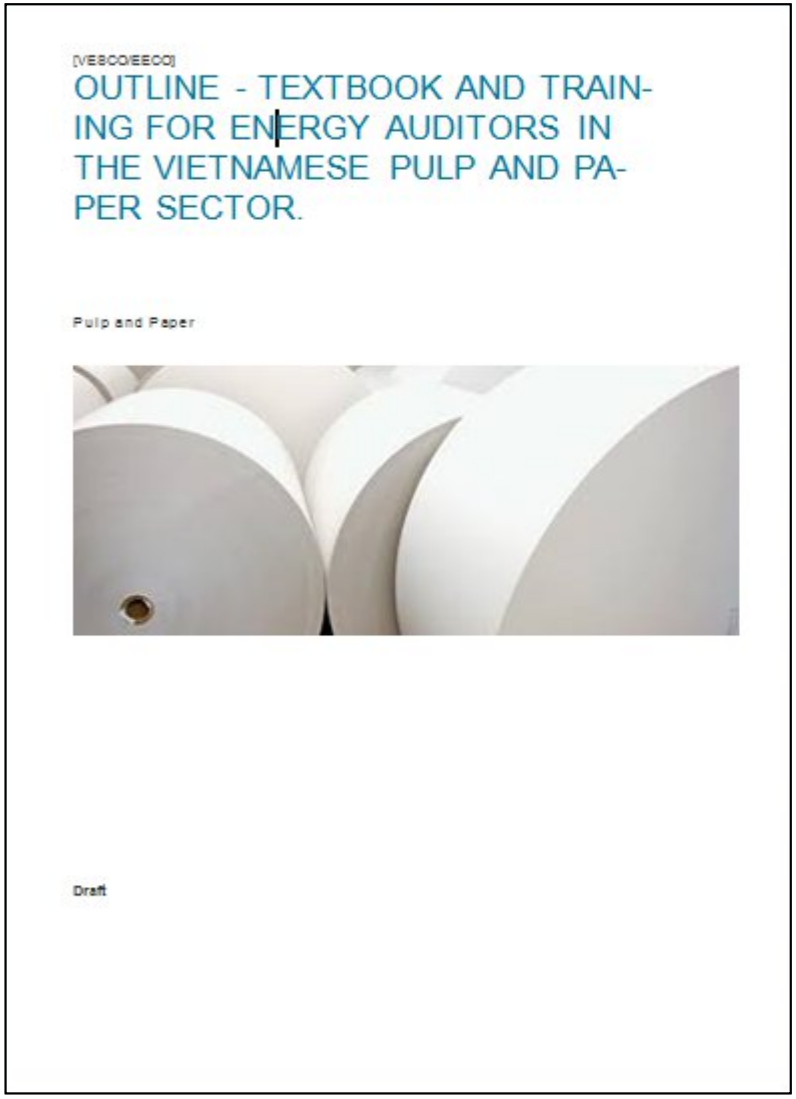


AGENDA

- Introduction to the handbook

- Introduction to the training program
  - Day one: Audit
  - Day two: Production
  - Day three: Utility
  - Day four: Site visit

INTRODUCTION TO THE HANDBOOK



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OUTLINE - TEXTBOOK AND TRAINING FOR ENERGY AUDITORS IN THE VIETNAMESE PULP AND PAPER SECTOR.

Pulp and Paper

Draft

INTRODUCTION TO THE HANDBOOK

- **1 Introduction to pulp and paper in Vietnam**
- **2 Overview pulp and paper production**
  - 2.1 Overview
  - 2.2 Production process of pulp and paper
  - 2.3 Energy use in the Vietnamese pulp and paper sector
  - 2.4 Specific energy consumption and benchmark
- **3 Efficiency Analysis, Energy Management and Energy Audit**
  - 3.1 Energy Audit
  - 3.2 Energy Analysis
  - 3.3 Energy mapping
  - 3.4 Basis thermodynamics in relation to paper production
  - 3.5 Energy Management and good housekeeping
- **4 Energy efficiency in the pulp and paper production**
  - 4.1 Energy efficiency related to pulping and pre-treatment
  - 4.2 Energy efficiency related to paper production
  - 4.3 Emerging Energy Efficiency Technologies

INTRODUCTION TO THE HANDBOOK

- **5 Energy Efficiency in Utility Systems**
  - 5.1 Electrical Efficiency
  - 5.2 Thermal Efficiency
  - 5.3 Combined heat and power
  - 5.4 Heat pumps
- **6 Bibliography**
- **7 Appendix**
  - 7.1 Acronyms and definitions
  - 7.2 Symbols
  - 7.3 Units and Conversion factors
  - 7.4 Legal regulations
  - 7.5 EU Commission implementing decision of 26 Sep. 2014
  - 7.6 Additional Energy savings measures

INTRODUCTION TO THE TRAINING PROGRAM

- **Day one: Introduction and Audit**
  - **Morning: Class room training and exercise**
  - **Afternoon: Class room training and exercise**
- Day two: Production
  - Morning: Class room training and exercise
  - Afternoon: Class room training and exercise
- Day three: Utility
  - Morning: Class room training and exercise
  - Afternoon: Class room training and exercise
- Day four: Site visit
  - Morning: Site visit
  - Afternoon: Evaluation

INTRODUCTION (I)

- The main products of Vietnam's pulp and paper sector are:
  - Newsprint
  - Printing-writing paper
  - Packaging paper
  - Tissue paper:
  - Joss paper:

  - Pulp is produced from two kinds of different materials, which are:
    - Plant fibre materials such as wood, bamboo wood
    - Waste paper.

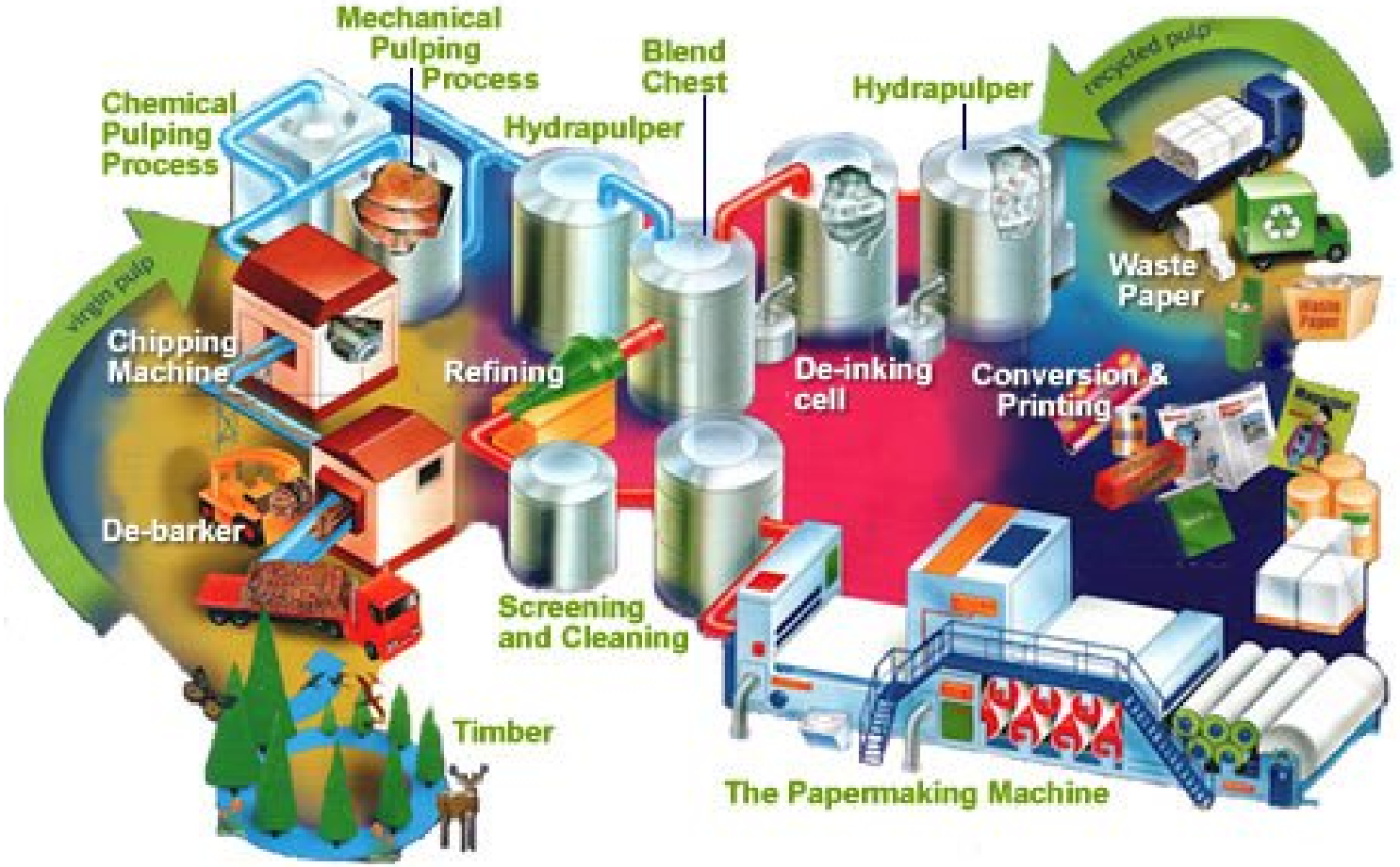
INTRODUCTION (II)

Pulp types	Capacity (Ton)	Production (Ton)	Domestic demand (Ton)	Important (Ton)	The percentage of meeting domestic demand (%)	Ghi chú Notes
BHKP	205,000	190,000	268,000	78,000	70.9	Although the operation is in 100% of the capacity, it is inadequate to meet domestic demand
UHKP	120,000	80,000	95,000	15,000	84.2	Full capability to meet domestic demand
Mechanical pulp	-	-	-	-	-	There is only one production line in Tan Mai Jsc, now it is stopping working temporaryly.
Semi-chemical pulp	120,000	90,000	90,000	-	-	Vietnam meets domestic demand and doesn't require to import. The production of this pulp supply mainly exported joss paper manufacturing

INTRODUCTION (III)

Pulp types	Capacity (Ton)	Production (Ton)	Domestic demand (Ton)	Important (Ton)	The percentage of meeting domestic demand (%)	Ghi chú Notes
Newsprint	45,000	35,000	92,000	57,000	38	Although the operation is in 100% of the capacity, it is inadequate to meet the domestic newsprint demand
Printing-writing paper	545,000	242,000	387,000	145,000	62.53	Provide fully domestic consumer demand. However, it is inadequate to meet paper demand of high quality products such as chalk coated paper, light weight coated (LWC) paper
Packaging paper	1,700,000	1,280,000	1,965,000	685,000	65.1	
Tissue paper	-	208,000	-	-	-	Export 36,000 tons in 2014
Joss paper	-	-	-	-	-	Do not serve to the domestic demand, mainly export to Taiwan, Malaysia
Other paper	-	-	-	-	-	Import 100% demand

INTRODUCTION (IV)



AUDIT

- Energy audit
- Energy analysis
- Energy mapping
- Basis thermodynamics
- Management and good house keeping

AUDIT – ENERGY AUDIT (I)

What is an energy audit?

- An **energy audit** is an inspection, survey and analysis of energy flows for energy censervation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s).
- In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expense and carbon footprints
- http://en.wikipedia.org/wiki/Energy_audit

- Energy audit is an activity toward to establish the energy efficiency programs. Energy audit includes activities to detect, identify opportunities to save energy, then implement energy saving programs accordingly.
- Handbook



AUDIT – ENERGY AUDIT (II)

Why conduct an energy audit?

- Create an overview and herby identify savings
- Energy costs reduction
- Production costs reduction
- Emission reduction
- Conservation of fossil energy sources
- Initiate a plan for future improvements an optimisations





AUDIT – ENERGY AUDIT (III)

Who must participate:

- Technical staff
- Operators
- Management
- Maintenance department
- Suppliers
- Financial department
- IT
- Etc.

AUDIT – ENERGY AUDIT (IV)

Energy audit – Standards

- ISO 50002
- **EN 16247 – Part 1: General requirements**
- EN 16247 – Part 2: Buildings
- EN 16247 – Part 3: Processes
- EN 16247 – Part 4: Transport



AUDIT – ENERGY AUDIT (V)

Energy audit process – EN 16247

The energy audit process shall be*:

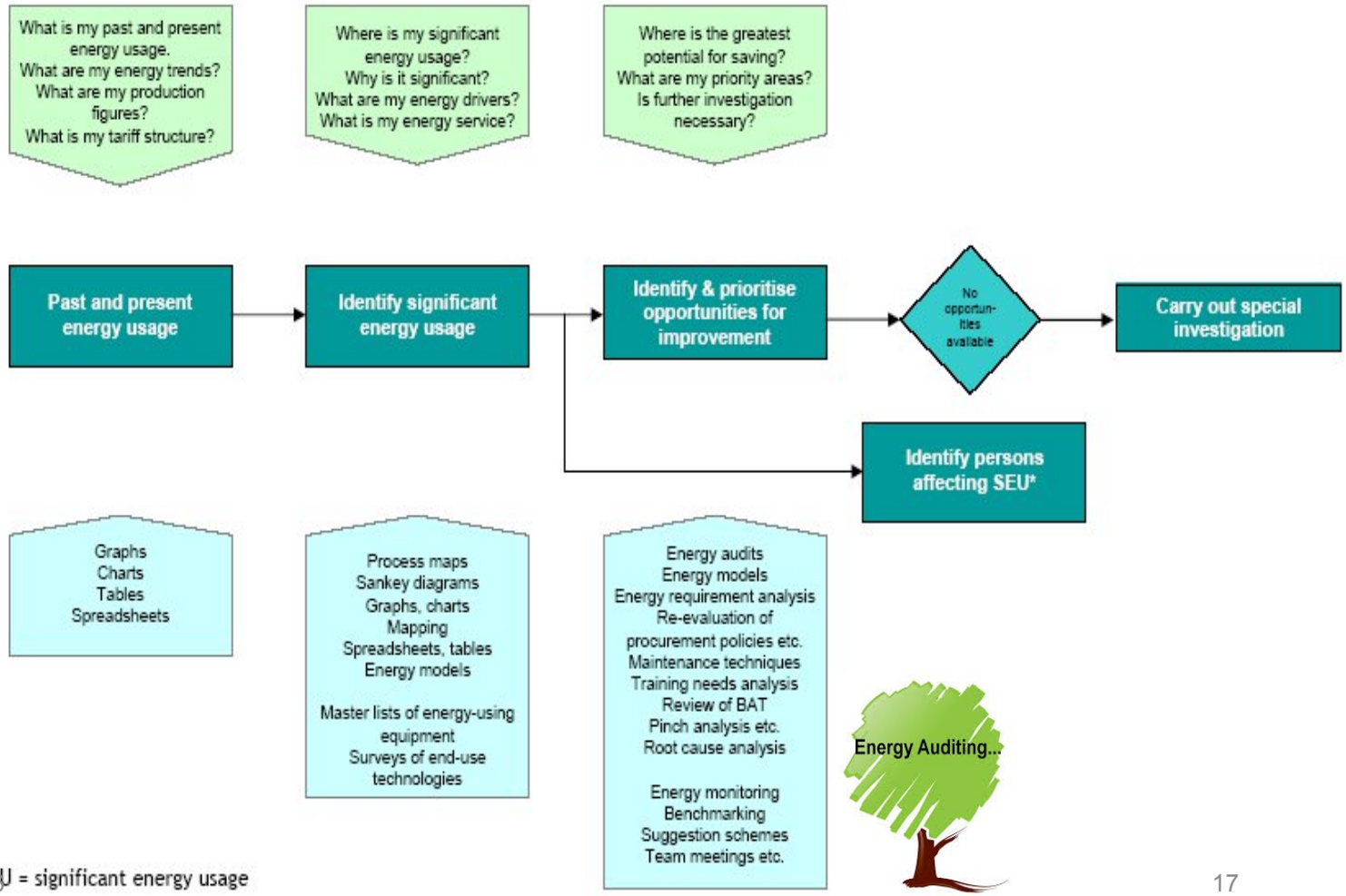
- **appropriate:** suitable to the agreed scope, aims and thoroughness
- **complete:** in order to define the audited object and the organisation
- **representative**: in order to collect reliable and relevant data
- **traceable:** in order to trace the origin and processing of data
- **useful:** in order to include a cost effectiveness analysis of the energy saving opportunities identified
- **verifiable**: in order to allow the organisation to monitor the achievement of the targets of implemented energy efficiency improvement opportunities



