

Preliminary data 2: Assessment of the energy and economic intensity of the simulated large-scale bioprocess based on a mesophilic or thermophilic bacterial host

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MOTIVATION

- The purpose of this modelling experiment using SuperPro Designer software from Intelligen, Inc. (USA) was to assess the energy and economic intensity of a simulated large-scale batch biotechnological process (1,000 L fermenter) based on the **mesophilic** production organism growing at **30°C** (requiring medium sterilisation) OR the **thermophilic** production organism growing at **50°C** (without medium sterilisation).

RESULTS: Modelling process **with** media sterilisation, fermentation temp. **30°C**

Heating to 121°C in bioreactor (sterilisation)

HEAT-1 - autoklaw_1etap (Batch Heating) in P-5

Oper.Cond's Volumes Vent/Emissions Labor, etc. Description Batch Sheet Scheduling

Final Temperature °C

Heating Utility ☐ Ignore

☐ Electricity

Power Type

Power kW

Efficiency

☒ Heating Agent

Agent

Name

Inlet Temp. °C

Outlet Temp. °C

Rate kg/h

Heat Transfer Efficiency %

Duty kcal/h

Duration

Setup Time min

Heating Time

☐ Set by User min

☒ Calculated Based on Heating Rate

☒ Constant

Rate °C/min

☐ Exponential

Overall UA kcal/h·°C

☐ Set by Master-Follower Relationship

Match the duration of this operation to the duration of another operation or string of operations.

Ignore Labor ☒

OK Anuluj Pomoc

Cooling to 30°C in bioreactor (process temperature)

COOL-1 - autoklaw_3etap (Batch Cooling) in P-5

Oper.Cond's Volumes Vent/Emissions Labor, etc. Description Batch Sheet Scheduling

Final Temperature °C

Cooling Utility ☐ Ignore

☐ Electricity

Power Type

Power kW

Performance Coefficient

☒ Cooling Agent

Agent

Name

Inlet Temp. °C

Outlet Temp. °C

Rate MT/h

Heat Transfer Efficiency %

Duty kW

Duration

Setup Time min

Cooling Time

☐ Set by User h

☒ Calculated Based on Cooling Rate

☒ Constant

Rate °C/min

☐ Exponential

Overall UA kcal/h·°C

☐ Set by Master-Follower Relationship

Match the duration of this operation to the duration of another operation or string of operations.

Ignore Labor ☒

OK Anuluj Pomoc

RESULTS: Modelling process **with** media sterilisation, fermentation temp. **30°C**

