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FORSKNINGS-SENTER FOR MILJØVENNLIG ENERGI
Norges forskningsråd

NTNU

GRANS NEW BREWERY

April 23, 2018

Presentation

1. Planned process. Baseline
2. Alternative design
3. Results and recommendations

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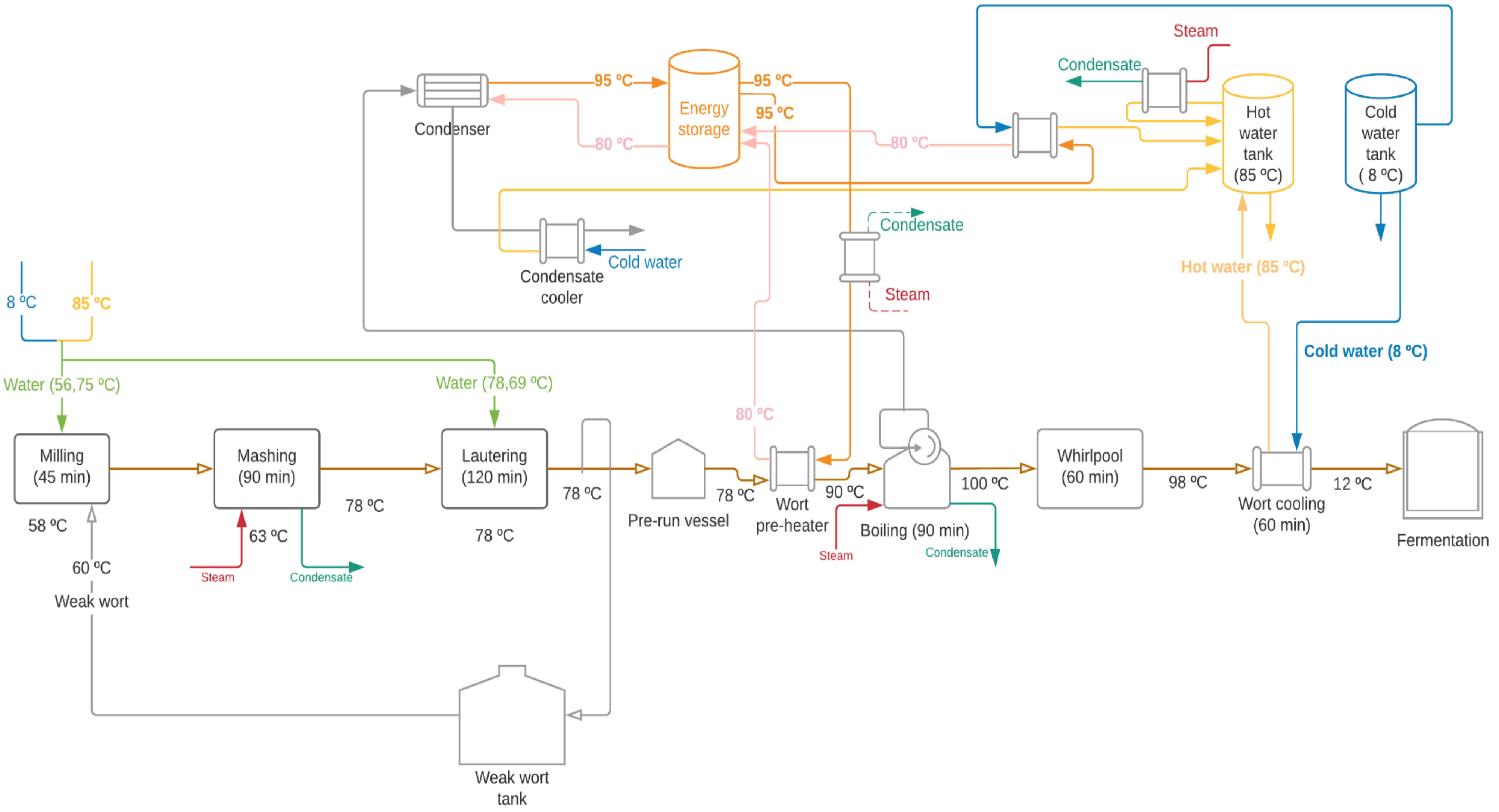
Baseline: Key points