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (VI)

Energy audit process overview



AUDIT – ENERGY AUDIT (VII)

Elements of the energy audit process (I)

- a) The energy auditor shall agree with the organisation on*:

  1) aims, needs and expectations concerning the energy audit;
  2) scope and boundaries;
  3) degrees of thoroughness required;
  4) timescale to complete the energy audit;
  5) criteria for evaluating energy efficiency improvement measures (e.g. pay back period);
  6) time commitments and other resources from the organisation;
  7) requirement for data to be collected prior to the energy audit commencing and the availability, validity and format of the energy and activity data;
  8) foreseeable measurement and/or inspection to be made during the energy audit.



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (VII)

Elements of the energy audit process (II)

- b) The energy auditor shall request information about*:

  1) the energy audit context;

  2) regulatory or other constraints affecting the scope or other aspects of the proposed energy audit;

  3) strategic wider programme (planned projects, outsourcing facilities management);

  4) management system (environmental, quality, energy management system or others);

  5) changes that may have a bearing on the energy audit and its conclusions;

  6) any existing opinions, ideas and restrictions relating to potential energy efficiency improvement measures;

  7) expected deliverables and required format of the report;

  8) whether a draft of the final report to the organisation should be presented for comment.



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (VIII)

Elements of the energy audit process (III)

- c) The energy auditor shall inform the organisation of any*:

  1) special facilities and equipments required to enable the energy audit to be carried out;

  2) commercial or other interest which could influence his or her conclusions or recommendations.

* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (IX)

Start-up meeting (I)

- a) The energy auditor shall request the organisation to*:

1) nominate the person ultimately responsible for the energy audit within the organisation;

2) nominate a person to liaise with the energy auditor, where necessary supported by other appropriate individuals constituted as a team for the purpose;

3) inform affected personnel and other interested parties about the energy audit and any requirements placed on them in connection with it;

4) ensure the cooperation of the affected parties;

5) disclose any unusual conditions, maintenance work or other activities that will occur during the energy audit. or other interest which could influence his or her conclusions or

* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (X)

Start-up meeting (II)

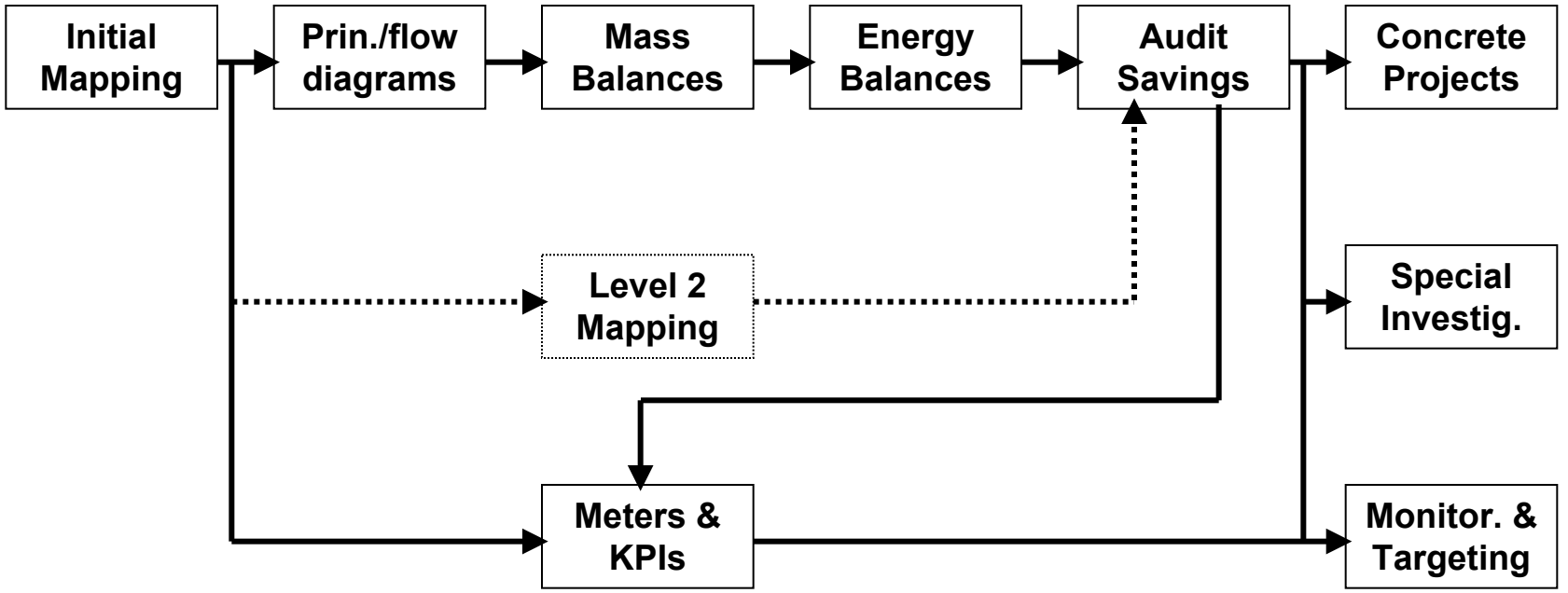
- b) The energy auditor shall agree with the organisation on*:

1) arrangements for access for the energy auditor;
2) safety and security rules;
3) resources and data to be provided;
4) non-disclosure agreements (e.g. tenants in a building);
5) proposed schedule of visits with priorities for each;
6) requirements for special measurements;
7) procedures to be followed for installation of measuring equipment, if needed.

* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (XI)

Work flow in a energy audit



AUDIT – ENERGY AUDIT (XII)

Detailed energy audit - level 1 mapping:

- Identify consumption (energy and mass balance level)
  - Unit of operation ideal/ non-Ideal
  - Utility's
  - Losses
- Identify who is influencing the consumption
- Detailed mapping based on:
  - Theory
  - Measurements
  - Testing
  - Experience from similar operations
  - Data collection



AUDIT – ENERGY AUDIT (XIII)

Preliminary energy audit - level 2 mapping:

- Overview on a overall level
- Types of energy use
- Mapping is based on existing information
- Savings only based on estimates and exciting information's
- Basis for further investigation and level 1 mapping



AUDIT – ENERGY AUDIT (IXV)

Collecting data (I)

The energy auditor shall, in cooperation with the organisation, collect the following (where available)*:

- a) list of energy using systems, processes and equipment
- b) detailed characteristics of the audited object(s) including known adjustment factors and how the organisation believes they influence energy consumption
- c) historical data:
  1) energy consumption;
  2) adjustment factors;
  3) relevant related measurements.
- d) operational history and past events that could have affected energy consumption in the period covered by the data collected



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (XV)

- **Collecting data (II)**
- e) design, operation and maintenance documents
- f) energy audits or previous studies related to energy and energy efficiency
- g) current and projected tariff, or a reference tariff to be used for the protection of commercial confidence
- h) other relevant economic data
- i) the status of the energy management system



AUDIT – ENERGY AUDIT (XVI)

Field work (I)

Aim of field work - The energy auditor shall*:

- a) inspect the object(s) to be audited;
- b) evaluate the energy use of the audit object(s) according to the aim, scope and thoroughness of the energy audit;
- c) understand the operating routines, user behaviour, and their impact on energy consumption and efficiency;
- d) generate preliminary ideas for energy efficiency improvement opportunities;
- e) list areas and processes for which additional quantitative data is needed for later analysis.



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (XVII)

- **Field work (II)**

Conduct - The energy auditor shall*:

- a) ensure that measurements and observations are made in a reliable fashion and in situations which are representative of normal operation and, where relevant, under appropriate weather conditions; it is accepted that it may be beneficial to make observations and measurements outside normal working hours, during shut-down periods, or when no climatic load is expected;
- b) promptly inform the organisation of any unexpected difficulties encountered during the work. for which additional quantitative data is needed for later analysis.



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (XVIII)

Field work (III)

Site visits - The energy auditor shall ask the organisation to*:

- a) nominate one or more individuals to act as guide and escort for the energy auditor's personnel during site visits as required; these individuals shall have necessary competences and authority to carry out direct operations on processes and equipment if required;
- b) give the energy auditor access to drawings, manuals and other technical documentation relevant to the installation together with the results of any commissioning tests that have been carried out.

* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (IXX)

Analysis (I)

During this phase, the energy auditor shall establish the existing energy performance situation of the audited object*

- a) The existing energy performance situation becomes a reference against which improvements can be measured. It shall include:
  1) a breakdown of the energy consumption by use and source;
  2) energy flows and an energy balance of the audited object;
  3) pattern of energy demand through time;
  4) relationships between energy consumption and adjustment factors;
  5) one or more energy performance indicators suitable to evaluate the audited object.

* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (XX)

Analysis (II)

Based on the existing energy performance situation of the audited object, the energy auditor shall identify energy efficiency improvement opportunities.

- b) The energy auditor shall evaluate the impact of each energy efficiency improvement opportunity on the existing energy performance situation based on:
  1) the financial savings enabled by the energy efficiency improvement measures;
  2) the necessary investments;
  3) the return on investment or any other economical criteria agreed with the organisation;
  4) the other possible non-energy gains (such as productivity or maintenance);
  5) the comparison in terms of both cost and energy consumption between alternative energy efficiency improvement measures;
  6) technical interactions between multiple actions.



AUDIT – ENERGY AUDIT (XXI)

Analysis (III)

- c) In those cases where it is appropriate to the agreed scope aim and thoroughness of the energy audit, the energy auditor shall complement these results with:
  1) requirements for additional data;
  2) the definition of need for further analysis.
- d) The energy auditor shall:
  1) evaluate the reliability of data provided and highlight defaults or abnormalities;
  2) use transparent and technically appropriate calculation methods;
  3) document the methods used and any assumption made.
  4) subject the results of the analysis to appropriate quality and validity checks
  5) consider any regulatory or other constraints of the potential energy efficiency improvement opportunities.



AUDIT – ENERGY AUDIT (XXII)

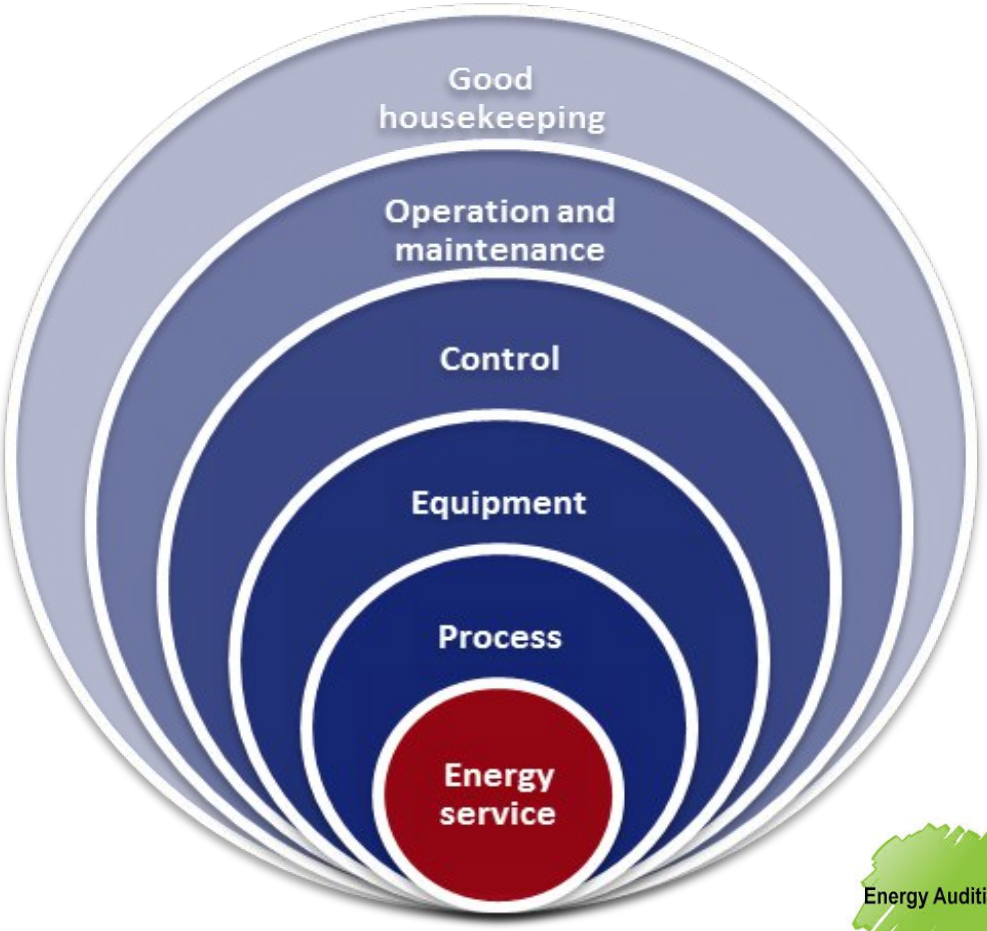
Analysis (IV)

- Historically energy analysis has been approached in many different ways:
  - single equipment analysis,
  - utility system analysis,
  - very detailed analysis taking the starting point at the actual energy service and then working the way out through all the related services.