Fermentatation at 30°C
100% Energy dissipation to heat

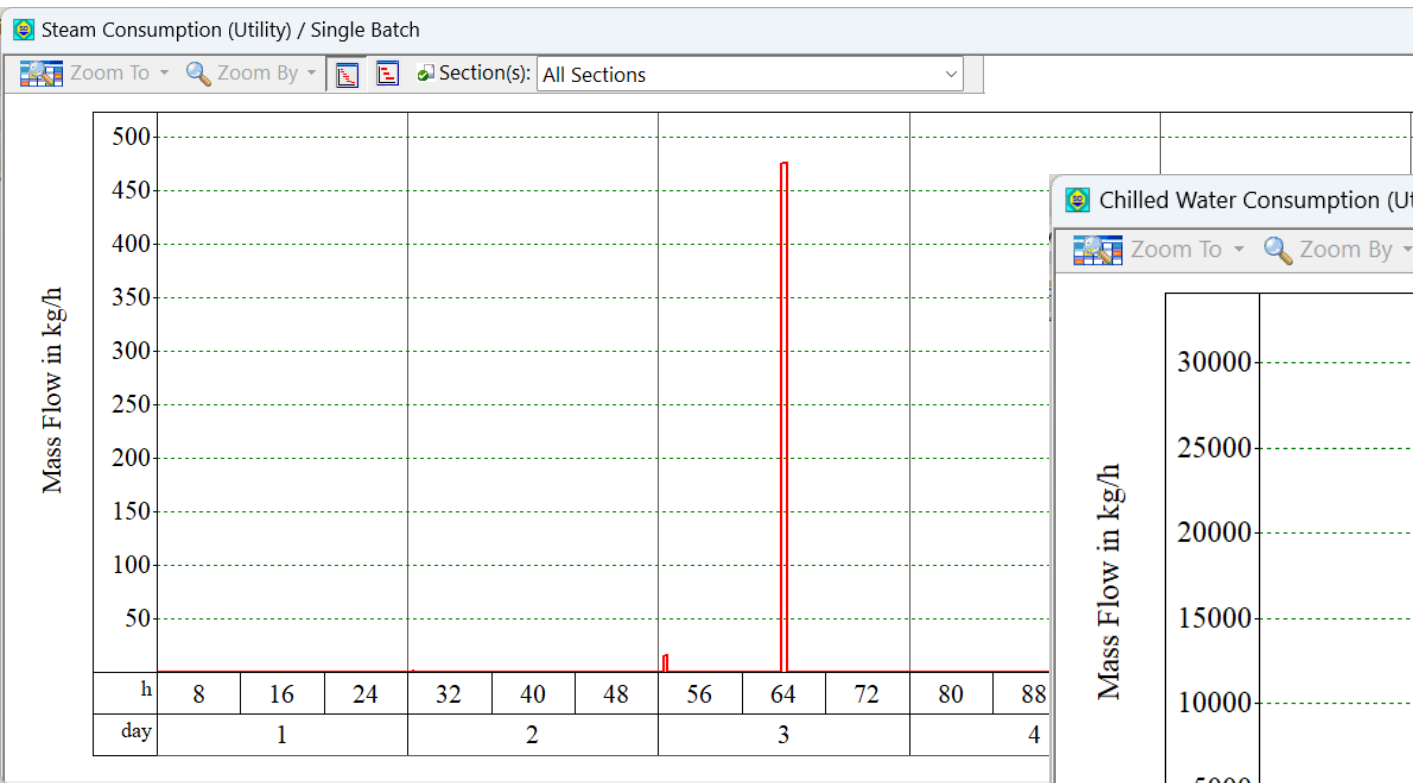
The screenshot shows the 'FERMENT-1 (Batch Stoich. Fermentation) in P-5' window. The 'Thermal Mode' section has 'Set Final Temp.' at 30.0 °C. The 'Heat Transfer' section shows 'Agent' as Chilled Water, 'Inlet Temp.' at 5.0 °C, 'Outlet Temp.' at 10.0 °C, and 'Rate' at 402.99 kg/h. The 'Power Consumption (for Agitation, etc.)' section shows 'Power Type' as Power, 'Set Specific Power' at 2.0000 kW/m³, 'Set Total Power' at 2.4885 kW, and 'Power Dissipation to Heat' at 100.00 %. The 'Duration' section shows 'Setup Time' at 0.00 min and 'Reaction Time' set by user at 48.00 h. The 'Broth Aeration' section shows 'Air Supply Stream' as In #12: Powietrze_3, 'Aeration Rate' calculated to achieve 1.000 VVM (STD), and 'Secondary Air Supply Stream' as In #11: (none). The 'Secondary Aeration Rate' section shows 'Calculated to Achieve' at 0.000 VVM (STD).