- Great demand of steam: process + CIPs
- Steam produced by burning LPG
- Heat being rejected to the ambient
- Installation of an energy storage

Baseline: Process



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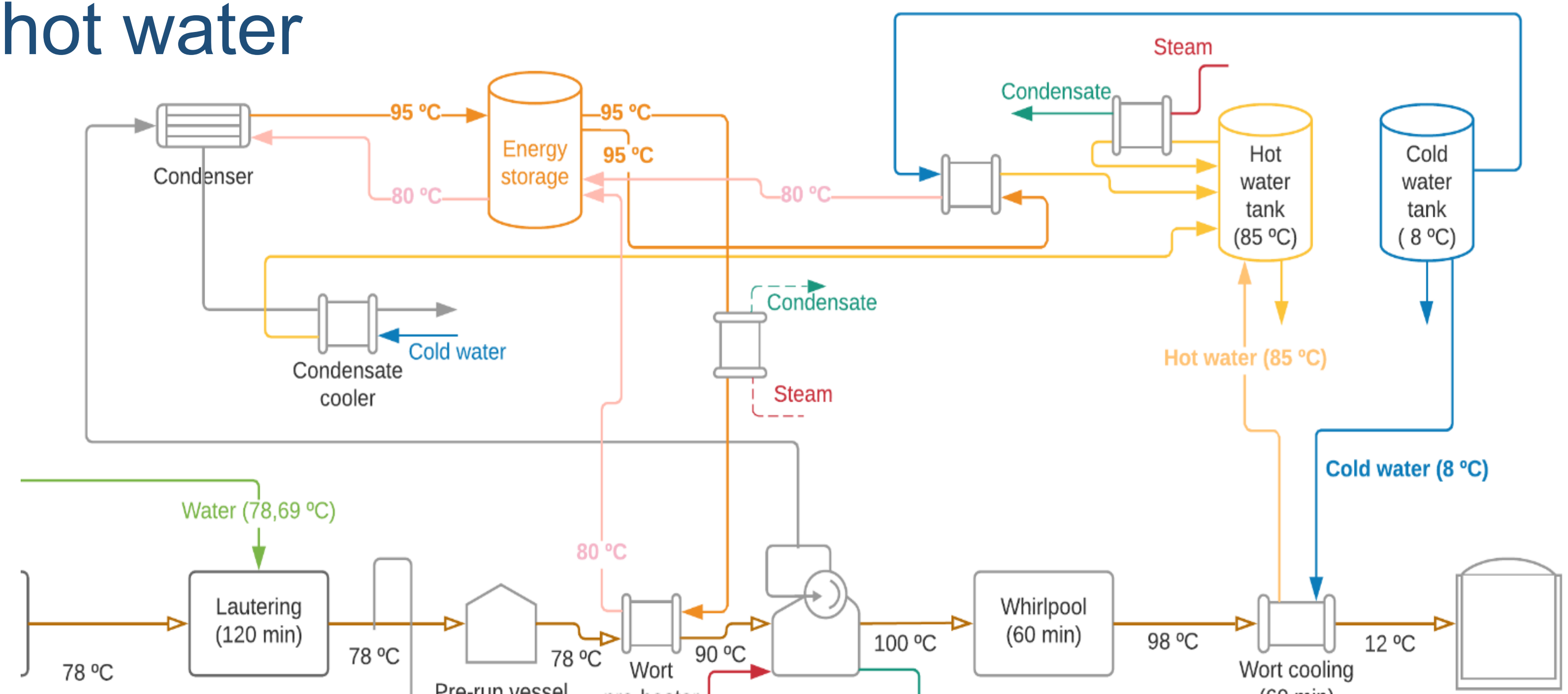
Baseline: Energy storage

