INOGATE

PROGRAMME FUNDED BY THE EU

ENERGY COOPERATION BETWEEN THE EU, THE LITTORAL STATES OF THE BLACK & CASPIAN SEAS AND THEIR NEIGHBOURING COUNTRIES

INDUSTRIAL ENERGY EFFICIENCY

“INOGATE Technical Secretariat & Integrated Programme in support of the Baku Initiative and the Eastern Partnership energy objectives”

Contract No 2011/278827

A project within the INOGATE programme

Lecture 1 A

Initial Data Analysis

Lecture Learning Objectives

- To introduce the student to the structured and data approach to management of energy in an industrial setting
- To complement the learnings of the student to date in industrial energy efficiency technologies
- To inform the student of the mechanisms typically used within European member states to manage and improve industrial energy efficiency on an ongoing basis

No Silver Bullet

- There is no magic solution behind energy efficiency in industry
- Energy management is delivered by proper energy understanding
- A balance between investment in technology, operational control and management overview

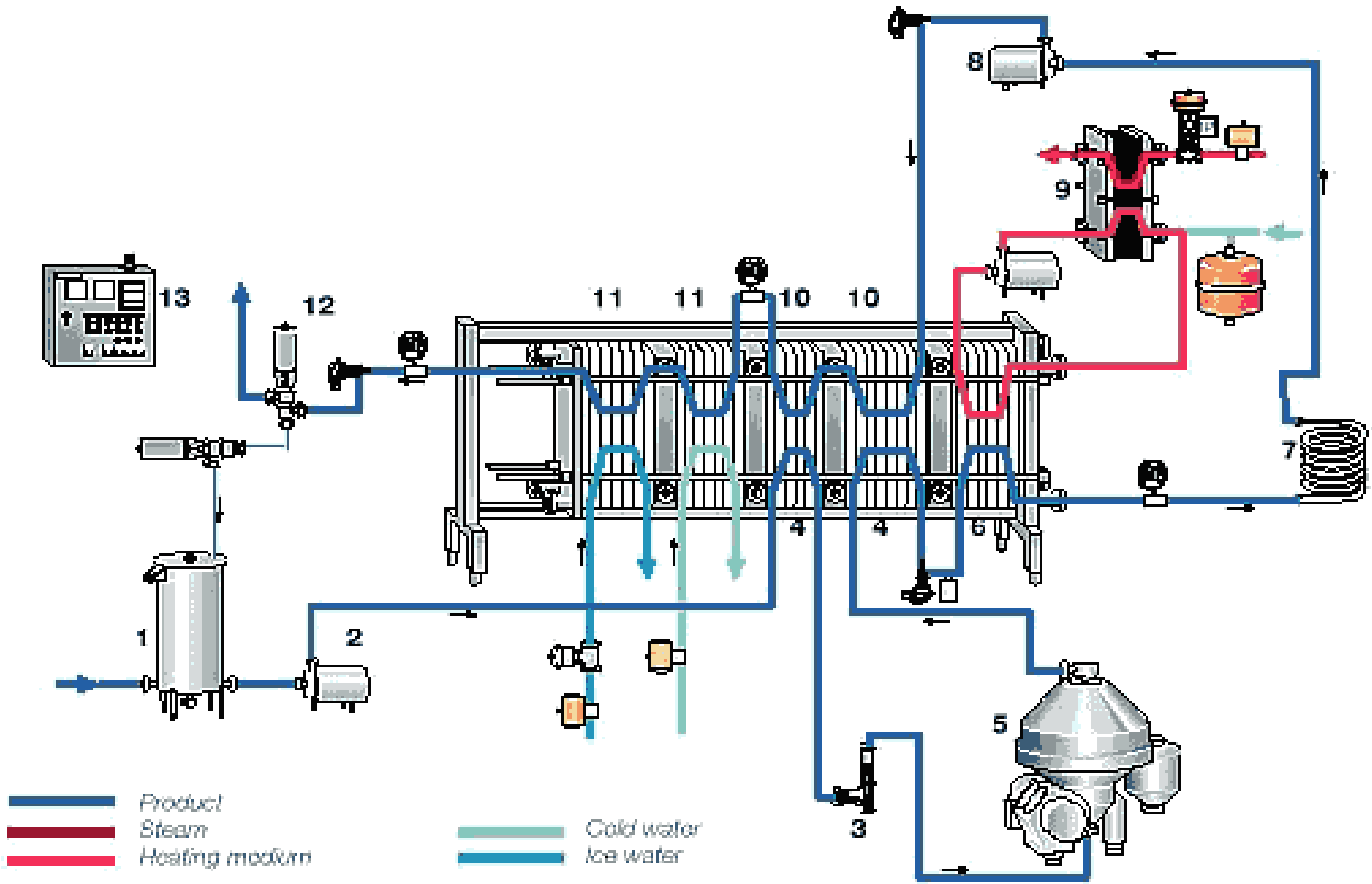
Case Study

- The plant under consideration is a large dairy plant manufacturing butter and powdered skim milk

- It receives whole fat milk in bulk tankers to site at a temperature less then 4 degrees C. (2-4^{o}C acceptable)

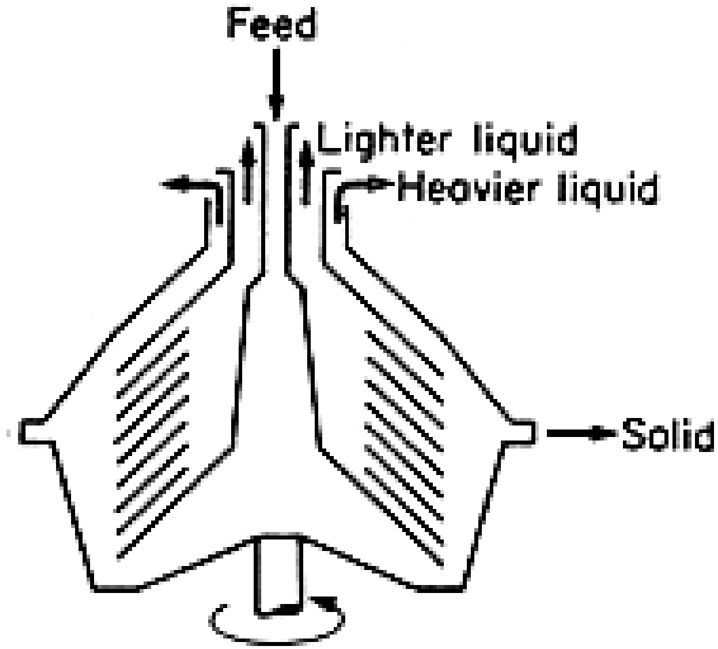
- The milk is initially sent to bulk storage tanks
- The milk is then pasteurised (HTST >72^{o}C for 15 seconds)
- The pasteurised milk is returned to bulk tanks for storage at less than 4^{o}C

Pasteurisation Process



Process (continued)

- The pasteurised whole milk (approx. 3% fat) then is taken through a centrifugal separator and separated to cream (approx. 30% fat) and skim milk