Fermentatation at 30°C
50% Energy dissipation to heat

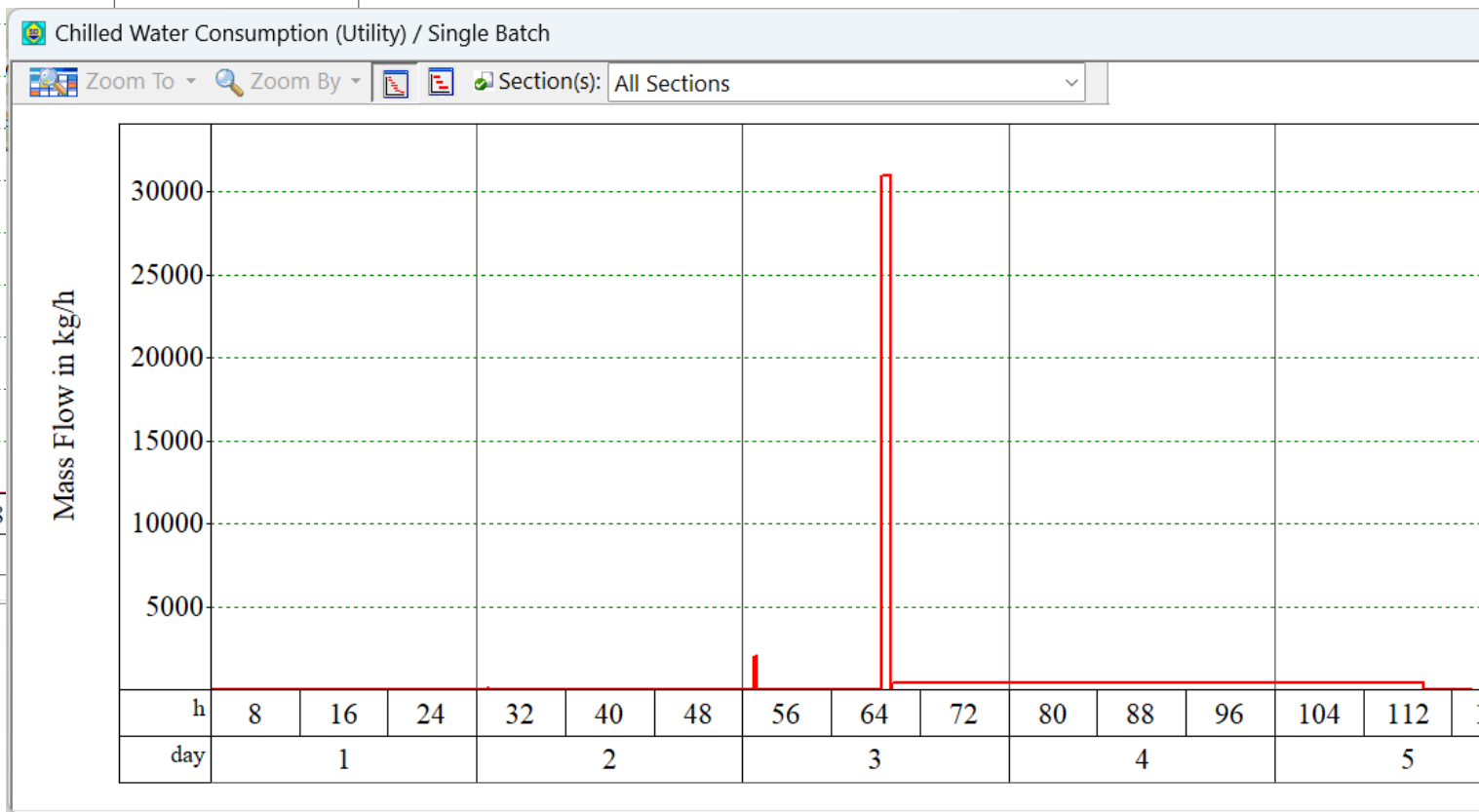
The screenshot shows the 'FERMENT-1 (Batch Stoich. Fermentation) in P-5' window. The 'Thermal Mode' section has 'Set Final Temp.' at 30.0 °C. The 'Heat Transfer' section shows 'Agent' as Chilled Water, 'Inlet Temp.' at 5.0 °C, 'Outlet Temp.' at 10.0 °C, and 'Rate' at 189.82 kg/h. The 'Power Consumption (for Agitation, etc.)' section shows 'Power Type' as Power, 'Set Specific Power' at 2.0000 kW/m³, 'Set Total Power' at 2.4885 kW, and 'Power Dissipation to Heat' at 50.00 %. The 'Duration' section shows 'Setup Time' at 0.00 min and 'Reaction Time' set by user at 48.00 h. The 'Broth Aeration' section shows 'Air Supply Stream' as In #12: Powietrze_3, 'Aeration Rate' calculated to achieve 1.000 VVM (STD), and 'Secondary Air Supply Stream' as In #11: (none). The 'Secondary Aeration Rate' section shows 'Calculated to Achieve' at 0.000 VVM (STD).

RESULTS: Modelling process with media sterilisation, fermentation temp. 30°C

Heating to 121°C in bioreactor



Cooling to 30°C in bioreactor



RESULTS: Modelling process **with** media sterilisation, fermentation temp. **30°C**

Factor - level of energy dissipation to heat during fermentation (mixing with 2 kWh/m³)

8. UTILITIES COST (2022 prices) - PROCESS SUMMARY

Utility	Unit Cost (Pln)	Annual Amount	Ref. Units	Annual Cost (Pln)	%
Power	0.9650	15340.24	kW-h	14803.3356	6.14
Steam	60.0000	26.38	MT	1582.7549	0.66
Chilled Water	50.0000	4496.03	MT	224801.6071	93.19
Freon	0.7500	72.00	MT	54.0036	0.02
TOTAL				241241.7012	100.00