- Condensing steam from the boiling
- Preheating the wort
- Producing hot water



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Baseline: Demands

Production schedule

- 14 brews per week for 135.000 hl/year
- Analysis for 15-minute intervals

Inputs and outputs

- Water at 8 ºC, 80 ºC, 85 ºC and 95 ºC
- Steam

CIP: beer + soft drinks

Net demands

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Baseline: Demands of the process

	4:00	4:15	4:30	4:45	5:00	5:15	5:30	5:45	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30
BATCH 1	**Milling (S1B1)**			**Mashing (S1B1)**						Lautering (S1B1)								Boiling (S1B1)						Whirlpool (S1B1)				Wort cooling (S1B1)			
Temperature (ºC)	52	52	52	53	63	63	63	63	78	78	78	78	78	78	78	78	78	90	100	100	100	100	100	98	98	98	98	12	12	12	12
Hot water (85 ºC) input (l/min)	107	107	107							157	157	157	157	157	157	157	157														
Water (95 ºC) input (l/min)																		1120	454	454	242,1										
Water (80 ºC) input (l/min)																			454	454	454	454	454								
Cold water (8 ºC) input (l/min)	62	62	62							14	14	14	14	14	14	14	14		86,1	86,1	45,9							375,3	375,3	375,3	375,3
Steam 3.5 bar input (kg/min)				12,3					18,4										15,9	15,9	15,9	15,9	15,9								
Hot water (85 ºC) output (l/min)																			86,1	86,1	45,9							375	375	375	375
Water (95 ºC) output (l/min)																			454	454	454	454	454								
Water (80 ºC) output (l/min)																		1120	454	454	242,1										
Cold water (8 ºC) output (l/min)																															
BATCH 2									**Milling (S1B2)**			**Mashing (S1B2)**						Lautering (S1B2)								Boiling (S1B2)					
Hot water (85 ºC) input (l/min)									107	107	107							157	157	157	157	157	157	157	157						
Water (95 ºC) input (l/min)																										1120	454	454	242,1		
Water (80 ºC) input (l/min)																											454	454	454	454	454
Cold water (8 ºC) input (l/min)									62	62	62							14	14	14	14	14	14	14	14		86,1	86,1	45,9		
Steam 3.5 bar input (kg/min)												12,3					18,4										15,9	15,9	15,9	15,9	15,9
Hot water (85 ºC) output (l/min)																											86,1	86,1	45,9		
Water (95 ºC) output (l/min)																											454	454	454	454	454
Water (80 ºC) output (l/min)																										1120	454	454	242,1		
Cold water (8 ºC) output (l/min)																															
TOTAL																															
Hot water (85 ºC) needed (l/min)	107	107	107	0	0	0	0	0	107	264	264	157	157	157	157	157	157	157	70,9	70,9	111,1	157	157	157	157	0	-86,1	-461	-421	-375	-375
Water (95 ºC) needed (l/min)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	0	0	-212	-454	-454	0	0	1120	0	0	-212	-454	-454
Water (80 ºC) needed (l/min)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1120	0	0	211,9	454	454	0	0	-1120	0	0	211,9	454	454
Cold water (8 ºC) needed (l/min)	62	62	62	0	0	0	0	0	62	76	76	14	14	14	14	14	14	14	100	100	59,9	14	14	14	14	0	86,1	461	421,2	375	375
Steam 3.5 bar needed (kg/min)	0	0	0	12,3	0	0	0	0	18,4	0	0	12,3	0	0	0	0	18,4	0	15,9	15,9	15,9	15,9	15,9	0	0	0	15,9	15,9	15,9	15,9	15,9