  This approached is also called the onion diagram approached.



AUDIT – ENERGY AUDIT (XXIII)





AUDIT – ENERGY AUDIT (IXXV)

Analysis - Outcome of the audit (V)

- Concrete projects
  - Savings that can be implemented with just minor efforts
    - Investment projects
    - Improved maintenance
    - Change of process parameters
    - Changed operation of equipment and processes
    - Etc.
- Special investigations
  - Savings that requires more detailed investigations
    - Due to technical complexity
    - Due to cross-organisational involvement
    - Due to required input from external specialists
    - Etc.
- Identified KPI's and energy management-routines



AUDIT – ENERGY AUDIT (XXV)

Report (I)

General - When reporting the results of the energy audit, the energy auditor shall*:

- a) ensure that the energy audit requirements agreed with the organisation have been met;
- b) check the quality of the report before submission to the organisation;
- c) summarise relevant measurements made during the energy audit, commenting on:
  1) consistency and quality of data;
  2) rationale for the measurements and how they contribute to analysis;
  3) difficulties encountered in data collection and field work.

.



* Elements from the EN 16247-1 standard

AUDIT – ENERGY AUDIT (XXVI)

Report (II)

- d) state whether the results of the analysis are on the basis of calculations, simulations or estimates;
- e) summarise the analyses detailing any assumptions;
- f) state the limits of accuracy of estimates of savings and costs;
- g) report the ranking of the energy efficiency improvement opportunities.



AUDIT – ENERGY AUDIT (XXVII)

Report (III)

- **Content of report -** The exact content of the report shall be appropriate for the scope, aim and thoroughness of the energy audit.

- a) Executive summary:
- b) Background:
- c) Energy audit:
- d) Energy efficiency improvement opportunities:
- e) Conclusions.

AUDIT – ENERGY AUDIT (XXVIII)

Final Meeting (I)

At the final meeting, the energy auditor shall*:

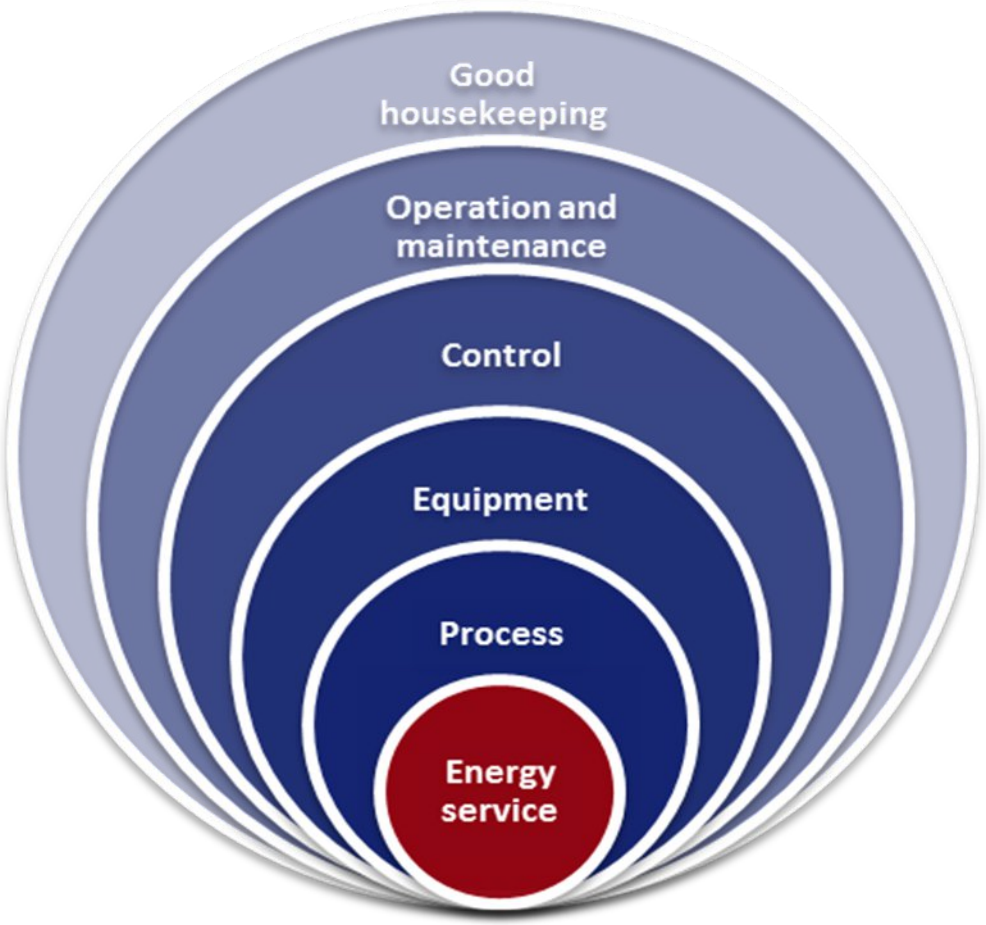
- a) hand over the report on the energy audit;
- b) present the results of the energy audit in a way that facilitates decision making by the organisation;
- c) be able to explain the results.

The need for follow-up shall be discussed and a conclusion shall be reached.

* Elements from the EN 16247-1 standard

ASSIGNMENT NO. 1

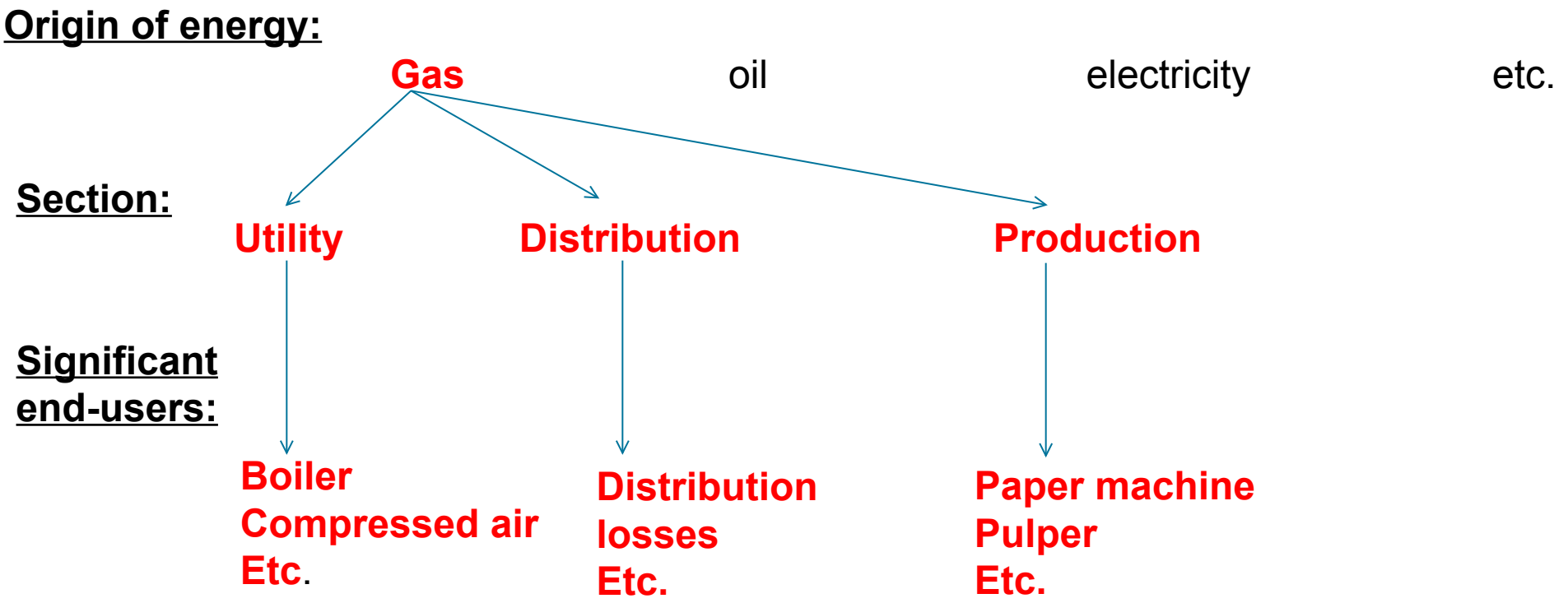
- What can be the consequances of not using the onion diagram approch in a process optimasation process?



AUDIT – ENERGY MAPPING (I)

What is energy mapping ?

Inventory of the energy consumption is devided in to the follwing categoryes:



AUDIT – ENERGY MAPPING (I)

Initial considerations

- Level 1 or 2 mapping
- Basis mapping
  - Distribution of consumption
  - Pie charts
- Add-on analysis
  - Temperature analysis
  - Pinch analysis
  - Effect analysis
  - Sankey diagrams
  - Etc.

AUDIT – ENERGY MAPPING (II)

Exampels of the use of energy mapping

- Overview / visualization of consumption
- Detail Analysis
- Prioritizing areas
- Process Optimization
- Conversion of energy
- Test the effect of changes (process, utilities, etc.).
- Generation of KPIs and objectives (consumption history)
- Basis for benchmark internally / between sites
- Element of energy management
- Revised gross list of projects
- Documentation of energy projects
- Special investigations

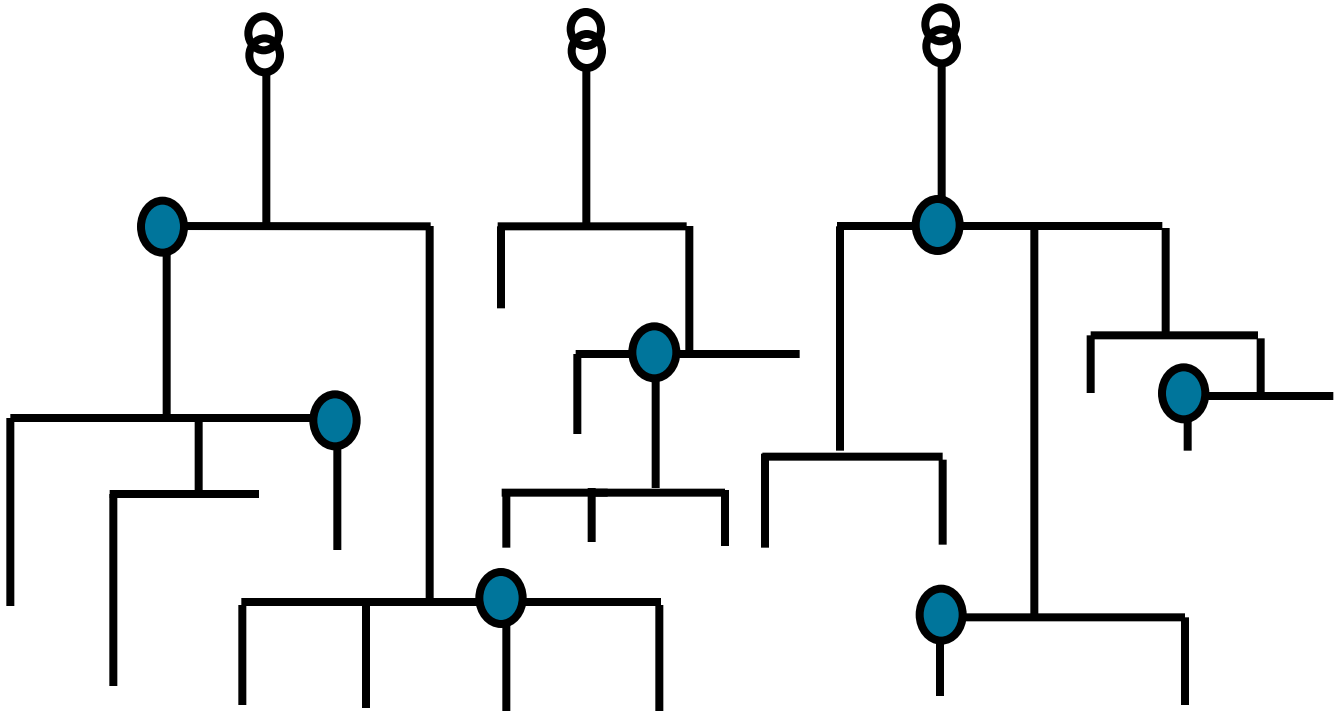
AUDIT – ENERGY MAPPING (III)

Collecting of data

- Operators
- Trends
- Manual readings
- Digital readings
- Experience
- Comparison from similar equipment
- Theoretical calculations
- Information's from suppliers
- Performing tests

AUDIT – ENERGY MAPPING (IV)

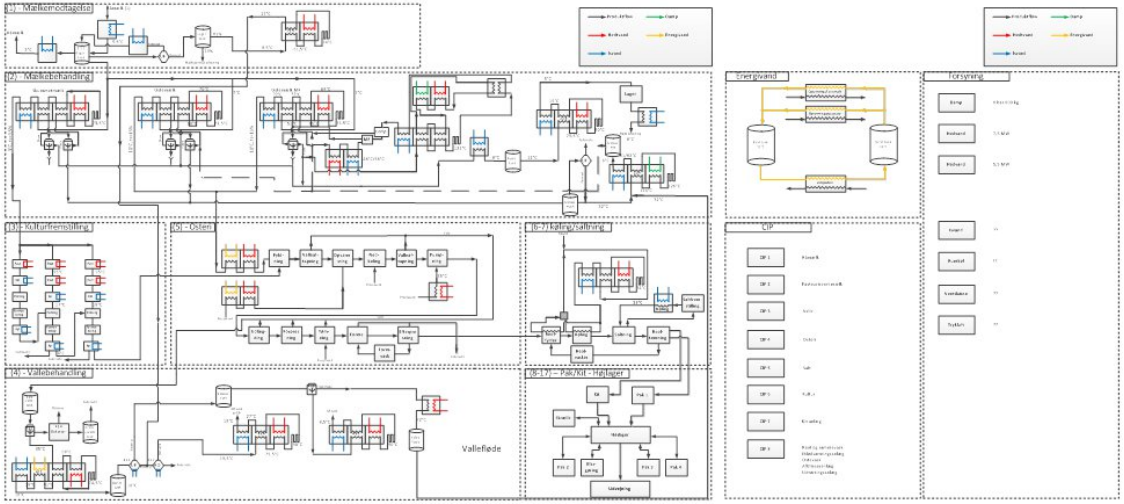
Barrier = Typical Metering Structure

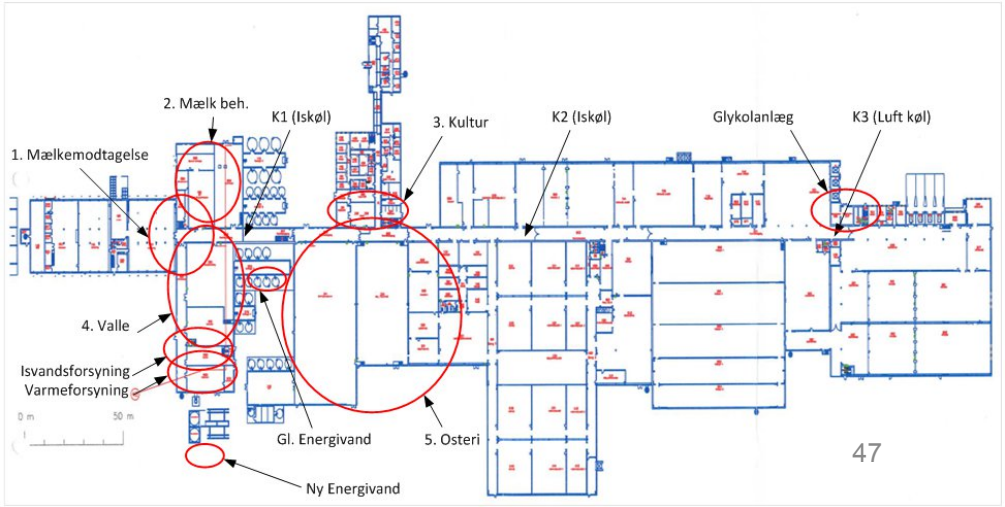


= meter

AUDIT – ENERGY MAPPING (V)