100% to heat

8. UTILITIES COST (2022 prices) - PROCESS SUMMARY

Utility	Unit Cost (Pln)	Annual Amount	Ref. Units	Annual Cost (Pln)	%
Power	0.9650	15340.24	kW-h	14803.3356	7.83
Steam	60.0000	26.38	MT	1582.7549	0.84
Chilled Water	50.0000	3452.36	MT	172617.9628	91.30
Freon	0.7500	72.00	MT	54.0036	0.03
TOTAL				189058.0569	100.00

50% to heat

RESULTS: Modelling process **without** media sterilisation, fermentation temp. **50°C**

Fermentatation at 50°C
100% Energy dissipation to heat

FERMENT-1 (Batch Stoich. Fermentation) in P-5

Oper.Cond's Volumes Fed Batch Reactions Intra/Extra Cell % Vent/Emissions Labor, etc. Description Batch Sheet Scheduling

Thermal Mode

☒ Set Final Temp. 50.0 °C

☐ Adiabatic

☐ Set Duty

☐ Heating 0.00 kcal/h

☒ Cooling 1067.53 kcal/h

Heat Transfer

Agent Chilled Water

Inlet Temp. 5.0 °C

Outlet Temp. 10.0 °C

Rate 212.56 kg/h

Heat Transfer Efficiency 100.00 %

Power Consumption (for Agitation, etc.)

Power Type Power

☒ Set Specific Power 2.0000 kW/m3

☐ Set Total Power 2.4935 kW

☐ Set Power per Unit 2.4935 kW

Power Dissipation to Heat 100.00 %

Gaseous Components Available To Feed ☒

Duration

Setup Time 0.00 min

Reaction Time

☒ Set by User 48.00 h

☐ Set by Master-Follower Relationship

Match the duration of this operation to the duration of another operation or string of operations.

Ignore Labor ☒

Broth Aeration

Air Supply Stream: In #12: Powietrze_3

Aeration Rate

☒ Calculated to Achieve 1.000 VVM (STD)

☐ Use Available on Air Supply Stream

Use Secondary Aeration ☐

Secondary Air Supply Stream: In #11: (none)

Secondary Aeration Rate

☒ Calculated to Achieve 0.000 VVM (STD)

☐ Use Available on Secondary Air Supply Stream

OK Anuluj Pomoc

With isolated tank, process requires a cooling.

Fermentatation at 50°C
50% Energy dissipation to heat

FERMENT-1 (Batch Stoich. Fermentation) in P-5

Oper.Cond's Volumes Fed Batch Reactions Intra/Extra Cell % Vent/Emissions Labor, etc. Description Batch Sheet Scheduling

Thermal Mode

☒ Set Final Temp. 50.0 °C

☐ Adiabatic

☐ Set Duty

☒ Heating 5.21 kcal/h

☐ Cooling 0.00 kcal/h

Heat Transfer

Agent Steam

Inlet Temp. 152.0 °C

Outlet Temp. 152.0 °C

Rate 0.01 kg/h

Heat Transfer Efficiency 90.00 %

Power Consumption (for Agitation, etc.)

Power Type Power

☒ Set Specific Power 2.0000 kW/m3

☐ Set Total Power 2.4935 kW

☐ Set Power per Unit 2.4935 kW

Power Dissipation to Heat 50.00 %

Gaseous Components Available To Feed ☒

Duration

Setup Time 0.00 min

Reaction Time

☒ Set by User 48.00 h

☐ Set by Master-Follower Relationship

Match the duration of this operation to the duration of another operation or string of operations.

Ignore Labor ☒

Broth Aeration

Air Supply Stream: In #12: Powietrze_3

Aeration Rate

☒ Calculated to Achieve 1.000 VVM (STD)

☐ Use Available on Air Supply Stream

Use Secondary Aeration ☐

Secondary Air Supply Stream: In #11: (none)

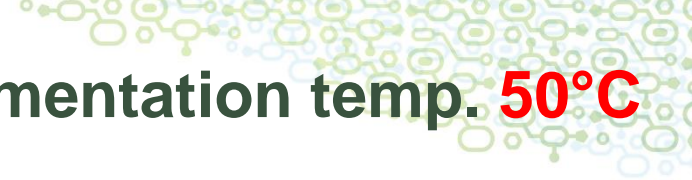
Secondary Aeration Rate

☒ Calculated to Achieve 0.000 VVM (STD)