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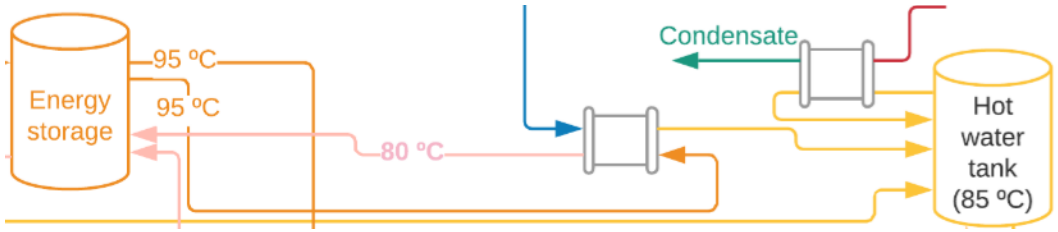
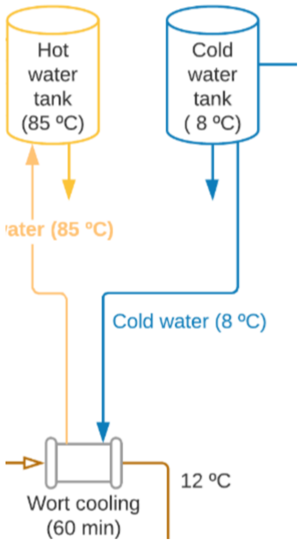
Baseline: Demands

Brewing process

Net demand	Per brew	Per week (14 brews)
Water at 80 °C (liters)	0	**0**
Water at 95 °C (liters)	0	**0**
Water at 85 °C (liters)	-2.132	**-29.857**
Water at 8 °C (liters)	30.257	**423.608**
Steam at 3,5 bar (kg)	1.588,5	**23.142**





Steam is **necessary** for a fast heat transfer

Baseline: Demands

Beer CIP

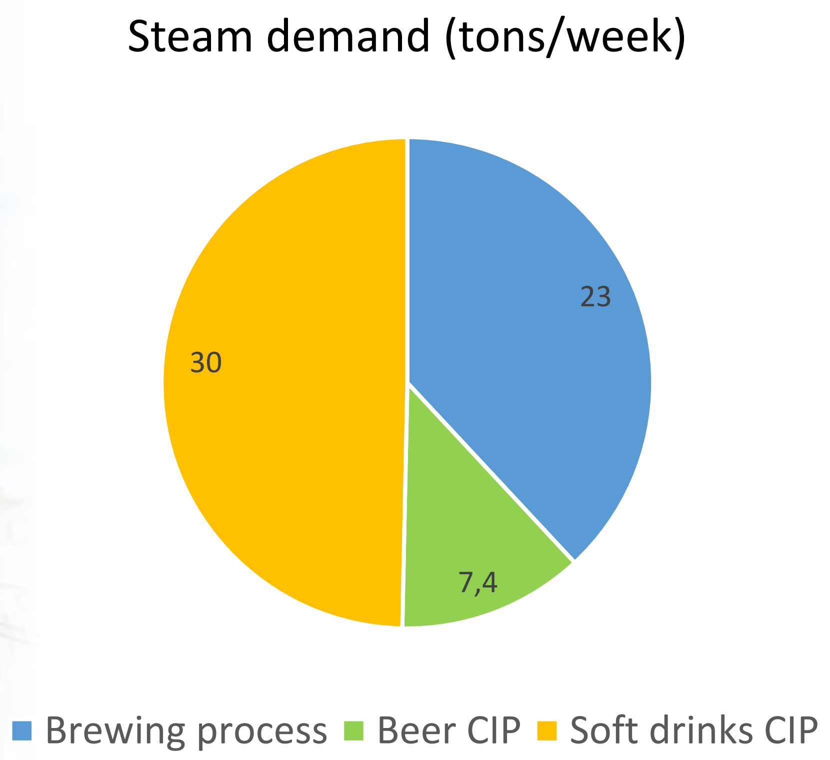
	Water at 100 ºC demand per cycle (liters)	Cycles per week	Total demand of water at 100 ºC (liters/week)	Total steam demand to heat the water up from 8 ºC to 100 ºC (kg/week)
Process	6.000	1	6.000	952
Filling line	5.520	7	38.640	6.130
Total	-	-	44.640	**7.402**