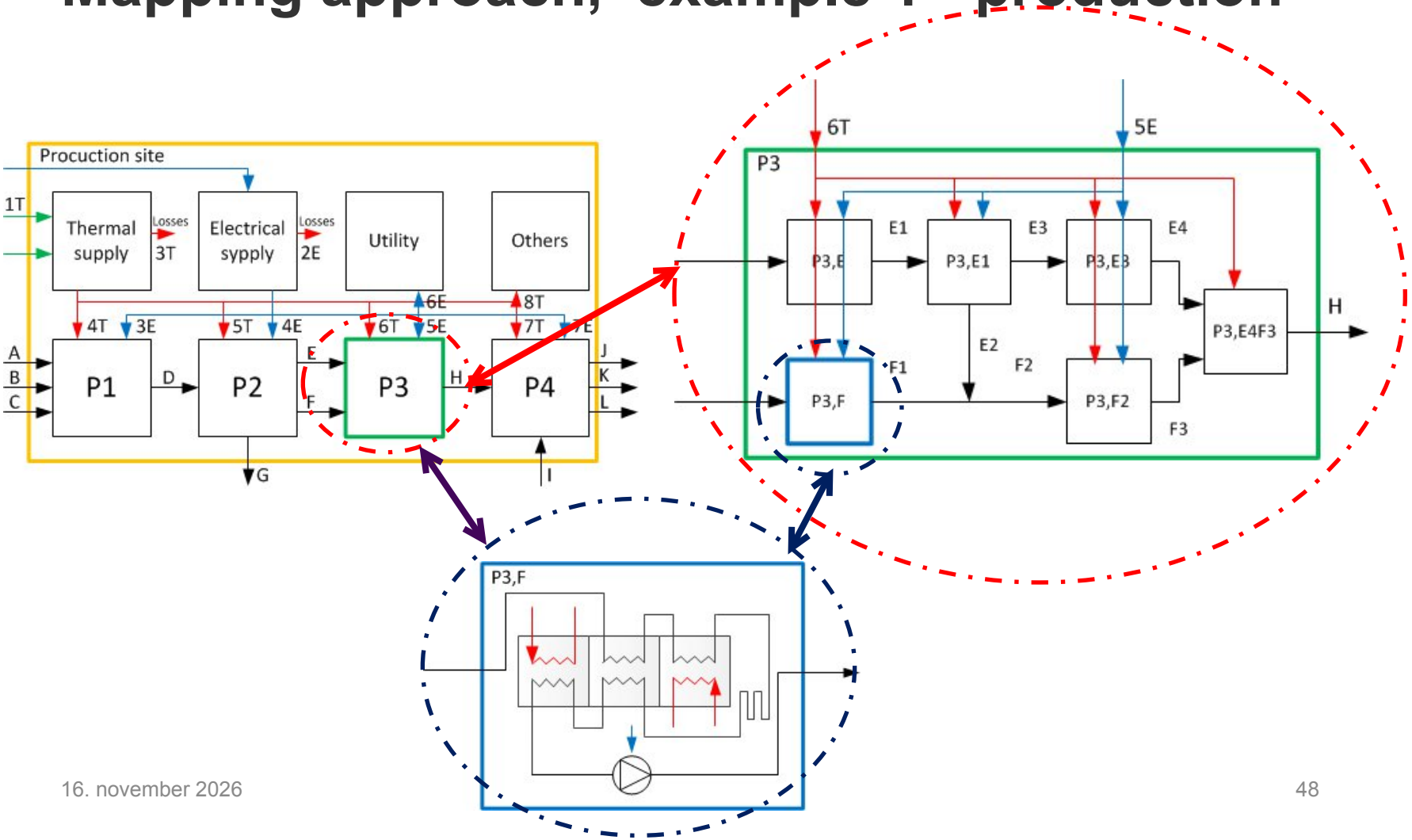
Overviwe





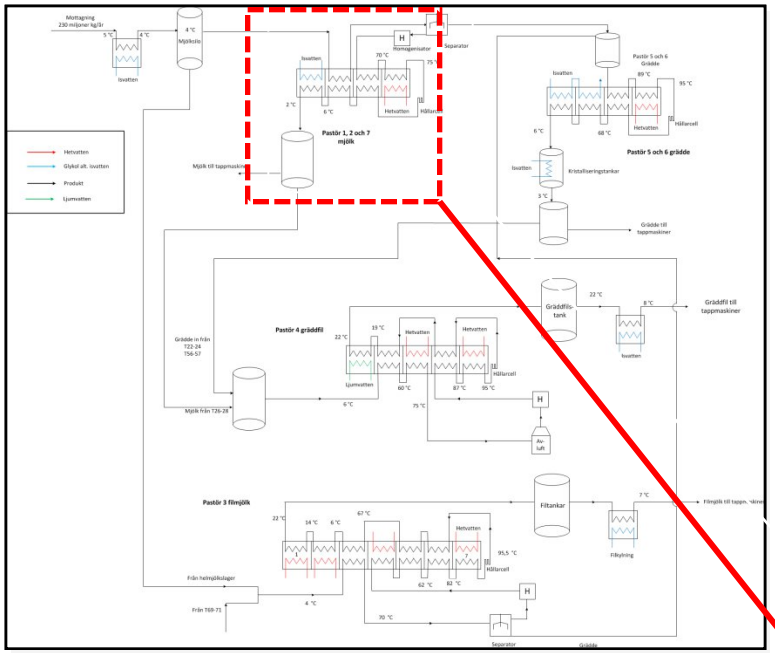
AUDIT – ENERGY MAPPING (VI)

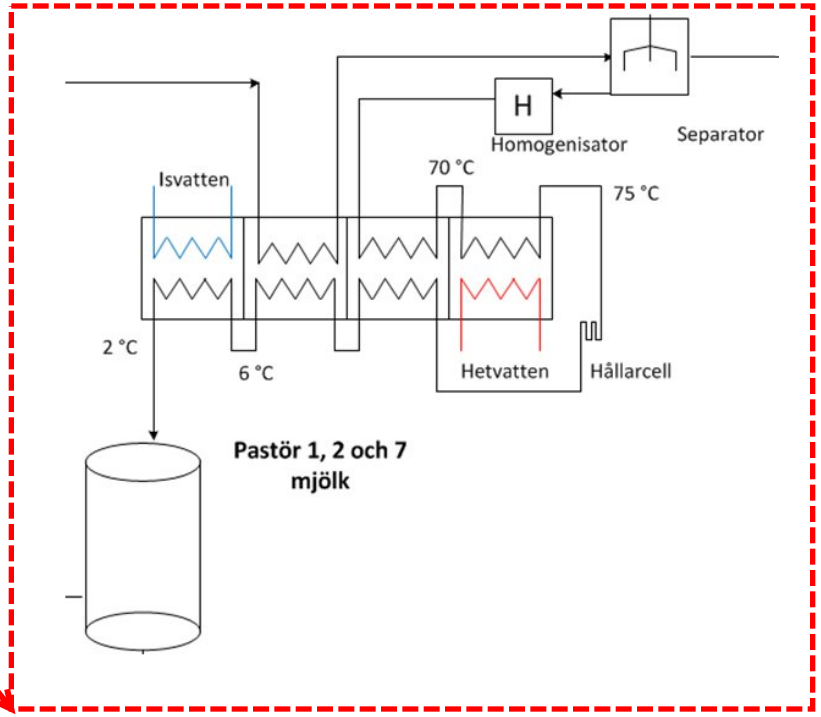
Mapping approach, example 1 - production



AUDIT – ENERGY MAPPING (VII)

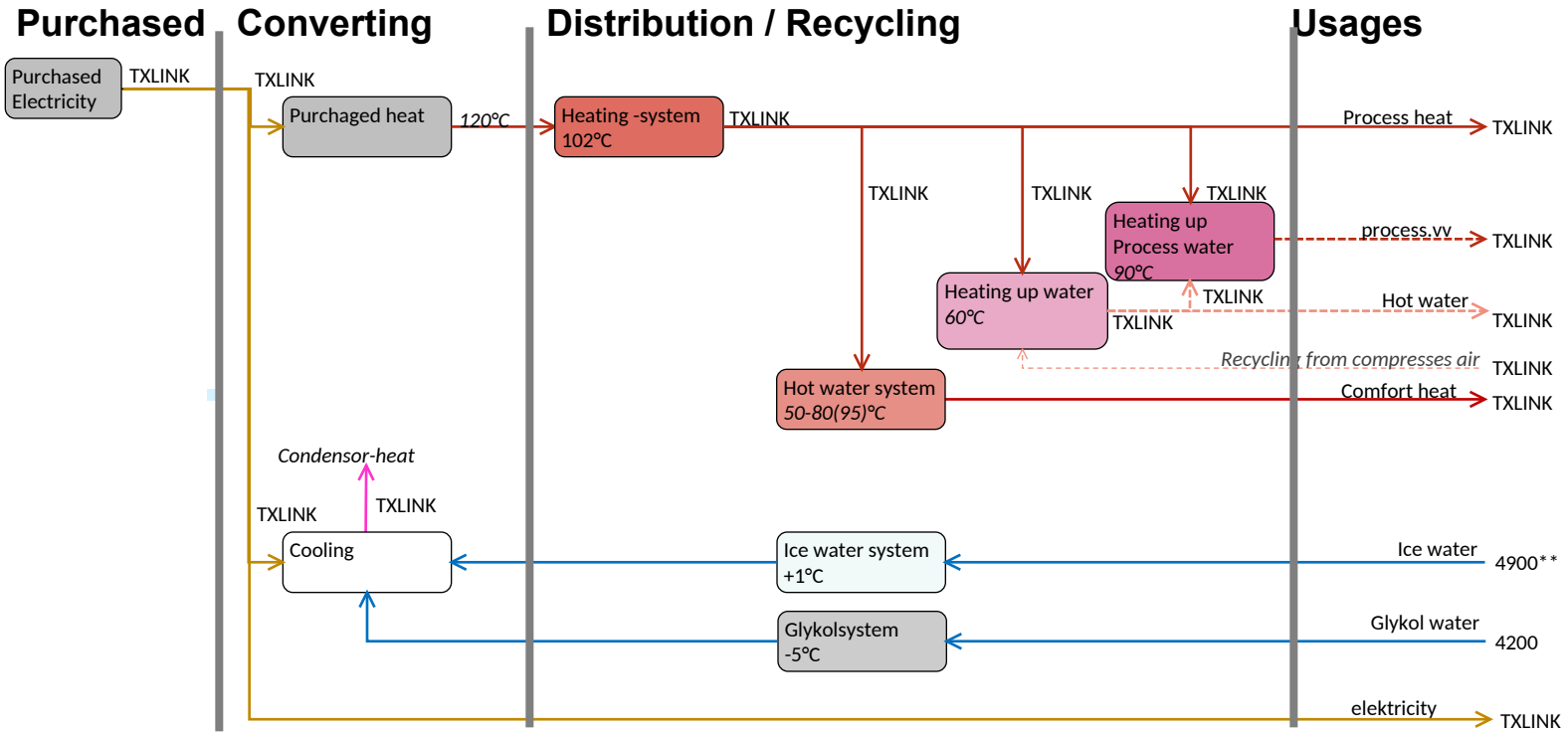
Mapping approach, example 2 - production





AUDIT – ENERGY MAPPING (VIII)

Mapping approach, example 3 – energy supply



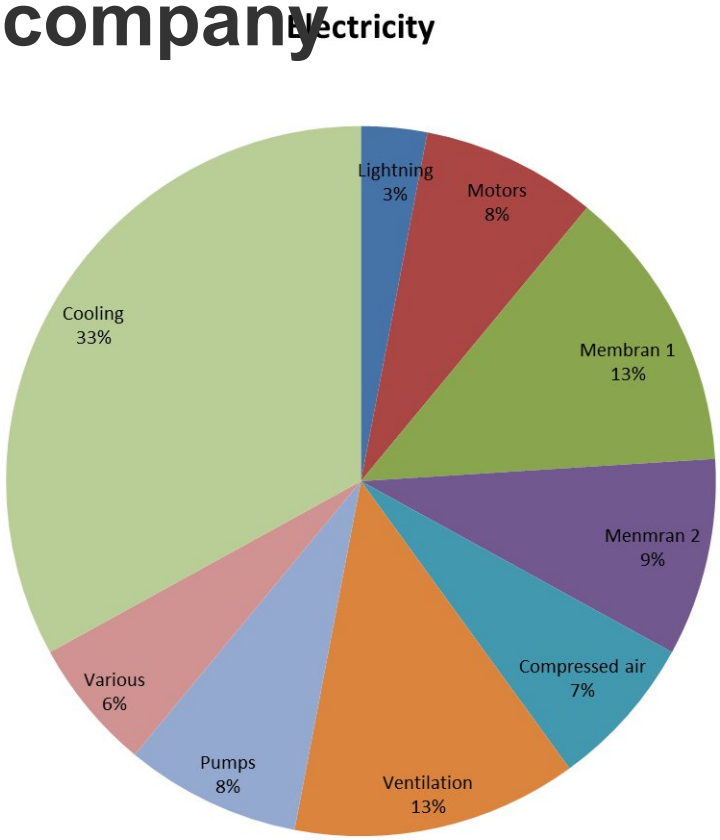
AUDIT – ENERGY MAPPING (IX)