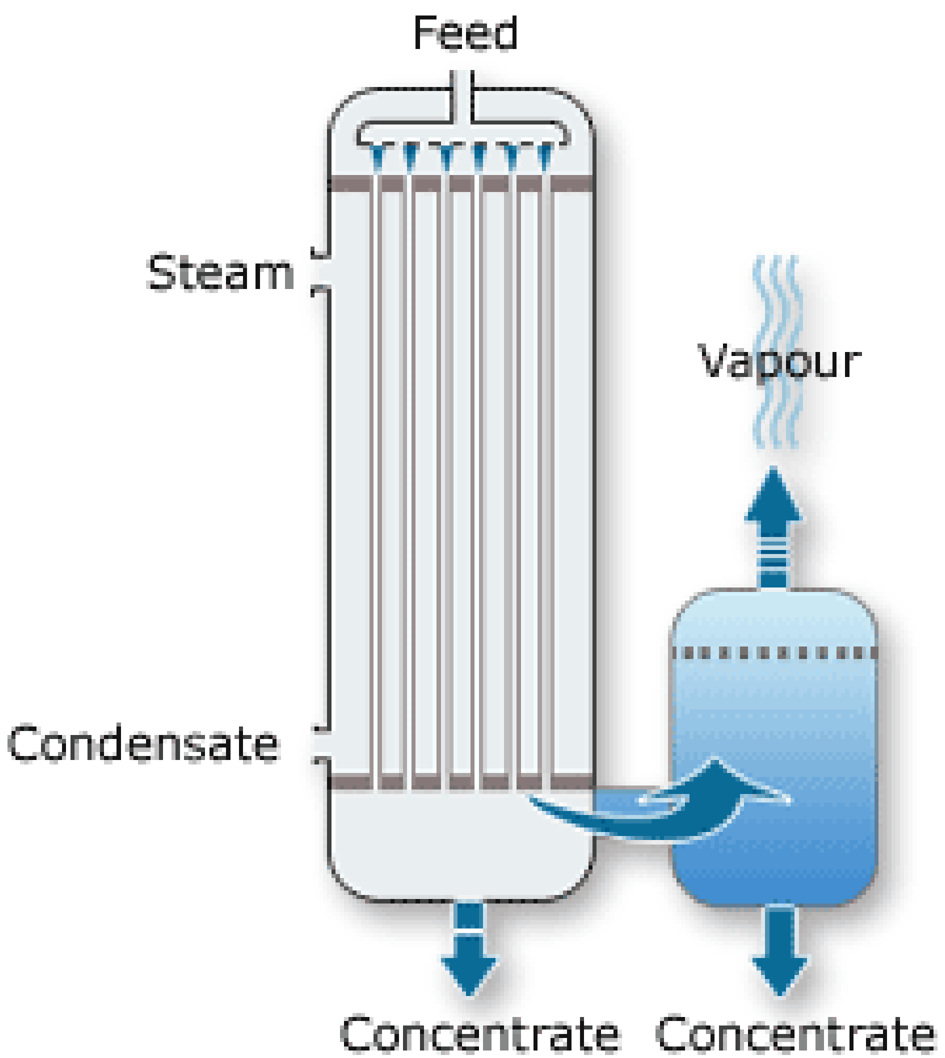


Process (continued)

- The cream is mechanically agitated to become butter

- The liquid skim milk (91% water) is then sent through an evaporation process where it becomes more concentrated by removal of water (to between 45-52% solid content)

Thermal Vapour Re-compression

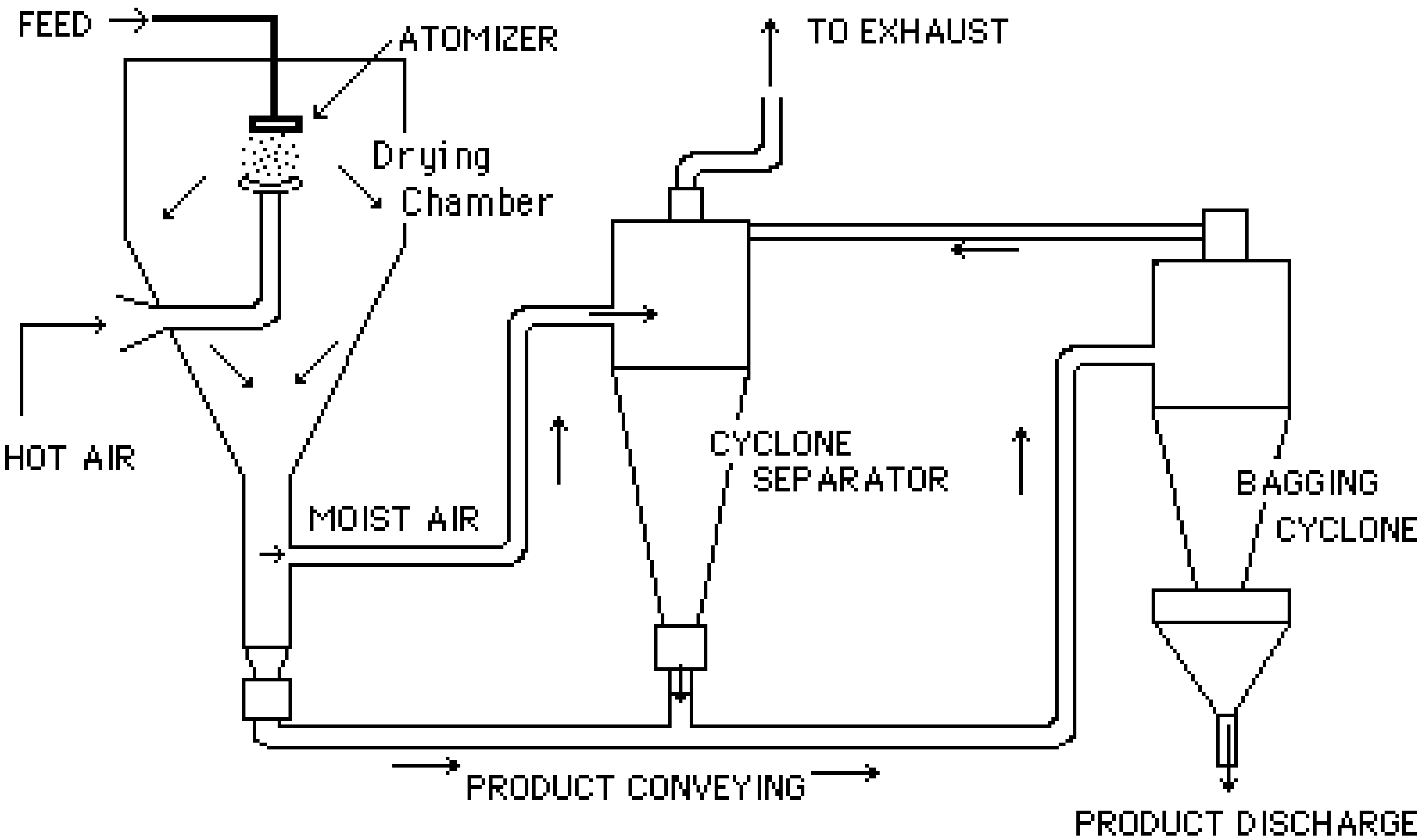


Process (continued)

- The concentrated skim milk is then sent to a spray drier to become powdered skim milk.

- The powder skim is bulk packaged in bags and then sent off site for further processing and packaging

Spray Dryer



FEED
ATOMIZER
TO EXHAUST
Drying
Chamber
HOT AIR
MOIST AIR
CYCLONE
SEPARATOR
BAGGING
CYCLONE
PRODUCT CONVEYING
PRODUCT DISCHARGE

Existing energy use

- Primary energy uses are Electricity and Oil – generated on site
- (Data provided)
- There is not a lot of individual metering on site to allow individual measurement of energy to processes
- Thermal energy is provided by steam generated in boilers
- Electricity supplied at 10kV distributed around the site and transformed down for use at low voltage 3 phase.