☐ Use Available on Secondary Air Supply Stream

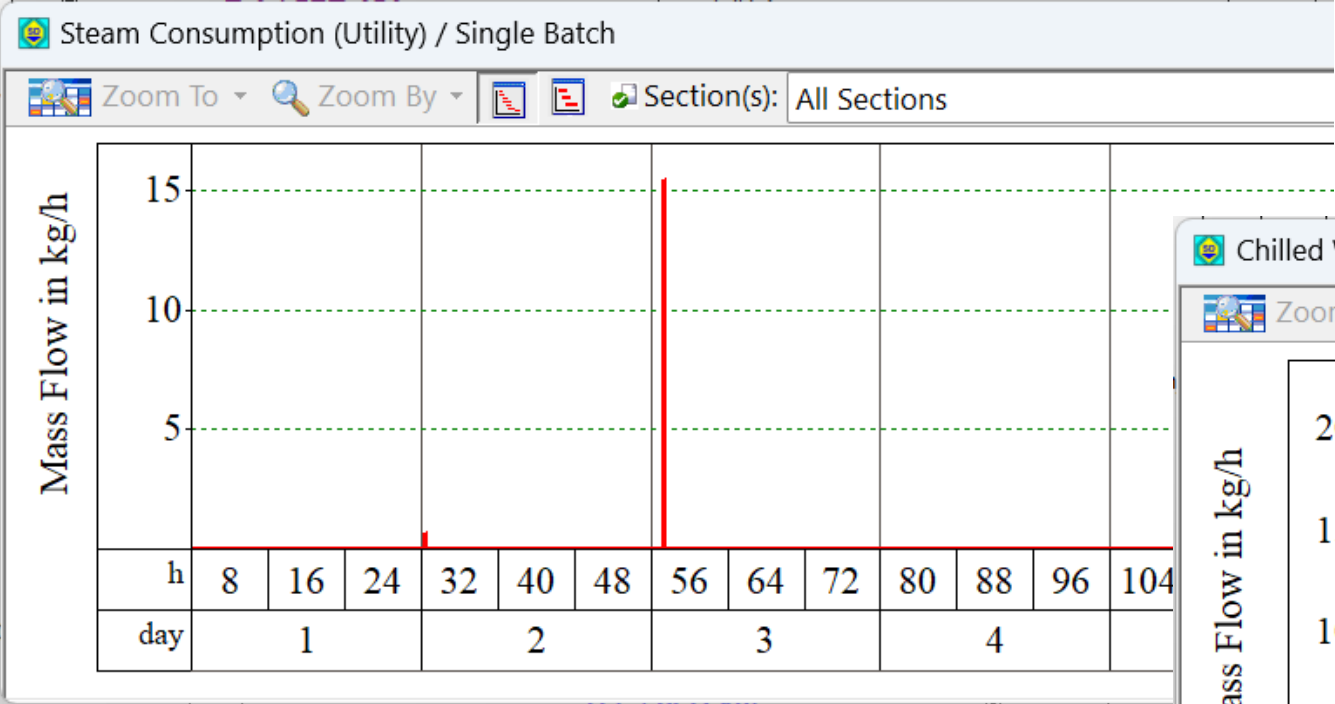
OK Anuluj Pomoc

With isolated tank, process requires a little heating.