Soft drinks CIP

	Water at 100 ºC demand per cycle (liters)	Cycles per week	Total demand of water at 100 ºC (liters/week)	Total steam demand to heat the water up from 8 ºC to 100 ºC (kg/week)
Large CIP	7.200	10	72.000	11.796
Small CIP	3.600	30	108.000	17.693
Total	-	-	180.000	**29.849**

Steam is **not necessary**: Obtain hot water by other means

Baseline: LPG consumption

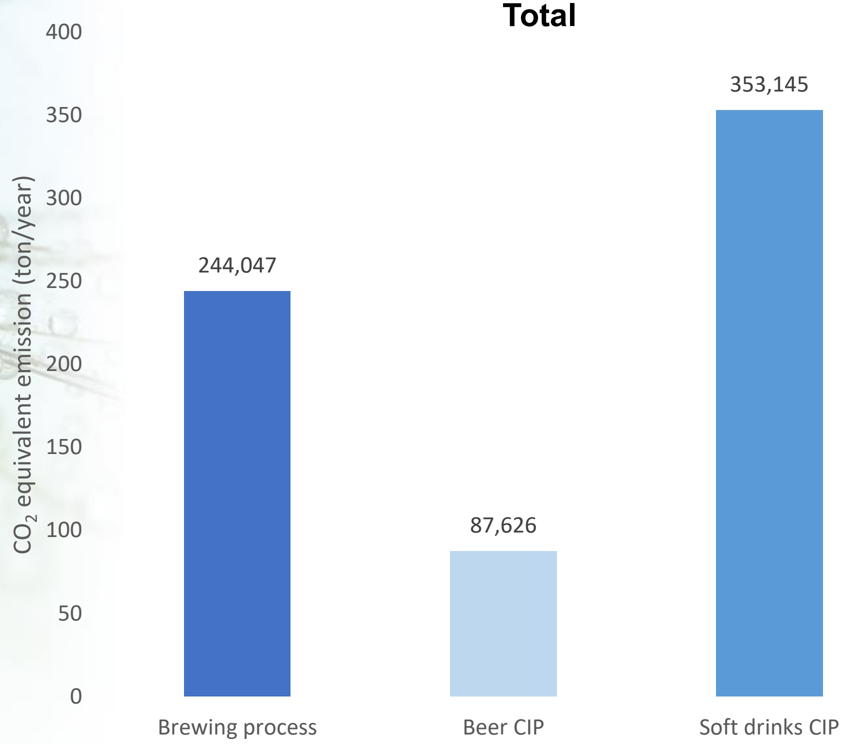


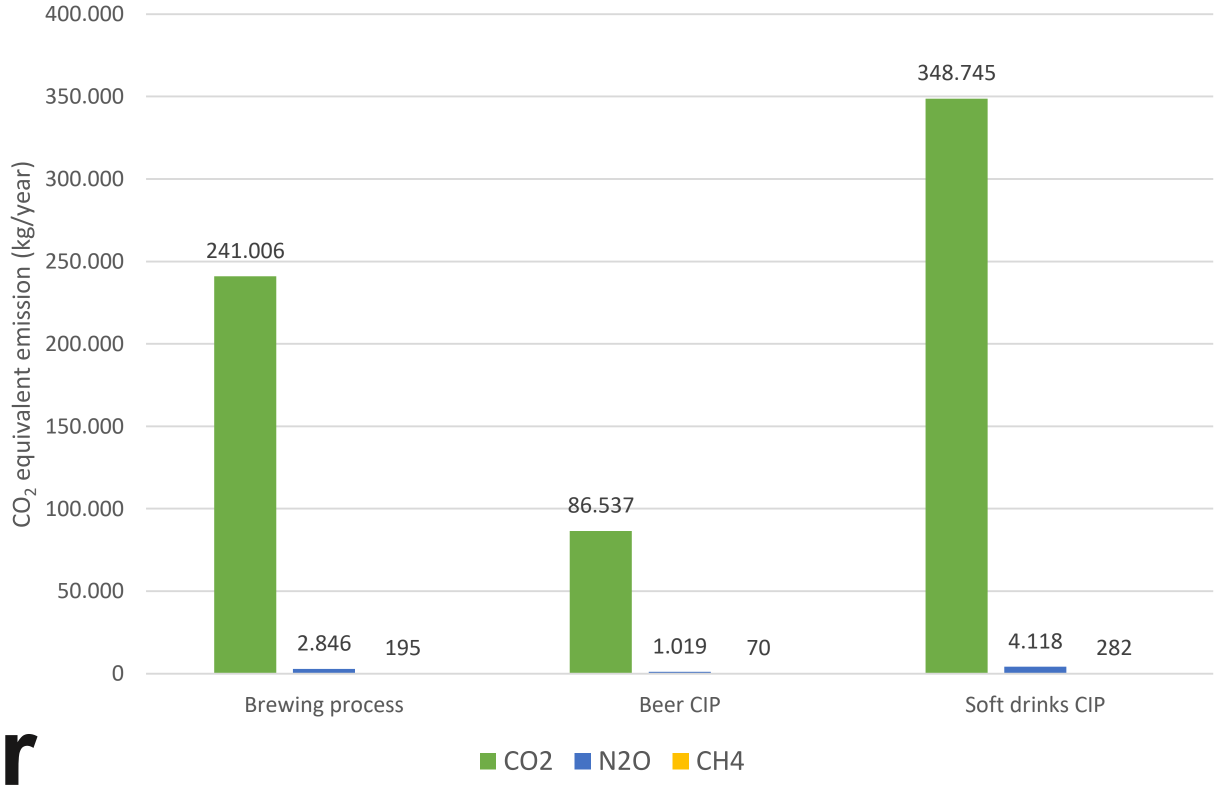