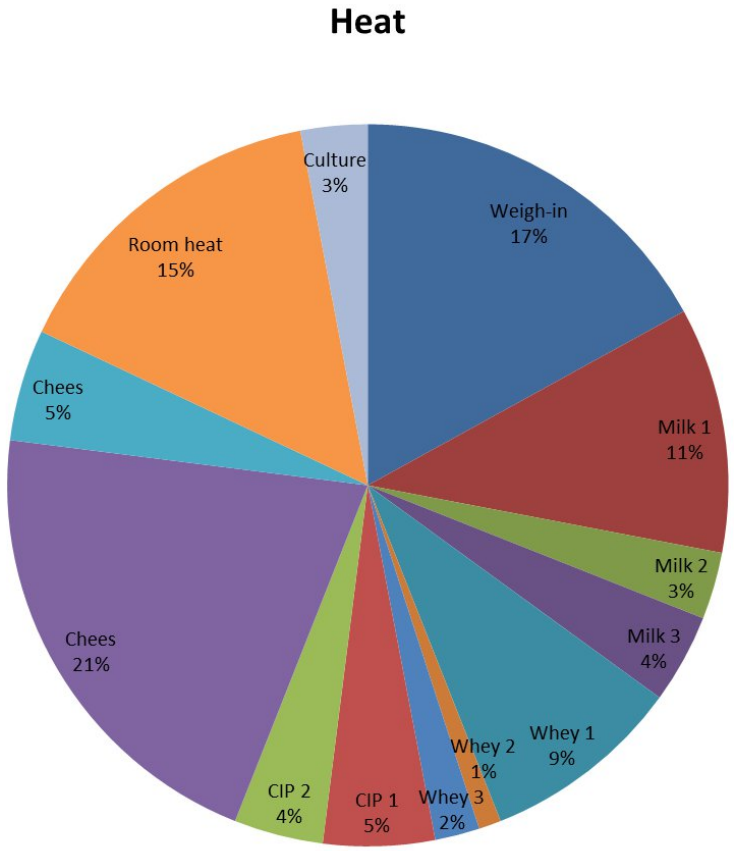
Process mapping

Område	Beskrivning	media	Temp in °C	Temp ut °C	Temperaturnivåer 0 10 20 30 40 50 60 70 80 90	Ånga/FJV/VP kWh	MWh
Pastör 1 - mjölk	Upphettare	ånga	70	74		128 267	128
Pastör 2 - mjölk	Upphettare	ånga	70	74		60 311	60
Pastör 3 - fil	Upphettare P1	ånga	68	95		117 300	117
Pastör 3 - fil	Upphettare P2, cirkulationskrets	ånga	68	78		116 500	117
Pastör 4 - grädde	Upphettare	ånga	90	95		19 900	20
CIP 1 - obeh	Tank 6500 lut - påfyllning	värmevatten berett m FJV o VP	5	65		17 800	18
CIP 1 - obeh	Tank 6500 lut -uppvärmning	ånga	65	75		2 964	3
CIP 1 - obeh	Tank 6600 syra - påfyllning	värmevatten berett m FJV o VP	5	65		17 800	18
CIP 1 - obeh	Tank 6600 syra -uppvärmning	ånga	64,5	65,5		300	0
CIP 2- behand.	Tank 7100 -påfyllning	värmevatten berett m FJV o VP	5	65		325 000	325
CIP 2- behand.	Tank 7101 - uppvärmning	ånga	65	85		108 187	108
CIP 2- behand.	Tank 7200 - påfyllning	värmevatten berett m FJV o VP	5	65		325 000	325
CIP 2- behand.	Tank 7201 - uppvärmning	ånga	65	75		54 093	54
CIP 2- behand.	Tank 7300 - påfyllning	värmevatten berett m FJV o VP	5	65		325 000	325
CIP 2- behand.	Tank 7301 - uppvärmning	ånga	65	95		162 280	162
Sterilisering	Pastör 1-4	ånga	25	95		104 000	104
Uppstarter	pastör 1-4	ånga	20	95		44 000	44
Förpackningsmaskiner	Cip disk tappmaskin B-D lutdisk	ånga	5	80		5 600	6
Förpackningsmaskiner	Cip disk tappmaskin B-D lut/syradisk	ånga	5	65		4 400	4
Förpackningsmaskiner	Cip disk tappmaskin B-D sterildisk	ånga	5	90		1 200	1
Tappvarmvatten	VV	värmevatten berett m FJV o VP	5	65		90 700	91
Total						2 030 602	2031

AUDIT – ENERGY MAPPING (X)

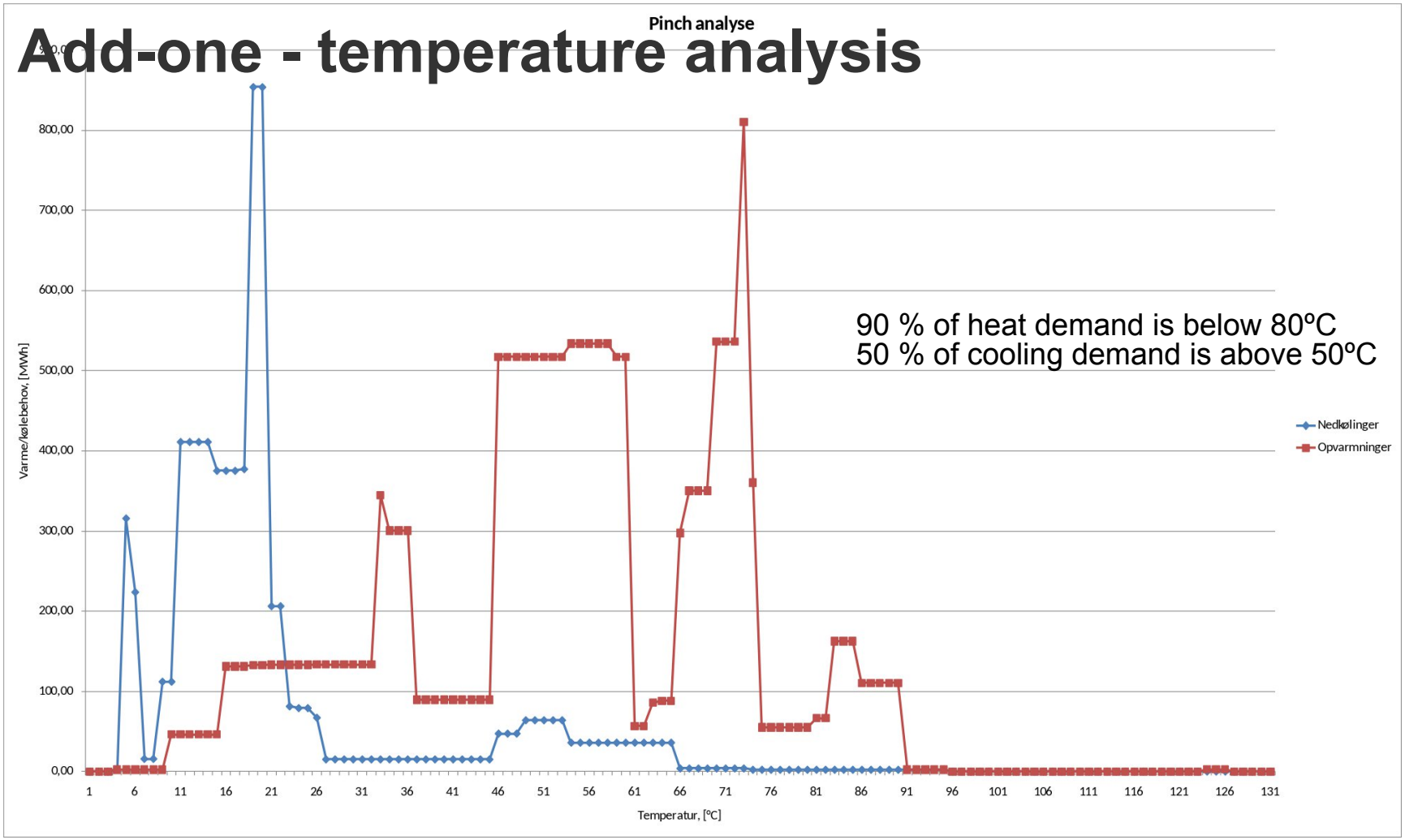
Example of energy distribution in a production company





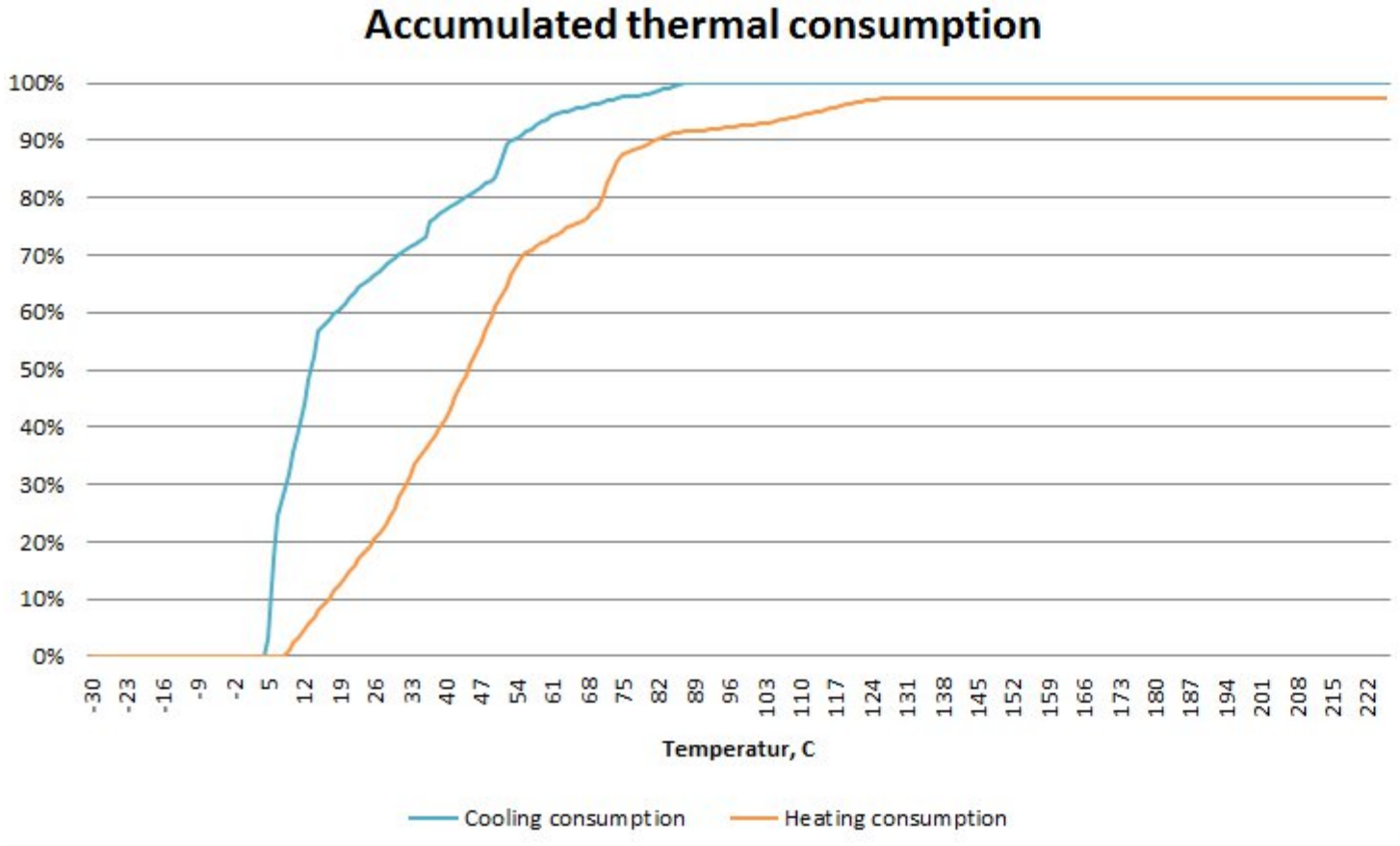
AUDIT – ENERGY MAPPING (XI)

Add-one - temperature analysis



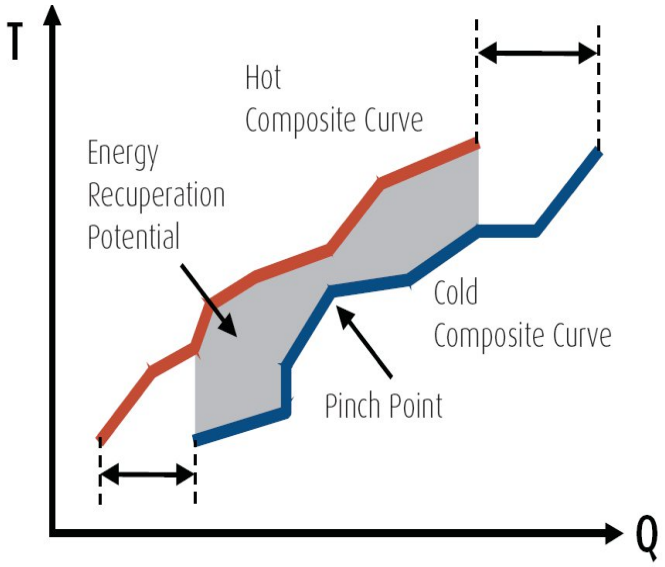
AUDIT – ENERGY MAPPING (XII)

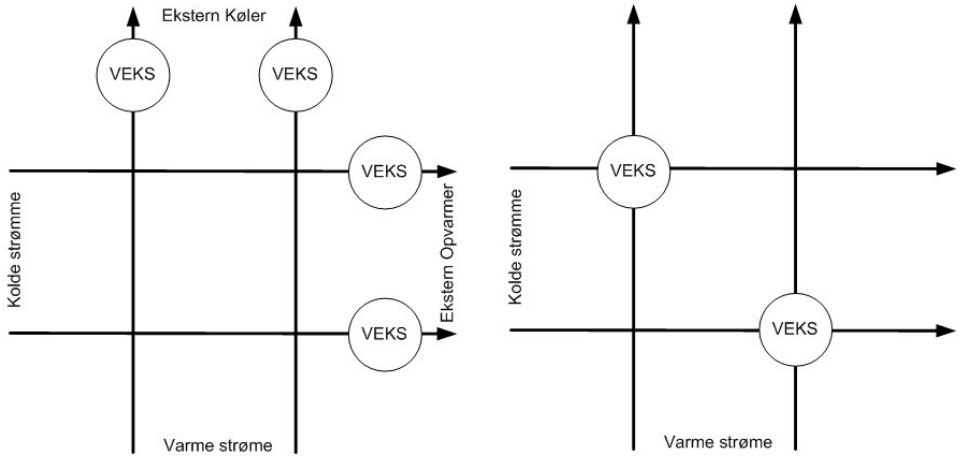
Add-one - temperature analysis



AUDIT – ENERGY MAPPING (XIII)