Energy and production data

	Whole Milk [L]	Butter [kg]	Skim Milk [kg]	Oil [L]	Electricity [MWh]	Total Energy MWh	Total product [kg]
January	365,000	18,220	3648	885,000	2,182	11,770	21868
February	37,370,000	1,868,410	373640	1,730,000	5,210	23,952	2242050
March	59,475,000	1,972,490	594723	2,100,000	7,135	29,885	2567213
April	64,054,250	3,200,732	640500	2,300,000	7,015	31,932	3841232
May	97,091,780	4,853,065	970886	2,800,000	8,843	39,176	5823951
June	67,877,300	3,392,256	678764	2,500,000	7,553	34,636	4071020
July	50,426,000	2,520,500	504234	1,800,000	6,222	25,722	3024734
August	60,832,000	3,040,632	608230	2,300,000	7,115	32,032	3648862
September	41,484,500	2,072,900	414834	1,850,000	5,362	25,404	2487734
October	51,760,270	2,587,329	517583	2,100,000	6,541	29,291	3104912
November	54,030,200	2,700,450	540302	2,300,000	6,236	31,153	3240752
December	5,985,500	297,125	59805	980,000	2,538	13,155	356930

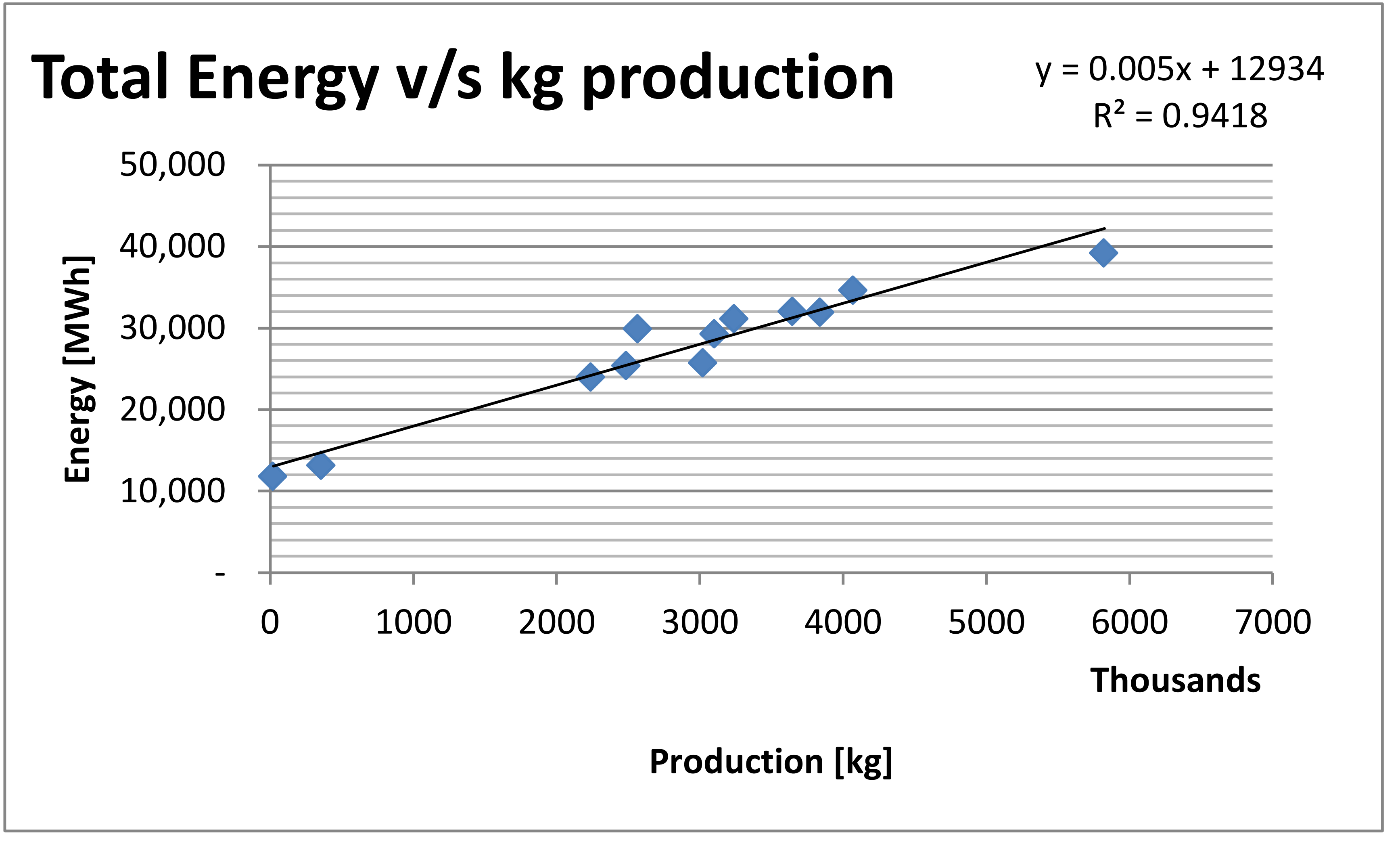
First Steps

- We first want to look at the raw energy data for the facility and identify if there are any clear trends that link the data with any clear driving factors
  - We would expect that manufacturing activity drives energy use
- We want to compare the energy use of the facility with any known benchmarks to see if the manufacturing site is energy efficient relative to similar manufacturing sites
- We want to identify the key areas that should be looked at in their own right as areas of significant energy use

Production related energy use

- Total production is 3,431,258 kg
- Total Energy is 328,106 MWh
- Does this mean 0.1 MWh/kg (326,108/3,341,258)?
- This is a common flaw in energy management in industry.
- Easy to meet energy targets in kwh/product when increasing production, but not when decreasing