- Brewing proces: 1,7 tons/week
- Beer CIP: 0,6 tons/week
- Sof drinks CIP: 2,5 tons/week

234 tons of LPG/year

Baseline: Emissions

CO_2 equivalent emission (kg/year)	CO_2	CH_4	N_2O
Brewing process	241.006	195	2.846
Beer CIP	86.537	70	1.019
Soft drinks CIP	348.745	282	4.118
Total	**676.288**	**547**	**7.983**





685 tons of CO_2/year

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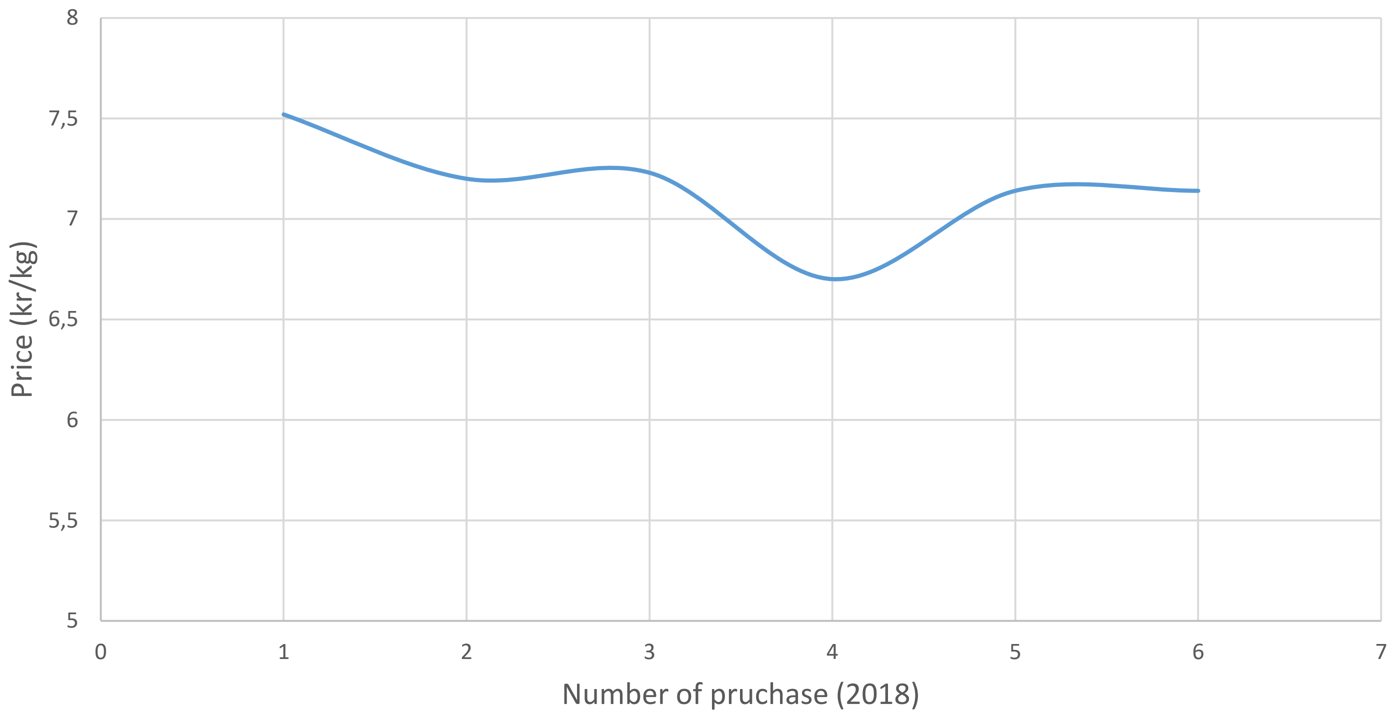
Baseline: Economic cost