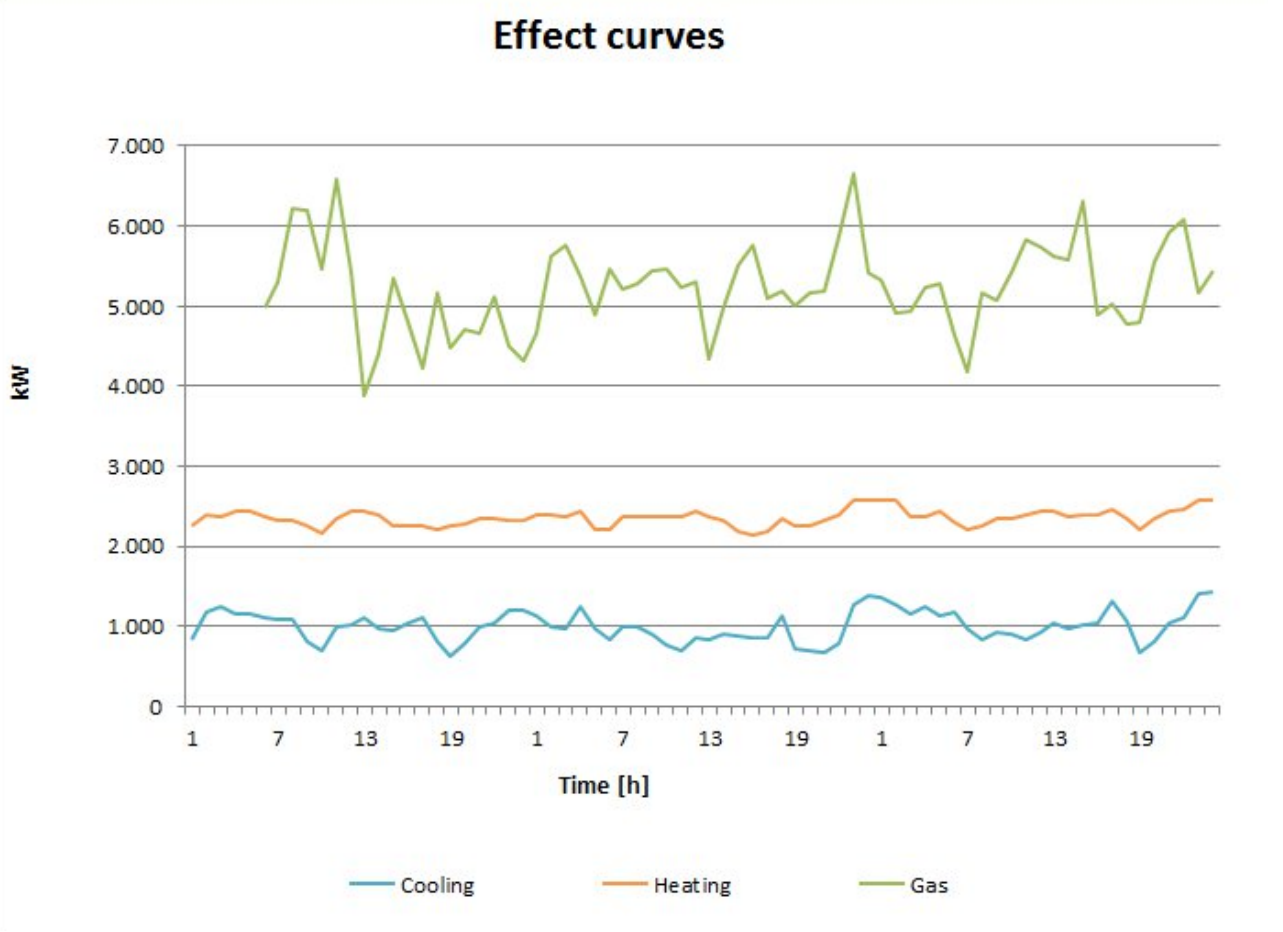
Add-one – pinch analysis





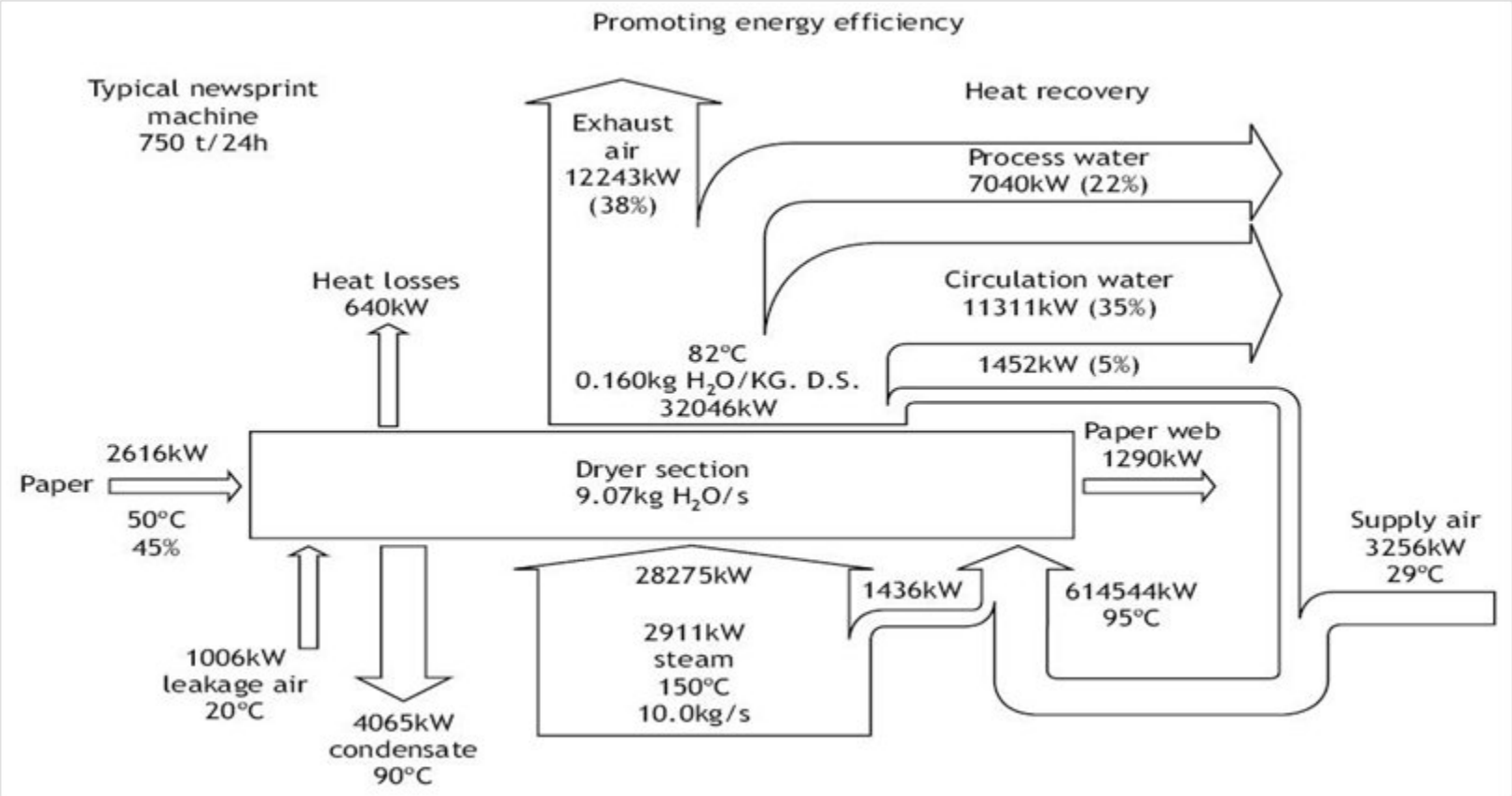
AUDIT – ENERGY MAPPING (IXV)

Add-one – effect analysis



AUDIT – ENERGY MAPPING (XV)

Add-one – Sankey diagram



ASSIGNMENT NO. 2

- What is the benifits of an energy mapping and what add-on analysis can be made?

ASSIGNMENT NO. 3

- List ways of gathering data e.g. from a drying process

ASSIGNMENT NO. 4

- List the 20 larges consumers in the paper and pulp production and devide them in to the following categoryies:

Origin of energy:

Gas oil electricity etc.

Section:

Utility Distribution Production

Significant end-users:

Boiler
Compressed air
Etc.

Distribution losses
Etc.

Paper machine
Pulper
Etc.

AUDIT – BASIS THERMODYNAMICS (I)

- Energy: The word energy is derived from the Greek: en (in or internal) and ergon (force or work). The concept was first formulated in the middle of the 19th century by lord Kelvin and Joule, after many scientists (Benjamin, Thomson, Carnot, Mayer and others) for decades has tried to find relations between mechanical work, power (horse power) and heat.

- Energy can be defined as follows:
  - Energy = motion or ability of motion.

AUDIT – BASIS THERMODYNAMICS (II)

- Potential energy — $W_{potential} = m \times g \times h$
- Electrical energy — $W_{electric} = U \times I \times t$
- Kinetic energy — $W_{kinetic} = ½ \times m \times v^2$
- Chemical energy — Heat value of eg. fuels
- Pressure or external energy — $W_{pressure} = P*V$
- Work — $W = F*S$
- Internal energy — $U = m*c*T$

- Heat

$$\mathbf{Q_{heat} = \Delta U = U2 - U1 = m*c*(T2-T1) = m*c*\Delta T}$$

AUDIT – BASIS THERMODYNAMICS (III)

- According to the **first law of Thermodynamic**, then energy cannot be destroyed.

- For a given system we let ΔE kin = large-scale mechanical energy, ΔE pot = large-scale potential energy, and ΔE tot = total energy. The first two quantities are specifiable in terms of appropriate mechanical variables, and by definition

$$E^{\mathrm{tot}} = E^{\mathrm{kin}} + E^{\mathrm{pot}} + U \ .$$

- For any finite process, whether reversible or irreversible,

$$\Delta E^{\mathrm{tot}} = \Delta E^{\mathrm{kin}} + \Delta E^{\mathrm{pot}} + \Delta U \ .$$

AUDIT – BASIS THERMODYNAMICS (IV)

- The first law in a form that involves the principle of conservation of energy more generally is

$$\Delta E^{\mathrm{tot}} = Q + W \ .$$

- Here Q and W are heat and work added, with no restrictions as to whether the process is reversible, quasistatic, or irreversible

- The fist law of thermodynamic is used to a grate extend in order to determine energy savings potential in the industry.

AUDIT – BASIS THERMODYNAMICS (V)

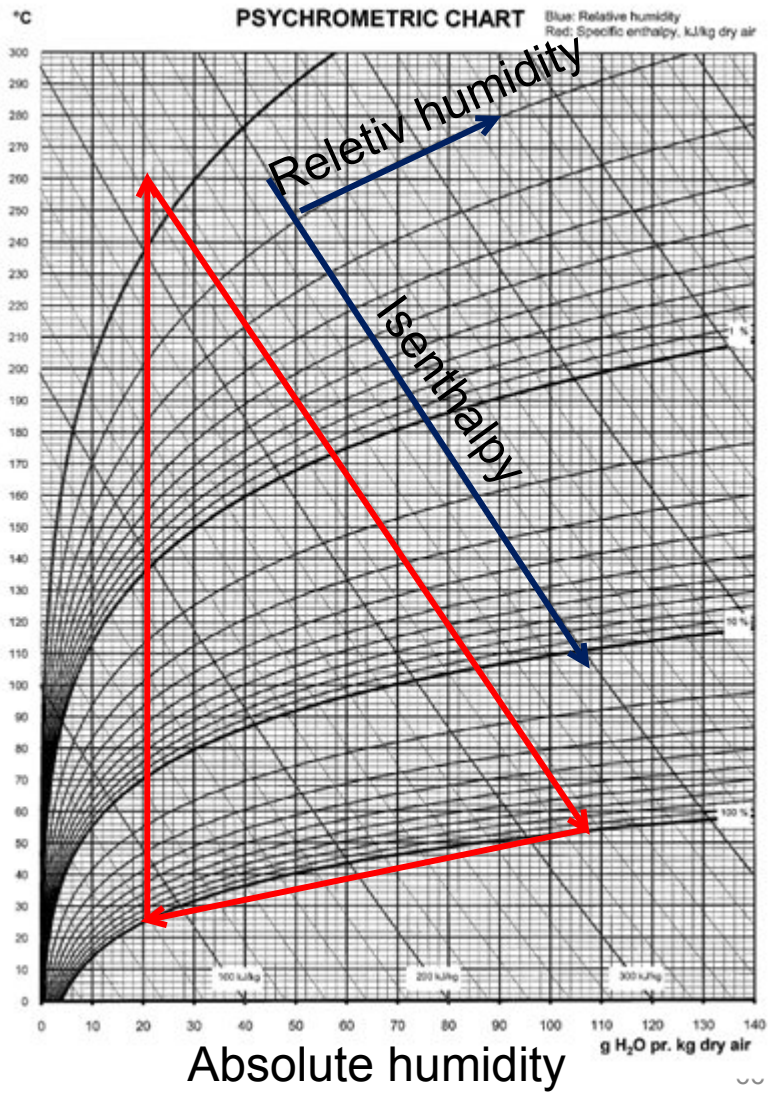
Fundamental of paper drying

- The drying process involved a number parameters that all needs to be in balance in order for the drying process to take place in a optimal way. Some of the most significant are:
  - Steam pressure and temperature
  - Temperature and humidity of air
  - Energy content of steam
  - Heat and mass transfer coefficients

AUDIT – BASIS THERMODYNAMICS (VI)

Properties of air

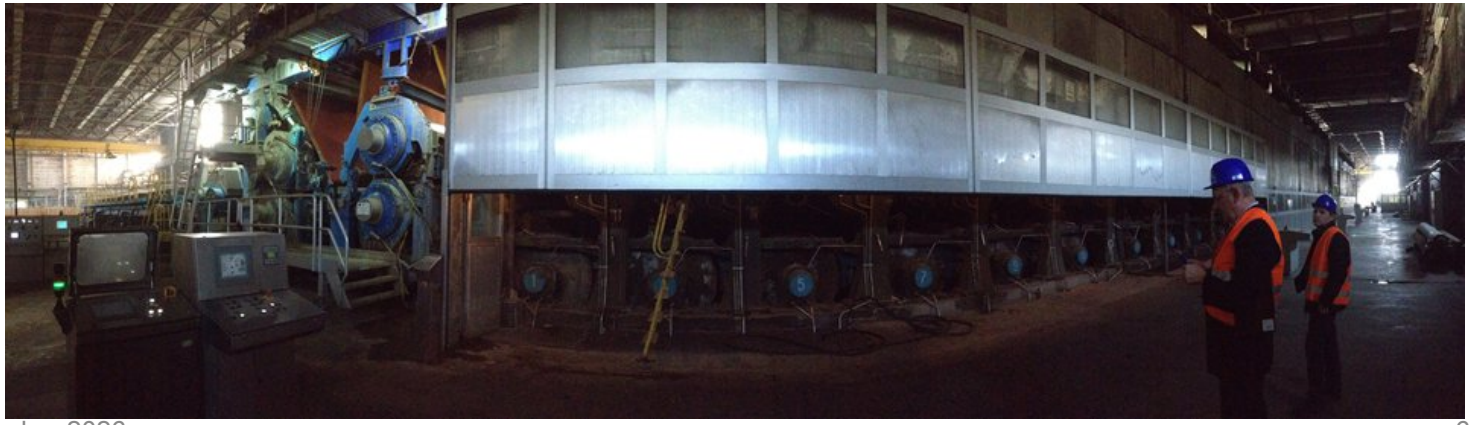
- Atmospheric air
- Hot air
- Cold air



AUDIT – BASIS THERMODYNAMICS (VII)

Types of dryers

- **Steam Cylinders/Cans/Drums** (Conduction)
  - Paper
    Board Paper
  - Steam cylinders are 1.2-1.5 meter in diameter and slightly longer than the width of the paper sheet. A typical paper machine has 40 to over 100 steam cylinders, depending on the line speed; the faster the line speed, the longer the drying section. Typical machines are as long as a football field and 3 to 5 stories tall. They require 0,37 to 0,46 kWh steam input per pound of water dried from the sheet.