Analysis



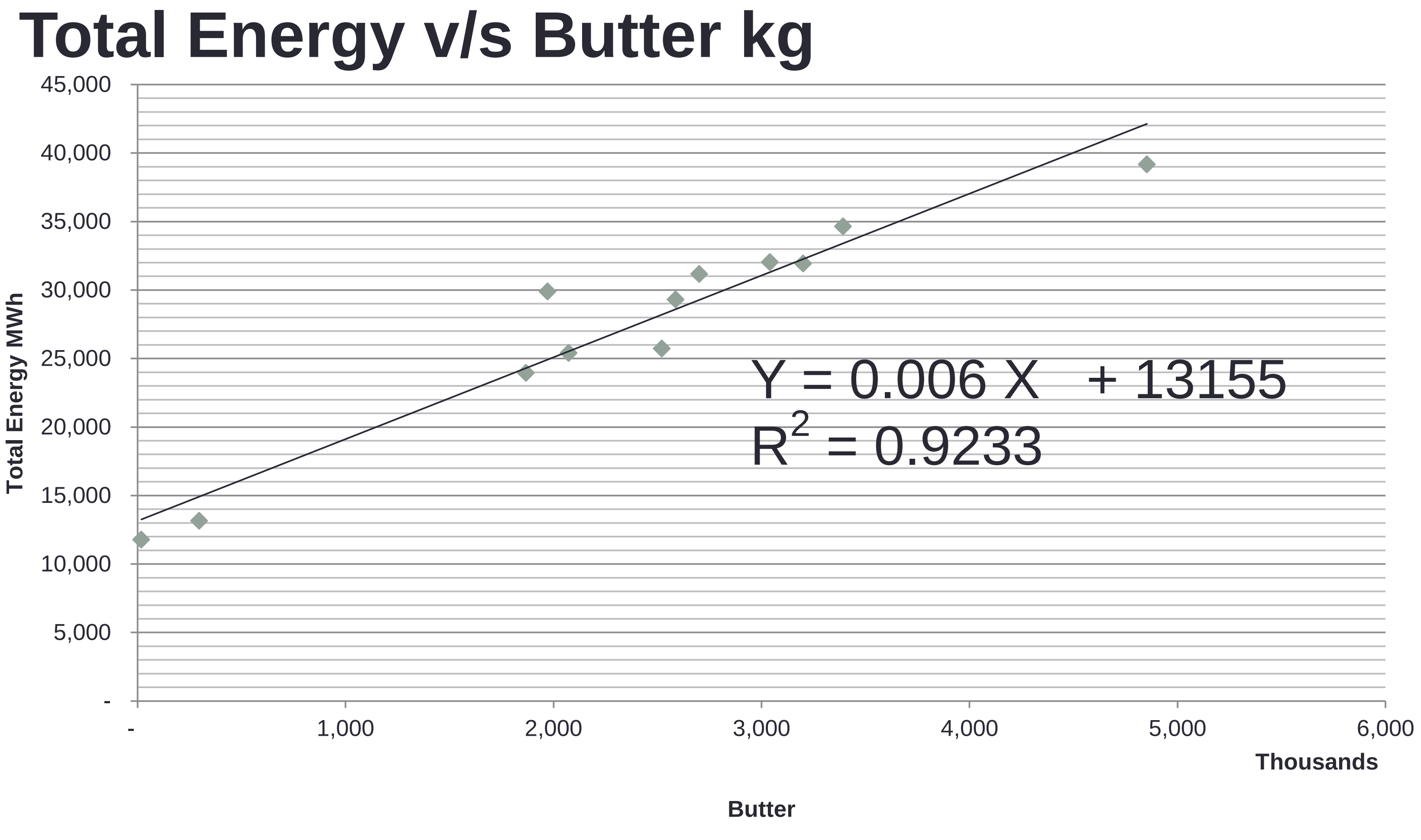
Total Energy v/s kg production
y = 0.005x + 12934
R² = 0.9418
50,000
40,000
30,000
20,000
10,000
-
Energy [MWh]
0
1000
2000
3000
4000
5000
6000
7000
Thousands
Production [kg]

What does it mean

$$R^2 = \frac{\sum(\hat{Y}_i - \bar{Y})^2}{\sum(Y_i - \bar{Y})^2}$$

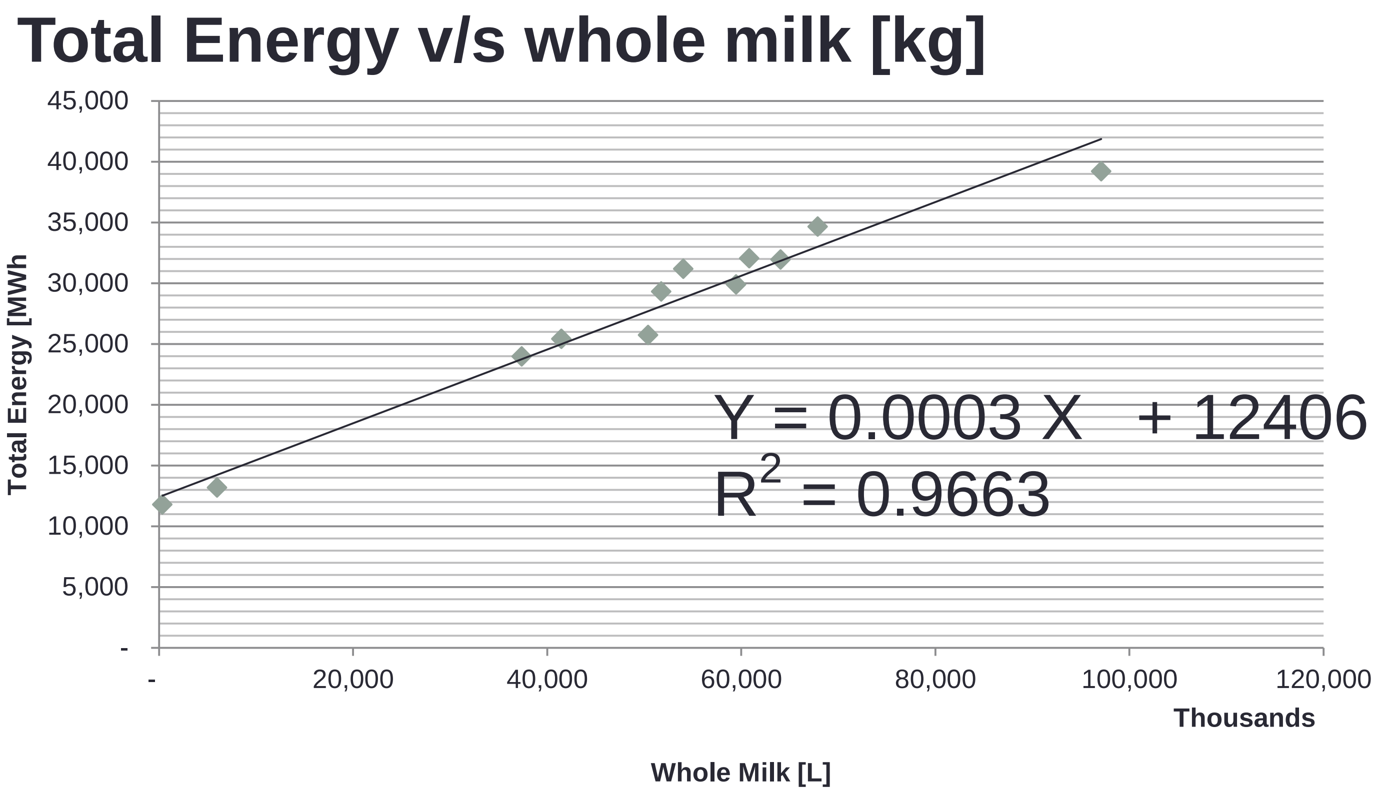
This is comparing the values predicted by the model, the mean values and the actual measured values to give an explanation of how much variation in the values is explained by the model

Concentrate again on co-relation



Note well

- A strong relationship does not imply causality and can cause incorrect assumptions to be made



Not always as simple

- In some industries you will not be able to find any meaningful relationship between the main output activity and energy consumption.
- Sometimes the driver will be weather
- More often the driver will be a combination of weather, production, occupancy and other factors
- When this occurs it is best to move on and not try to establish weak relationships for the sake of it.

Areas of significant energy use

- A small % of a large number is still a large number
- Focus of the areas of significant energy use to deliver significant energy savings
- We first want to identify the areas of significant energy use in the facility

The obvious ones

- Pasteurisation: All the milk intake goes through this process that heats and cools the milk
- Separation (small in reality)
- Butter making -churning (small in reality)
- Evaporation
- Drying

The Less Obvious ones

- Boiler plant generating steam
- Steam distribution system
- Ventilation system – heating and odour control
- Refrigeration
- Compressed air
- Pumping (the liquid needs to be pumped numerous times)
- Cleaning in Place – all plant needs to be cleaned daily
- Effluent Treatment – a typical forgotten entity

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Lecture 1 B

Technical analysis of sample areas

Areas of Significant energy use

Steam Boilers

- Oil boilers currently used to generate steam.
- 3 boilers in use at all times

Steam Distribution

- Distribution at 24Bar
- Reduced to 16 bar close to point of use

Areas of Significant energy use

Ventilation

- Factory floor area is air conditioned by ten large air handling units
- Controlled by building management system

Refrigeration

- Refrigeration plant used for the air conditioning system (ventilation) and Pasteurisation

Areas of Significant energy use

Pasteurisation

- High Temperature, Short Time pasteurisation is used to kill germs in the milk

Drying

- A portion of the milk is processed to use as powdered milk (baby food)