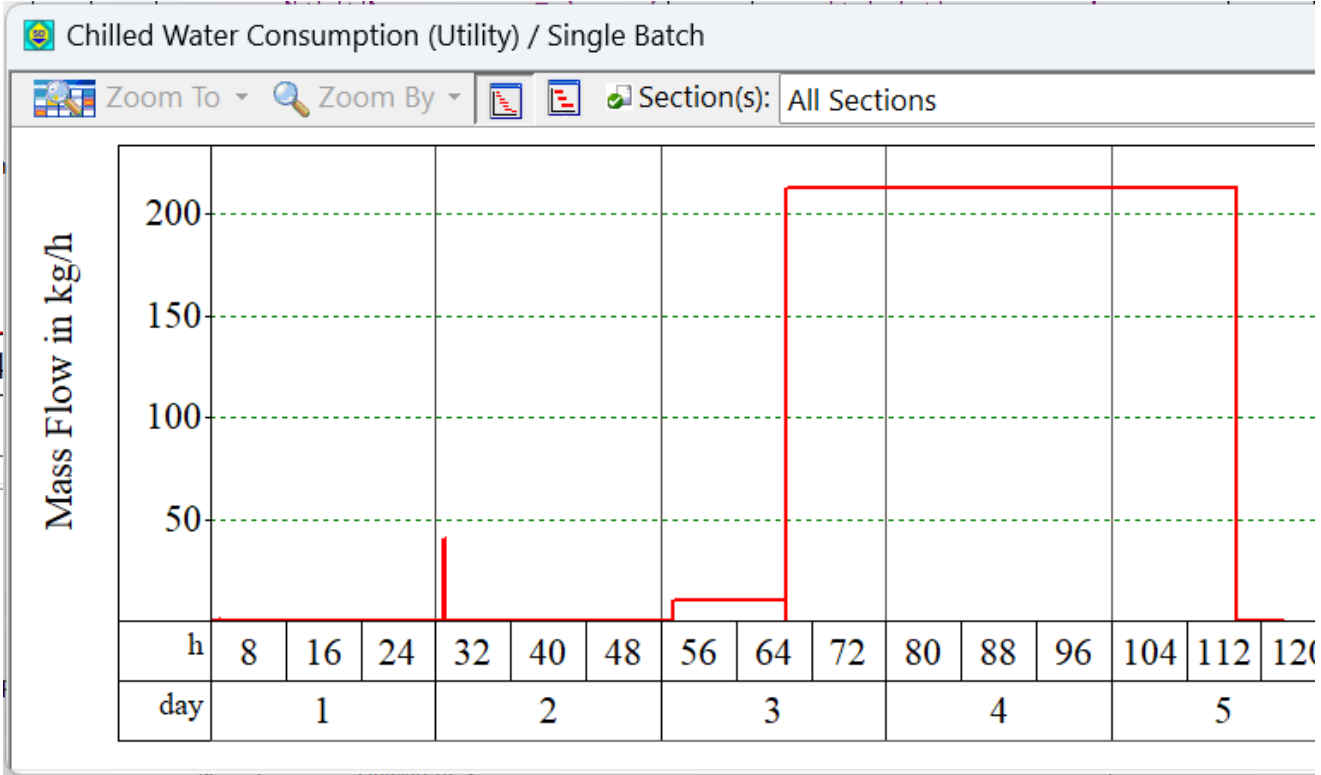


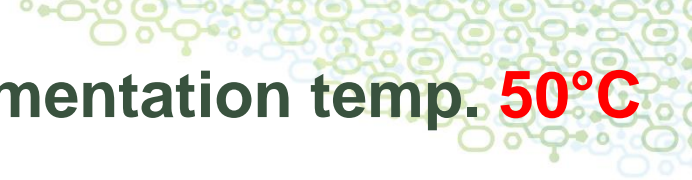
RESULTS: Modelling process **without** media sterilisation, fermentation temp. **50°C**

Heating to 50°C, consumption is very low



Cooling product before formulation





RESULTS: Modelling process **without** media sterilisation, fermentation temp. **50°C**

8. UTILITIES COST (2022 prices) - PROCESS SUMMARY

Utility	Unit Cost (Pln)	Annual Amount	Ref. Units	Annual Cost (Pln)	%
Power	0.9650	15673.20	kW-h	15124.6344	21.93
Steam	60.0000	0.14	MT	8.6537	0.01
Chilled Water	50.0000	1074.62	MT	53730.9663	77.89
Freon	0.7500	154.49	MT	115.8643	0.17
TOTAL				68980.1187	100.00

100% to heat

8. UTILITIES COST (2022 prices) - PROCESS SUMMARY

Utility	Unit Cost (Pln)	Annual Amount	Ref. Units	Annual Cost (Pln)	%
Power	0.9650	15673.20	kW-h	15124.6344	94.96
Steam	60.0000	0.20	MT	11.7537	0.07
Chilled Water	50.0000	13.52	MT	675.8036	4.24
Freon	0.7500	154.49	MT	115.8643	0.73
TOTAL				15928.0559	100.00

50% to heat



CONCLUSIONS

- Eliminating medium sterilisation reduces media costs (steam and chilled water), investment costs (no need to purchase high efficiency steam and chilled water production equipment, no need to maintain such equipment) and allows for shorter batch fermentation cycle times (more cycles per year).
- For continuous processes/sterilisation this difference will also be important!