AUDIT – BASIS THERMODYNAMICS (VIII)

Types of dryers

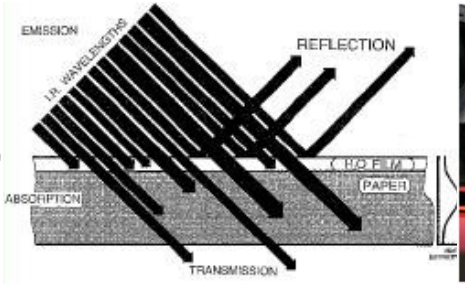


- **Air Dryers** (Convection)
  - Tissue - Yankee Dryer
    Market Pulp - Flakt Dryer

  - Air dryers are direct fired or use steam-to-air heat exchangers to produce a hot air stream that is forced over the surface of the paper. Hoods or 'caps' are used to contain and direct the air flow. Air dryers tend to be used on lighter weights of paper, such as tissues, and to supplement the drying of steam cylinders.
  - A Yankee Dryer is a specific kind of dryer used most commonly for Tissue and Toweling manufacturing that combines a large steam cylinder and an air hood.
  - The Flakt Pulp Dryer is also a special kind of air dryer that is used to dry "market pulp" (Pulp that is made in one location and sold for final paper manufacturing at another location). A Flakt Dryer is constructed in decks that the pulp serpentines through as hot air is blasted through it by a series of jets.

AUDIT – BASIS THERMODYNAMICS (IX)

Types of dryer



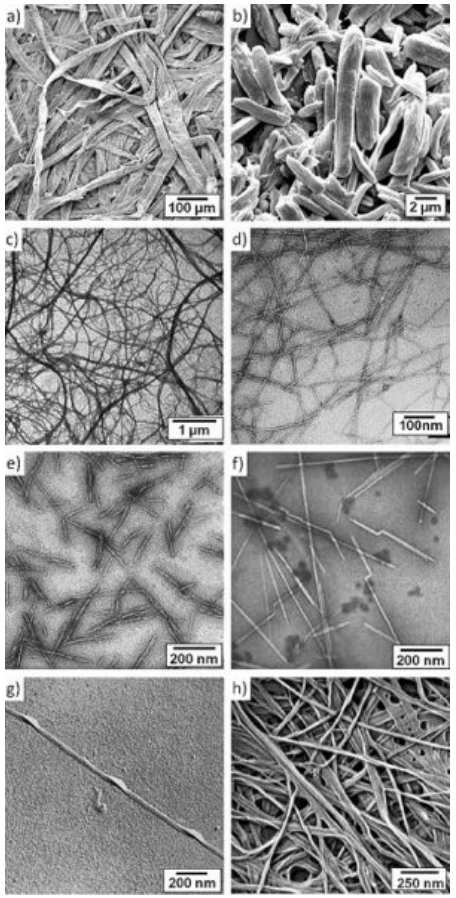


- **Infrared Dryers** (IR) (Radiation)
  - Coatings - Non-contact Dryer
  - IR Dryers produce infrared radiation from a hot surface. Different wave lengths are produced from different kinds of heaters and varies with temperature. How receptive a material is to IR energy is a function of its surface reflectance and the IR wavelength. The more receptive the material, the higher the IR system efficiency.
  - Natural Gas IR Heaters operating at about 1,000 °C produce an IR wave-length between 2 and 3.5 microns. This is also the segment that both paper and water have a high receptiveness. When the IR energy is absorbed by the surface water, its temperature rapidly increases and it evaporates. When the paper absorbs the IR, its temperature also increases and drives out the moisture from within the sheet. The net effect is a very efficient system that uses over 50% of the available energy to dry the sheet. In some applications the exhaust gas can be recovered to pre-heat incoming air and further increase efficiency.

AUDIT – BASIS THERMODYNAMICS (X)

Partial vapour pressure

- At the beginning of the drying process then the partial pressure is equal to the partial pressure of free water
- In the end of drying, partial vapour pressure on the web surface is lower than for free water surface at the corresponding temperature. This is because diffusion from the interior from the web controls vapour transport to the web surface and the hygroscopic nature of pulp fibres.



Cellulose fibers

Calculation: ln(p) = A – B/(T+C), where

p partial pressure, kPa

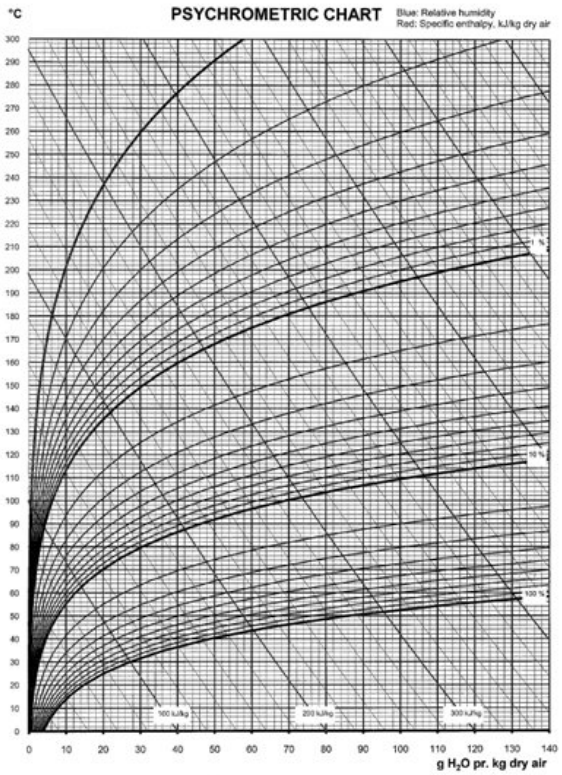
T temperature, Abs

A, B, C are constants; A= 8.007131; B = 1730.630; C= 233.426

AUDIT – BASIS THERMODYNAMICS (XI)

Relative humidity

- Relative humidity is the ratio between the amount of water contained in the air and the total amount it can contain at the same temperature and is expressed as percentage. When relative humidity reaches 100%, the air is said to be saturated and water vapour condenses in the air and falls out as small droplets. Relative humidity can be calculated from the following equation:



Calculation: **RH = p*100 /P_s**, where

RH % relative humidity

P partial vapour pressure, kPa

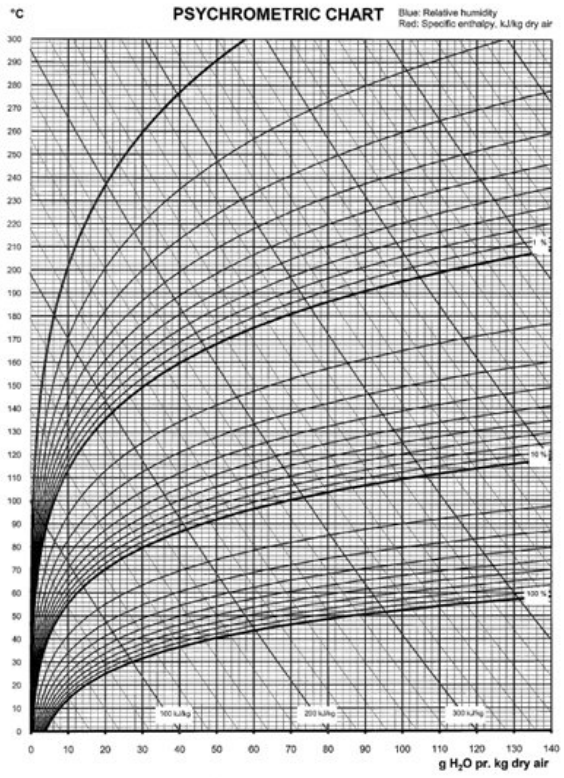
P_s saturated vapour pressure of water at temperature T.

Can water evaporate at a relatively humidity at 100%?

AUDIT – BASIS THERMODYNAMICS (XII)

Absolute humidity

- Absolute humidity refers to the moisture content of the air and the typical units are kg H2O/kg dry air. Psychometric chart could be used to obtain humidity value provided wet and dry bulb temperatures are known. Alternatively, it can be calculated from the partial vapour pressure of water in the air from the following equation:



Calculation: **H = Mw x p / [Ma x (P – p)]** , where

H	absolute humidity, H2O/kg dry air
p	partial vapour pressure, kPa
P	barometric pressure, kPa
Mw	Molecular weight of water: 18.02
Ma	Molecular weight of air: 28.97

AUDIT – BASIS THERMODYNAMICS (XIII)

Sorption isotherm

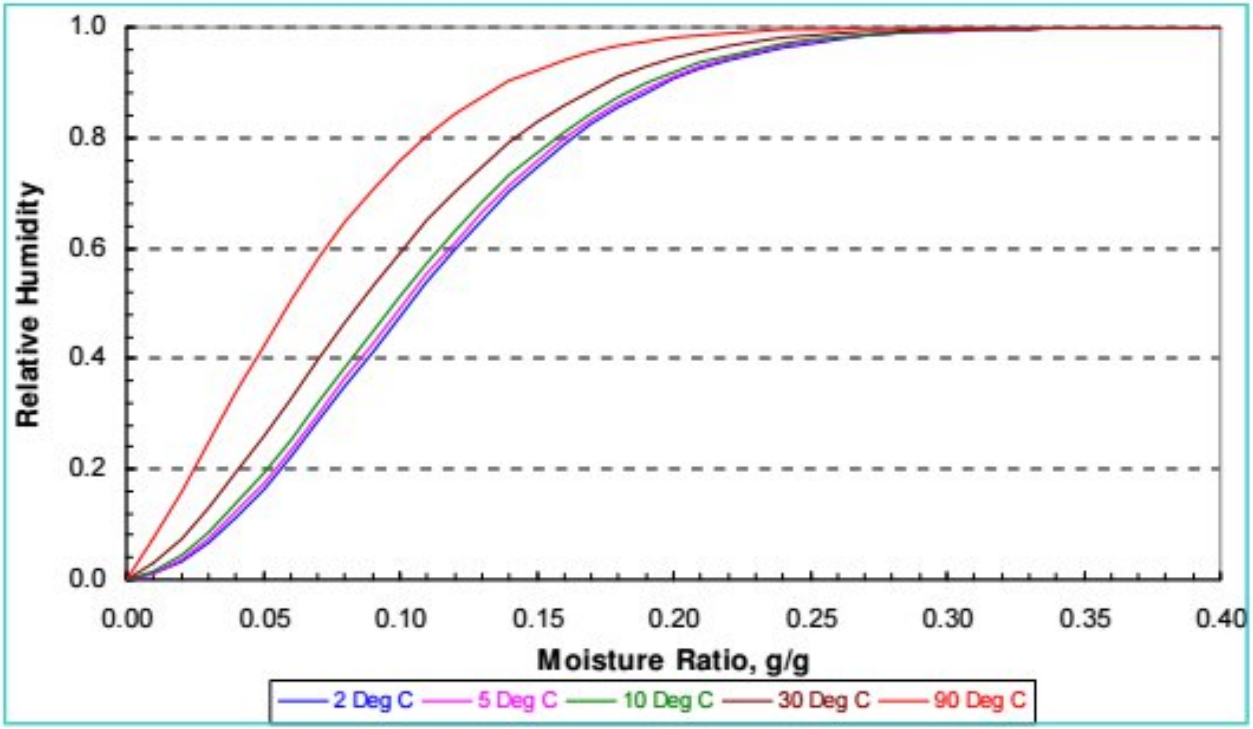
- Due to hygroscopic nature of paper, partial vapour pressure at the web surface or anywhere inside the web is a function of local temperature and moisture content. A correlation between relative humidity and the equilibrium moisture content at a constant temperature is a sorption isotherm. Equilibrium moisture content at a certain relative humidity gives slightly different values depending on whether the equilibrium is approached through wetting of initial dry materials (adsorption) or through drying (desorption). This phenomenon is called hysteresis. The sorption isotherm of paper depends on the type of fibres that have been used to manufacture the paper. Various correlations for sorption isotherms are available in the literature.