Areas of Significant energy use

Compressed Air

- Compressed air is generated by a bank of five compressed air units
- All units fixed speed, manually controlled
- Used to blow filters, agitate milk; operate instrumentation and milk powder transfer

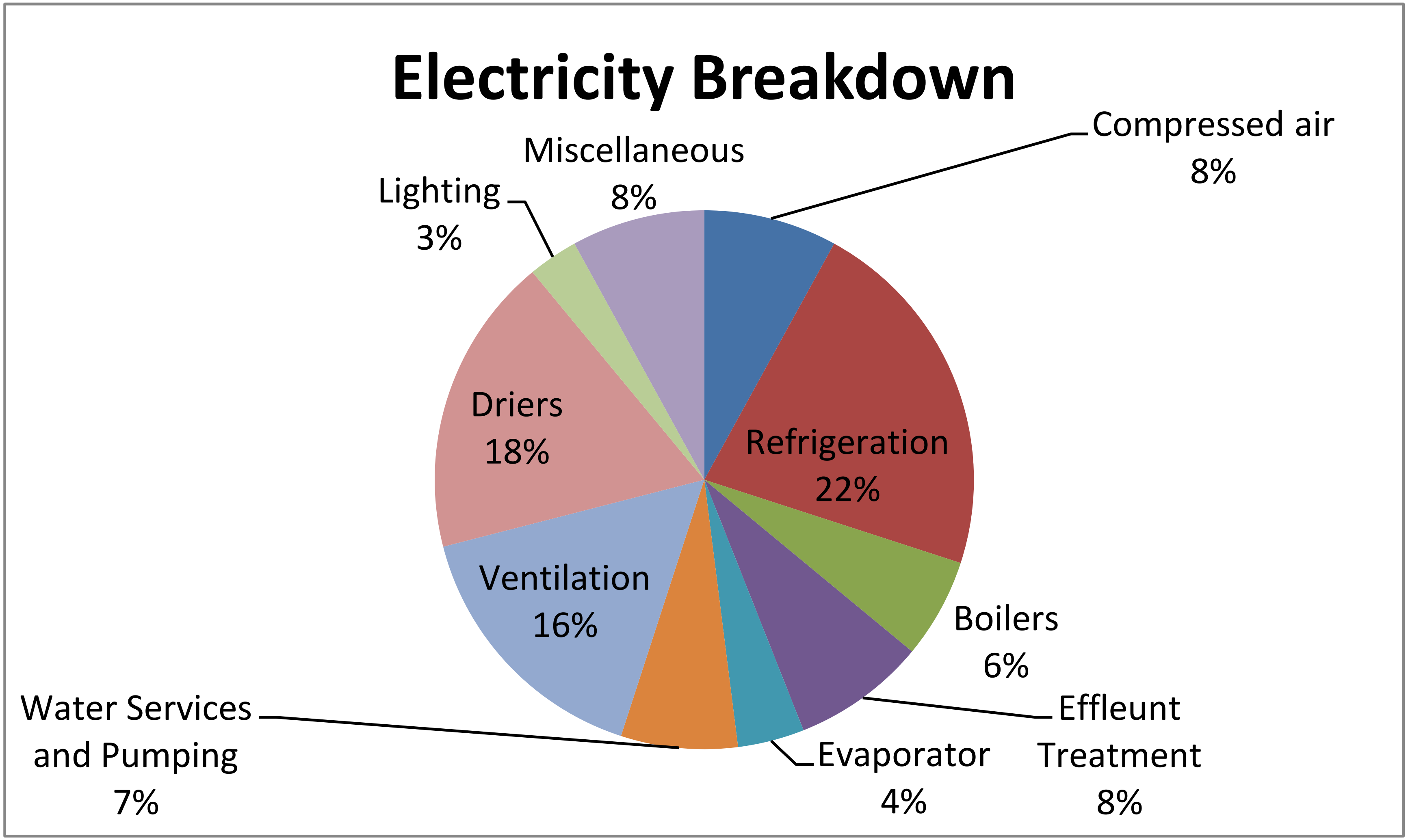
Cleaning in Place

- There is a significant amount of water use on site used for cleaning vessels and process equipment between production runs

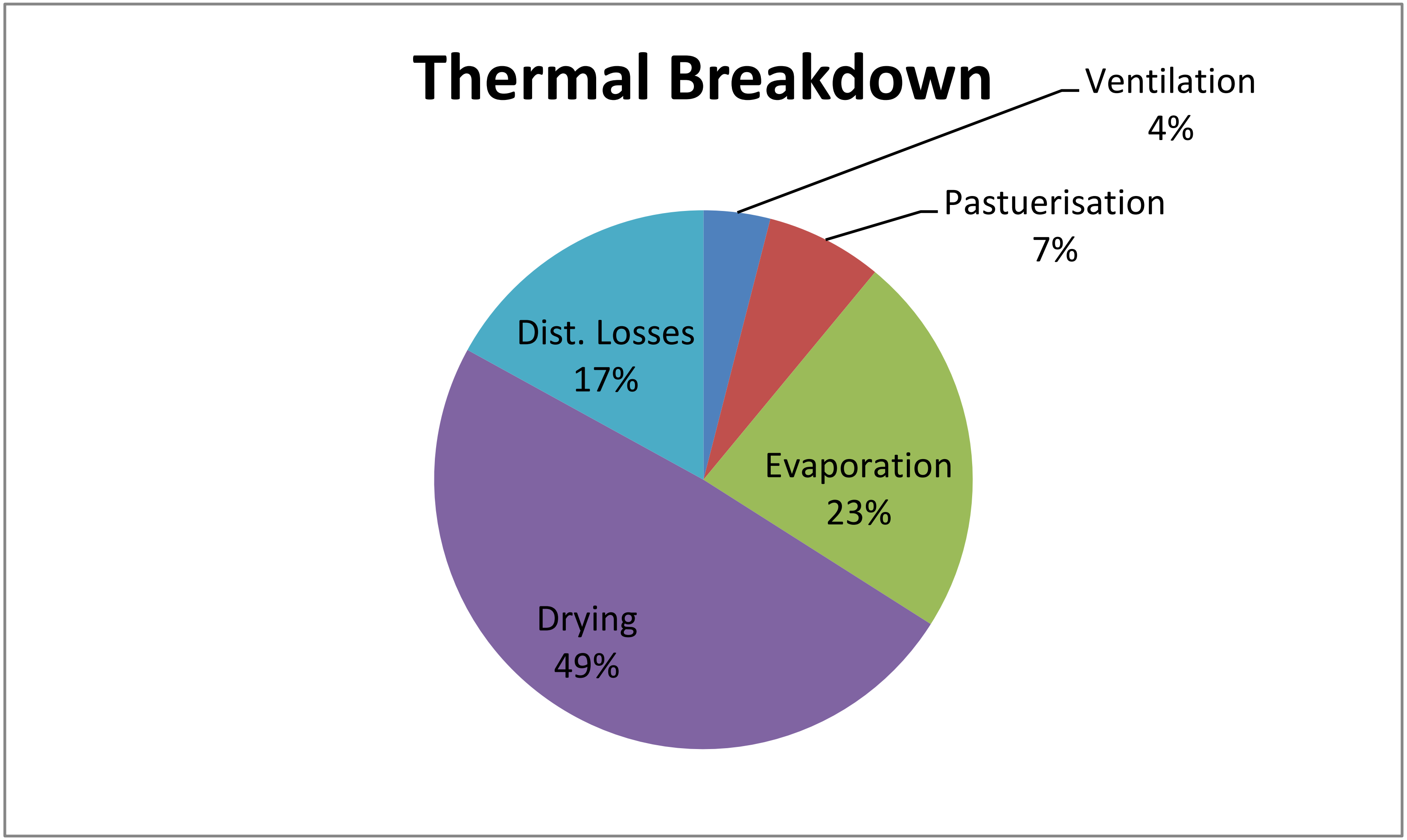
Exclusions

- Effluent Treatment is being excluded from our study as this area is being outsourced to an external specialist service provider for review who will come back with a proposal to install a methane gas collector and operate a methane engine selling electricity to the grid (a later lecture)
- Pumping - not significant in this case so pumps will be included with individual pieces of equipment.

Electricity breakdown



Thermal Breakdown



Selection of Sample areas

- To allow appropriate attention to be given to each area the lectures will assess 4 areas of significant energy use
- The student will be required to assess the four other areas in isolation with information provided.

Variables affecting significant energy use

- To fully understand the opportunities to save energy in relation to any area of energy we must be able to clearly identify first (not necessarily quantify at this stage) the things that affect the energy use of the system, in particular those that may change over time to affect the energy use of the system.
- These we call the variables affecting significant energy use
- One or other of these may be seen to have an impact that far outweighs the other

Persons affecting significant energy use

- To ensure that we are appropriately controlling energy use we need to understand the people that can affect the energy use of the systems by affecting one or other of the variables that have been identified as affecting energy use

- We can only be sure that they are appropriately controlling energy when we know that these people understand the energy impacts of what they do.

Opportunities may come in many different areas of the system

- Service
  - What does it need to do. E.g. Pasteurisation - needs to kill bacteria – this dictates temperature and time, anything in excess of these requirements needs to be questioned
- Process
  - What is the mechanism by which the service is being delivered, is there a better way of doing this. E.g. in some areas the ventilation system may be only providing people comfort, and may be better served by using infra-red heating

Opportunities may come in many different areas of the system

- Equipment –
  - Is the equipment properly suited to the job, is it properly sized, are there more recent models with energy improvements?
- Legal and Other Obligations –
  - Are there requirements from a legal requirement that we need to meet, or from a production quality requirement, has an excessive margin of safety crept in that has a significant energy impact?

Opportunities may come in many different areas of the system

- Controls
  - How is the equipment controlled – sometimes excessively tight controls can lead to energy waste (think of a room with a very defined set point for temperature (and always being heated or cooled, never neither), are there more recent improvements in control of this type of equipment
- Operations
  - How is the system operated. E.g. running multiple short runs of product will reduce effectiveness of heat recovery as against one long run

Opportunities may come in many different areas of the system

- Maintenance
  - Does maintenance take into account energy impacts – e.g. scale on a heat exchanger will cause increased energy use – does the maintenance system use energy indicators as possible indicators of things that may be going incorrect from a maintenance perspective?

Opportunities may come in many different areas of the system

- People
  - Who are the people that have most impact on the energy use of this equipment?
  - Do they know that they have such a significant impact and understand why?
  - Have they the appropriate level of training and understanding to allow them to make decisions best with optimum impact?
  - Sometimes the people closest to the scene have least real impact (the operator may seem to be the obvious person, but it may be the automation person that set up the equipment, or the engineer or process chemist that defined the set points, and the operator has no decision making role, doing what is pre-defined.

Opportunities may come in many different areas of the system

- Management
  - How is the system MANAGED – how do we know that whatever we have decided is the best way for the system to be set up, operated and maintained is actually happening in practice.
  - Is there any way to put a “number” to this so that it can be checked regularly

Steam Boilers & Steam Distribution

- **Variables affecting significant energy use**
  - Steam load; Steam pressure; steam load variation; condensate return rate; condensate return temperature; combustion efficiency of boiler; type of boiler; heat loss for boiler and distribution (insulation); blow-down rate; PPM set point; boiler feed water control; quality of feed-water
- **People affecting significant energy use:**
  - Steam users, maintenance personnel, utilities personnel; external service companies

Opportunities for improvement – Steam Boilers & Steam Distribution

- Reduce steam load (production related)
- *Improve condensate return rate*
- *Install economiser on boiler*
- *Reduce excess O_2 level in exhaust*
- ***Install blow-down heat recovery***
- ***Recover flash steam***
- *Assess correct boiler pressure and ppm setting*
- *Put in place performance indicator for boilers with target level and active monitoring*
- ***Consider installation of Gas/Oil fired CHP***
- *Insulation*

Evaporation

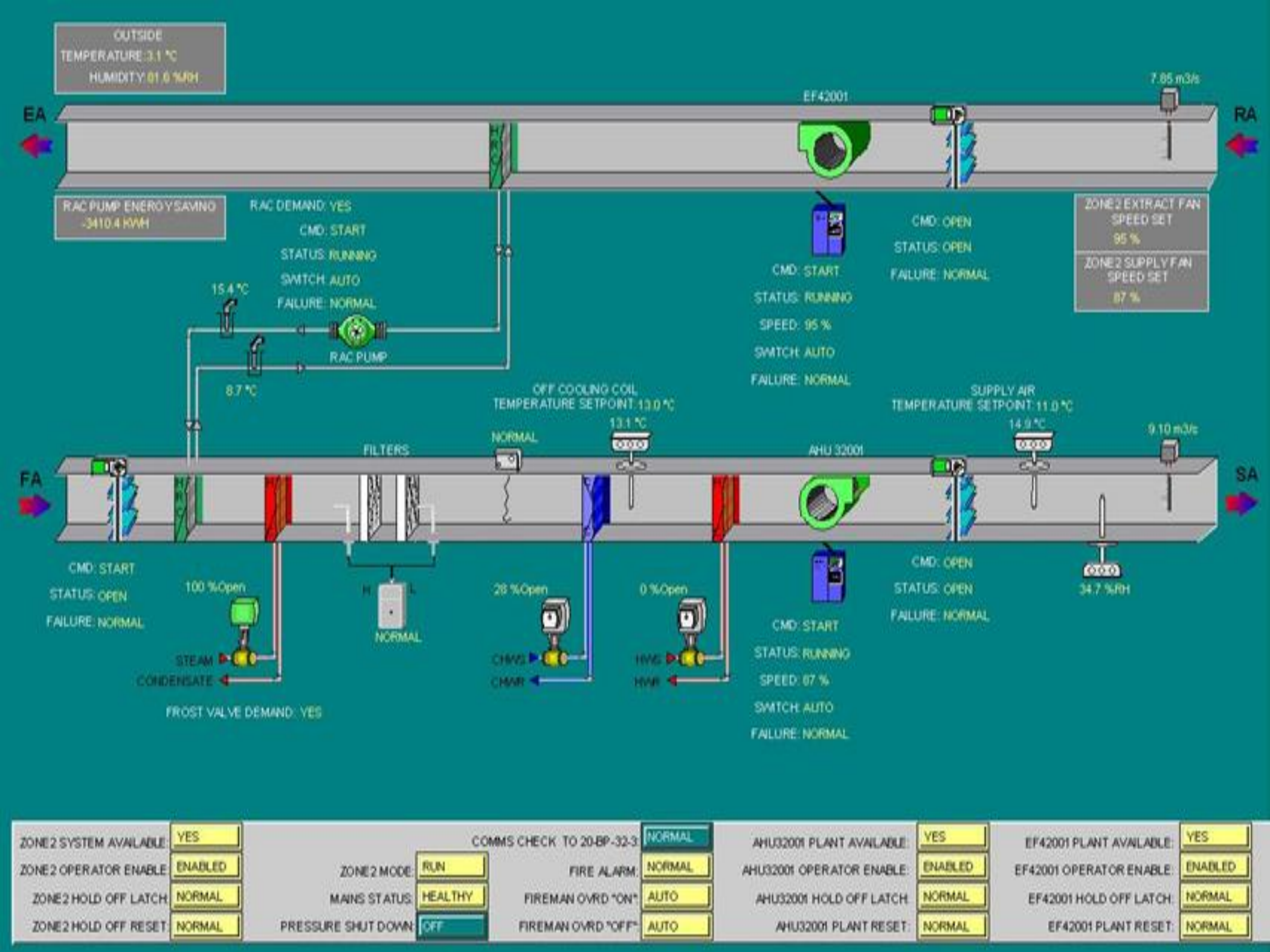
- **Variables affecting significant energy use**
  - Number of stages (effects) of evaporation, number of systems in use; solid requirements; milk throughput, management of temperatures on stages (effects), type of evaporator
- **People affecting significant energy use:**
  - Process control personnel (automation), operator