Calculation: **p = 1-e^[(C1 x Z^(C2)) + (C3 x T x Z^C4)]** , where

C1 = 47.58; C2 = 1.877; C3 = 0.10085/ ^{o}C; C4 = 1.0585
P Relative Humidity of air inside chamber/room/store ;
ρ*100 Relative Humidity, %
Z Equilibrium Moisture Ratio; Z*100 = Moisture Uptake, %
T Temperature, ^{o}C

AUDIT – BASIS THERMODYNAMICS (IXV)

Sorption isotherm



AUDIT – BASIS THERMODYNAMICS (XV)

Heat transfer

- In paper drying the predominant mode of heat transfer is by conduction for manufacturing majority of paper grades. Convective heat transfer also play significant role in dryer pocket ventilation system. For tissue grades where hot air impingement on the web is applied, heat transfer by convection is most important. Radiation heat transfer is usually ignored in conventional paper drying since its contribution to the overall heat transfer is much less than that due to conduction and convection. The basic form for one dimensional steady state heat conduction is shown in equation xx, while that of convective heat transfer is shown in equation xxx:

Calculation: **$Q = k \times A \times \Delta T / \Delta X$ or $Q = h \times A \times \Delta T$**, where

Q	heat transfer rate, J/s (W)	T	Temperature, K
k	thermal conductivity, W/m.K	X	diameter or thickness, m
A	heat transfer surface area, m^2	h	heat transfer coefficient, $W/m^2\ ^oC$

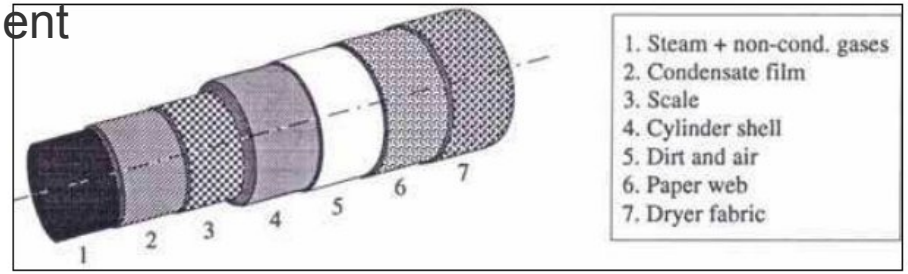
AUDIT – BASIS THERMODYNAMICS (XVI)

Heat transfer - resistance

- Heat is transferred from high temperature areas to the low temperature areas. The rate of heat transferred from the hot steam inside the cylinder to the cooler paper on the outside depends on the overall temperature gradient and on the different resistances to heat transfer:

Calculation: $\mathbf{Q = U \times A \times (T_s - T_p)}$, where

Q	rate of heat flow from inside dryer to paper
U	overall heat transfer coefficient
T_s	steam temperature
T_p	paper temperature



Calculation: $\mathbf{U = 1/(1/h_sA_1+L_c/k_cA_2+....+1/h_aA)}$

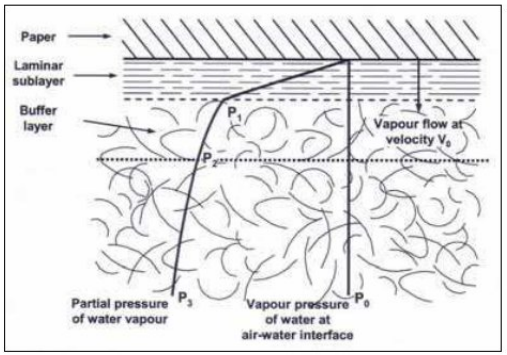
AUDIT – BASIS THERMODYNAMICS (XVII)

Mass treansfer

- In paper drying, mass transfer occurs after a sufficient amount of heat energy has been transmitted to the web, resulting in the transfer of mass of water from the paper to the air in the dryer section. The driving force for mass transfer is a concentration (or partial pressure) difference between two points. Mass transfer of water can occur by three different modes: molecular diffusion, convective or eddy diffusion and bulk movement or ventilation. The mass transfer occurring in paper drying can be described as molecular diffusion. Water is transferred from the moist paper surface through a boundary layer of air. Convective mass transfer involves this molecular diffusion through a laminar sub layer, a combination of molecular diffusion and turbulent mixing through a buffer layer, and turbulent mixing with the main body of air in a turbulent boundary layer. The process of convective mass transfer is shown in Figure xx.

AUDIT – BASIS THERMODYNAMICS (XVIII)

Mass treansfer



Calculation – mass transfer: $M_A = -D_v \, dC_A/d_x$, where

M_A mass transfer of A per unit area, kg/hr.m2

D_v molecular diffusivity (area/time)

C_A concentration of A

x distance

Calculation – mass transfer: $M_A = k_g \times (P_o - P_l)$, where

k_g mass transfer coefficient

P_o partial pressure of water at sheet surface

P_l partial pressure of water in surrounding air

Calculation – rate of evaporation: $M = k \times A \, (P_p - P_a)$, where

M rate of evaporation

K overall mass transfer coefficient

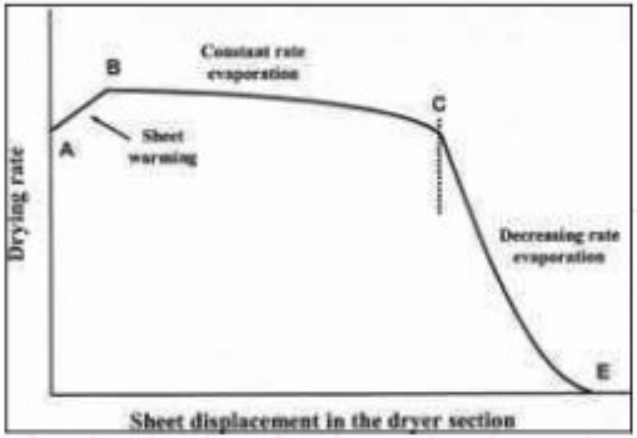
A evaporation area

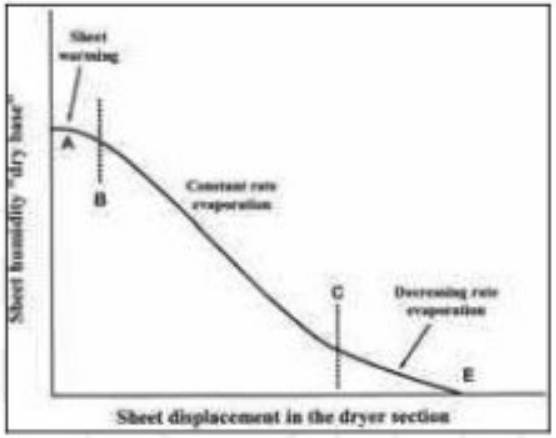
P_p vapour pressure of water in the paper

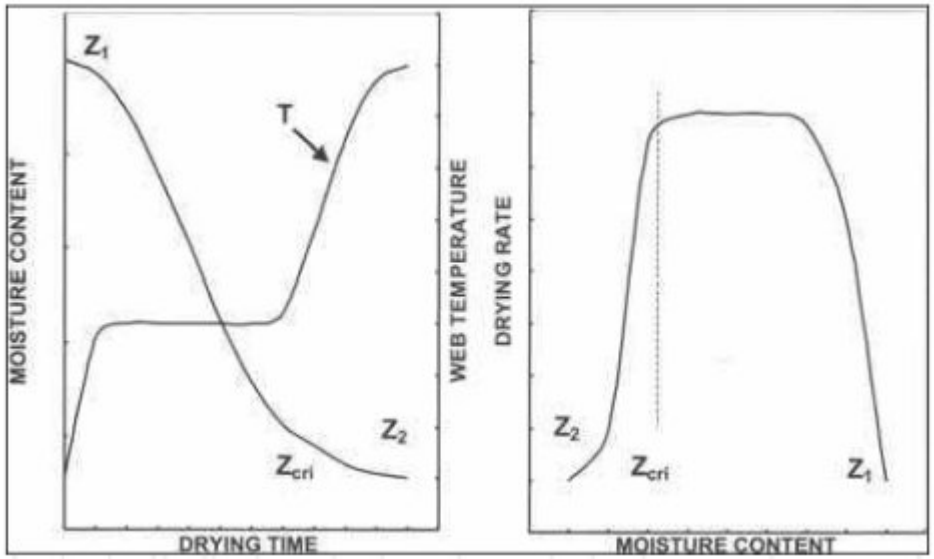
P_a vapour pressure of water in surrounding air

AUDIT – BASIS THERMODYNAMICS (IXX)

Drying phases







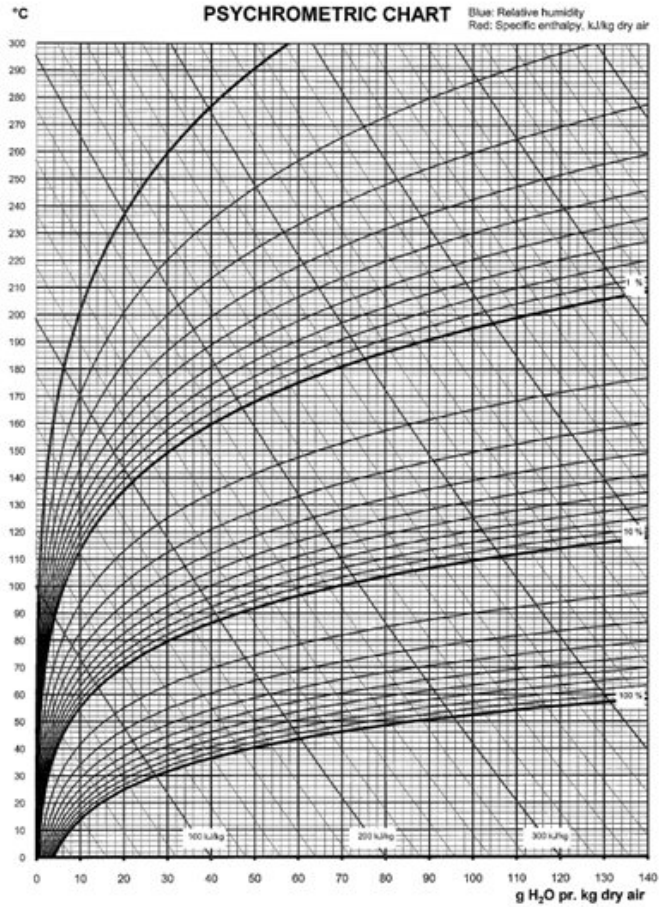
ASSIGNMENT NO. 5

- Calculate the mass flow of air needed to remove the vapor from the dryer with and evaporation rate of 1 kg/s

- Informations:
  - Air temperature 280 °C
  - Absolute humidity of 20 g H_2O/kg dry air
  - Assumption:
    - Saturated air out of the hood
    - No heat losses

- Calculate the potential preheating temperature of the incoming air

- Calculate the amount of water condensate in the preheater



AUDIT – MANAGEMENT AND GOOD HOUSE KEEPING (I)

What is good management and good house keeping?

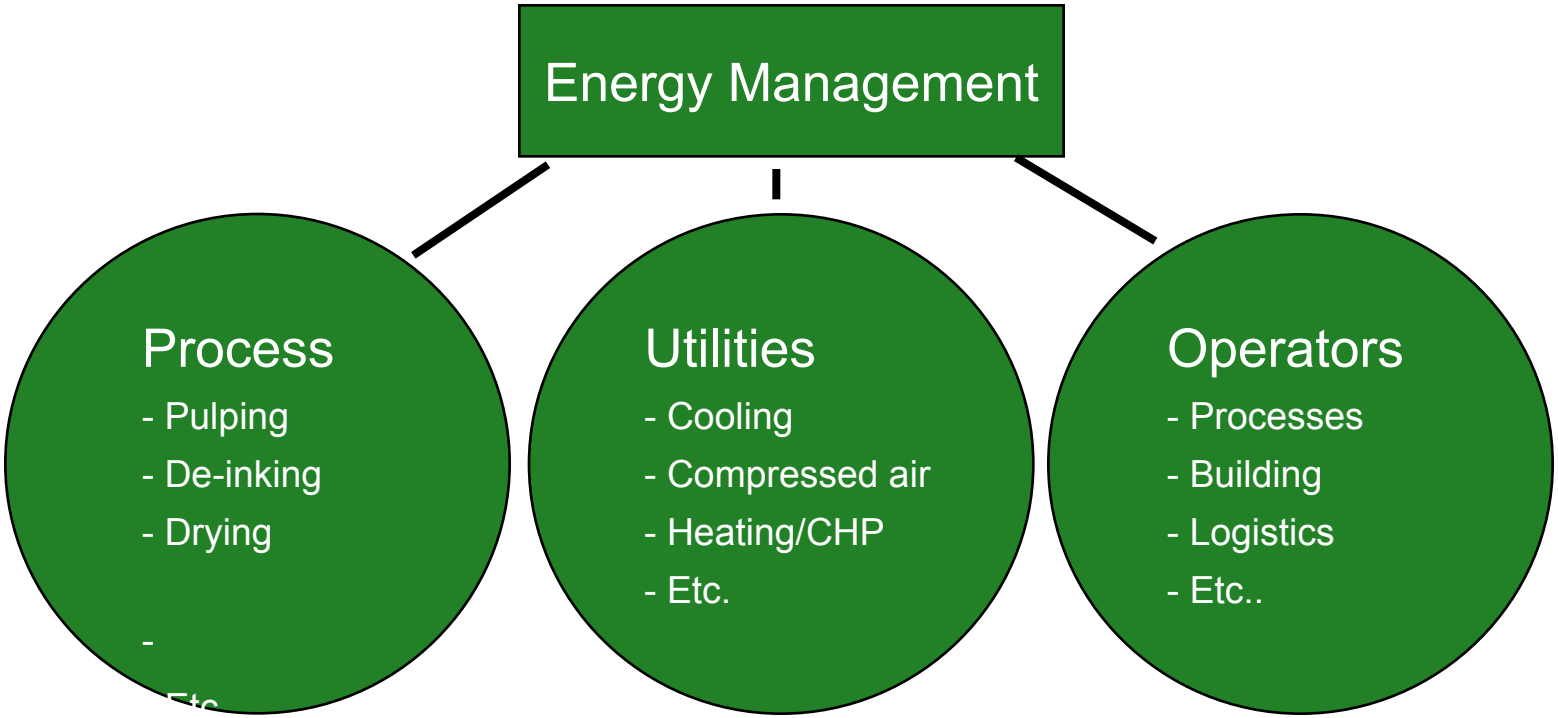
- Behavioral
  - Night reduction
  - Cleaning procedures
  - Closing openings
- Maintenance
  - Cleaning of heat exchangers
  - Leak detection
  - Technical insulation
  - Drive belts
- Basis management and monitoring
  - Key figures
  - Operational parameters
- Others?

AUDIT – MANAGEMENT AND GOOD HOUSE KEEPING (I)

Who have an influence?

- Operators operating major processes and equipment
- Technical department responsible for maintenance
- Facilities management responsible for buildings
- Design engineers responsible for new facilities
- External companies responsible for cleaning
- Service companies owing and operating utilities
- Production planning department
- QA-department
- Etc.

AUDIT – MANAGEMENT AND GOOD HOUSE KEEPING (I)



Process Engineers/chemists have the capabilities and responsibilities to change important process parameters

Mechanical engineers/techn-cians have the capabilities to maintain and optimize the operation of utility systems

Operators have the responsibility of operating processes and utility systems during daily operation

ASSIGNMENT NO. 6

- Who have an influance on the consumption and how?

FRIDOLIN MÜLLER HOLM

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Master of Science in Engineering

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