Opportunities for improvement – Evaporators

- *Install thermal Vapour Recompression Evaporator*
- *Put in place performance indicator for evaporator with target level and active monitoring/ alarms to indicate when effects not correctly controlled*

Ventilation – Air conditioning

- **Variables affecting significant energy use**
  - Heat load in area (winter), building envelope heat losses, ventilation heat losses, air change per hour, temperature set points, humidity/ RH set points, size of dead bands/ dead zones, control of AHU, cooling load in area (summer)
- **People affecting significant energy use:**
  - Management personnel for the area; controls persons (BMS); maintenance persons; external service personnel


OUTSIDE
TEMPERATURE 3.1 °C
HUMIDITY 81.6 %RH
EA
RA
EF42001
7.85 m3/s
RAC PUMP ENERGY SAVING
-3410.4 KWH
RAC DEMAND: YES
CMD: START
STATUS: RUNNING
SWITCH: AUTO
FAILURE: NORMAL
15.4 °C
RAC PUMP
8.7 °C
CMD: START
STATUS: RUNNING
SPEED: 95 %
SWITCH: AUTO
FAILURE: NORMAL
CMD: OPEN
STATUS: OPEN
FAILURE: NORMAL
ZONE2 EXTRACT FAN SPEED SET
95 %
ZONE2 SUPPLY FAN SPEED SET
87 %
OFF COOLING COIL TEMPERATURE SETPOINT 13.0 °C
SUPPLY AIR TEMPERATURE SETPOINT 11.0 °C
13.1 °C
14.9 °C
9.10 m3/s
FA
SA
FILTERS
NORMAL
AHU 32001
CMD: START
STATUS: OPEN
FAILURE: NORMAL
100 %Open
STEAM
CONDENSATE
FROST VALVE DEMAND: YES
NORMAL
28 %Open
CHWS
CHWR
0 %Open
HWS
HWR
CMD: START
STATUS: RUNNING
SPEED: 87 %
SWITCH: AUTO
FAILURE: NORMAL
CMD: OPEN
STATUS: OPEN
FAILURE: NORMAL
34.7 %RH
ZONE2 SYSTEM AVAILABLE: YES
ZONE2 OPERATOR ENABLE: ENABLED
ZONE2 HOLD OFF LATCH: NORMAL
ZONE2 HOLD OFF RESET: NORMAL
ZONE2 MODE: RUN
MAINS STATUS: HEALTHY
PRESSURE SHUT DOWN: OFF
COMMS CHECK TO 20-BP-32-3: NORMAL
FIRE ALARM: NORMAL
FIREMAN OVRD "ON": AUTO
FIREMAN OVRD "OFF": AUTO
AHU32001 PLANT AVAILABLE: YES
AHU32001 OPERATOR ENABLE: ENABLED
AHU32001 HOLD OFF LATCH: NORMAL
AHU32001 PLANT RESET: NORMAL
EF42001 PLANT AVAILABLE: YES
EF42001 OPERATOR ENABLE: ENABLED
EF42001 HOLD OFF LATCH: NORMAL
EF42001 PLANT RESET: NORMAL

Opportunities for improvement – Ventilation

- Reduce ventilation losses by sealing up building
- Improve controls on AHU
- Repair any passing valves
- **Reduce Air changes per hour to minimum requirements**
- **Widen dead-bands to maximum allowable**
- Reduce/ eliminate de-humidification and humidification
- Put in place appropriate energy performance indicator to assess fall off in performance to allow it to be addressed.

Refrigeration

- **Variables affecting significant energy use**
  - Cooling load; Insulation losses; pumping rate and flow control approach; cooling delivery set point, type of condenser in use (water, air, evaporative) condenser temperature set point, evaporator fouling; condenser fouling
- **People affecting significant energy use:**
  - Maintenance personnel, utilities personnel;

Opportunities for improvement – Refrigeration

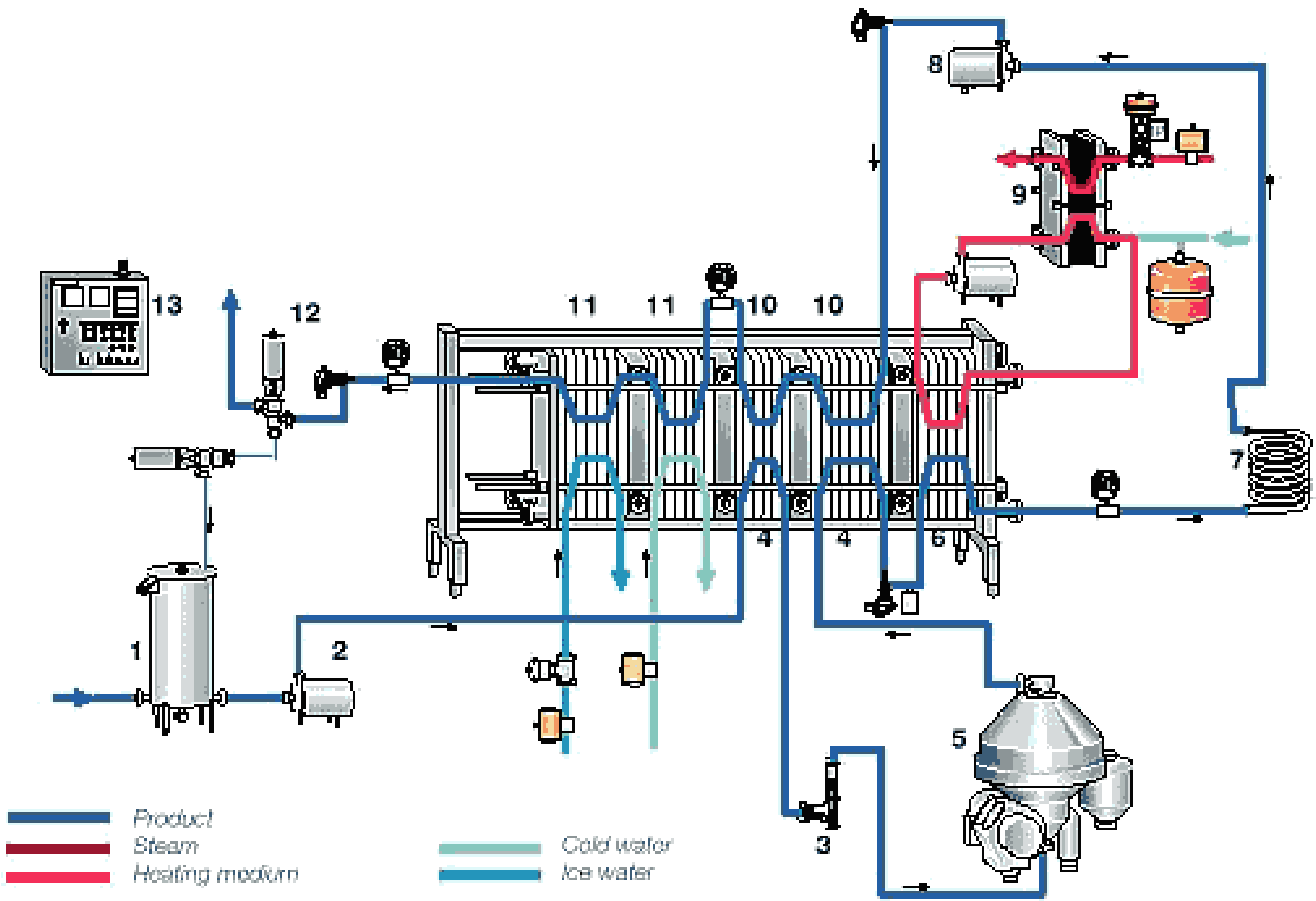
- Improve insulation on CHW distribution
- Increase CHW set point
- Reduce condenser set point in response to cooling medium temperature
- Consider installation of VSD on cooling tower fans
- Consider adaptive control of condenser set point (condenser reset
- **Consider modifying flow control arrangements to increase delta T**
- **Consider Pressure independent control valves**
- Put in place appropriate energy performance indicator to assess fall off in performance to allow it to be addressed.

Pasteurisation

- **Variables affecting significant energy use**
  - Quantity of milk processed; HT temperature set point; milk delivery temperature; heat exchanger approach temperatures; cooling temperature set point, fouling on heat exchangers; number of start and stop cycles

- **People affecting significant energy use:**
  - Process personnel, Quality personnel; schedule managers;

Pasteurisation Process



Opportunities for improvement – Pasteurisation

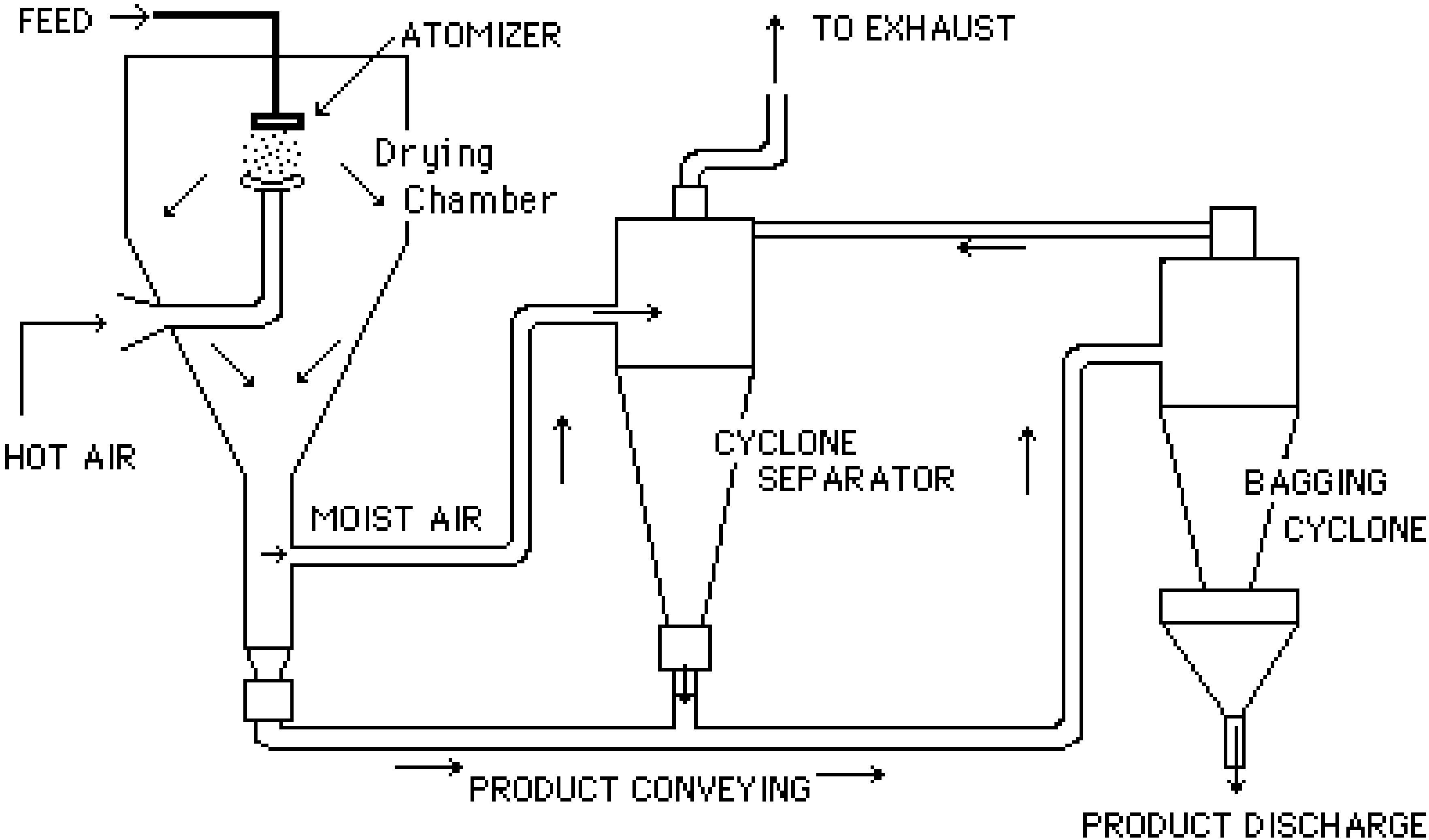
- **Increase plate surface area to minimise approach temperature**
- Is there excessive margins of error in achieving temperatures and retention time?
- Improved insulation on the system
- Put in place appropriate energy performance indicator to assess fall off in performance to allow it to be addressed.

Spray Dryers

- **Variables affecting significant energy use**
  - Quantity of milk powder processed; quality of “slurry” solution; temperature of air for drying; moisture content of air for drying; flow rate of air for drying; intake air temperature; exhaust air temperature; back-pressure on air flow

- **People affecting significant energy use:**
  - Process personnel, Quality personnel; schedule managers; external service personnel

Spray Dryer



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Opportunities for improvement – Spray Dryers

- **Pre-dry the incoming air using desiccant wheel**
- **Install heat recovery from exhaust**
- Improve atomisation of slurry mix spray to enhance drying
- Control fan on VSD to ensure maximum moisture draw by air in process
- Modify steam heat exchanger arrangement to ensure maximum heat extraction from steam used by ensuring that condensate is returned close to the incoming air temperature\

Opportunities for improvement – Spray Dryers (cont.)

- Regular cleaning of heat transfer surface area on heating coils
- Put in place appropriate Energy Performance Indicator to monitor performance and allow fall off in performance to be addressed
- Ensure scheduling is done to maximise throughput of drier to enhance efficiency of operation

Register of opportunities that we shall examine further

- Flash Steam recovery (Boilers and steam)
- Combined Heat and Power (Thermal and electrical)
- Reducing Air Change per Hour in Ventilation (ventilation)
- Hydraulic flow control on refrigeration systems (refrigeration)
- Increase Pasteurisation plate surface area (pasteurisation)
- Pre-dry incoming air to driers (Driers)

Questions/ comments?

IAN BOYLAN

BE, M.ENGSC, CEM CEA CMVP