LPG price increase since 2017 due to CO_2 taxes. It will continue to rise.

Best case scenario: **1,7 Million kroner per year**

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Baseline: Rejected heat. Tank farm

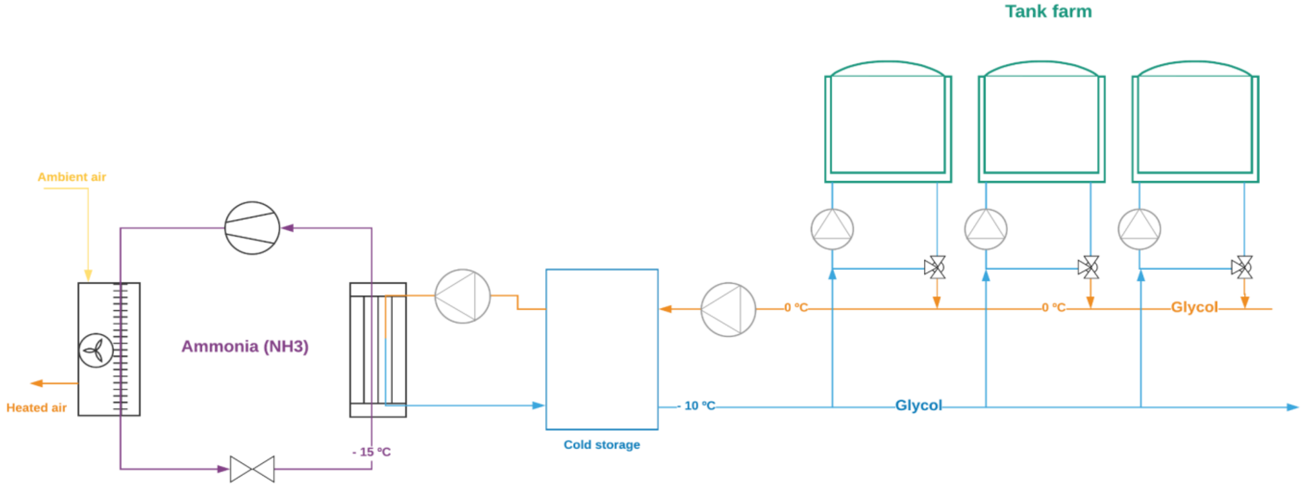
- 600 m^3 of beer in the tank farm

- 52 kW for cooling (Nominally)

Loses, insulation...

- **60 kW** at any time

Lost to the ambient air



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Baseline: Rejected heat. Residual water

- 184 m^3 of water at 20 ºC per day
- 5 days a week

If cooled to 5 ºC

- **133,5 kW available**

Currently lost

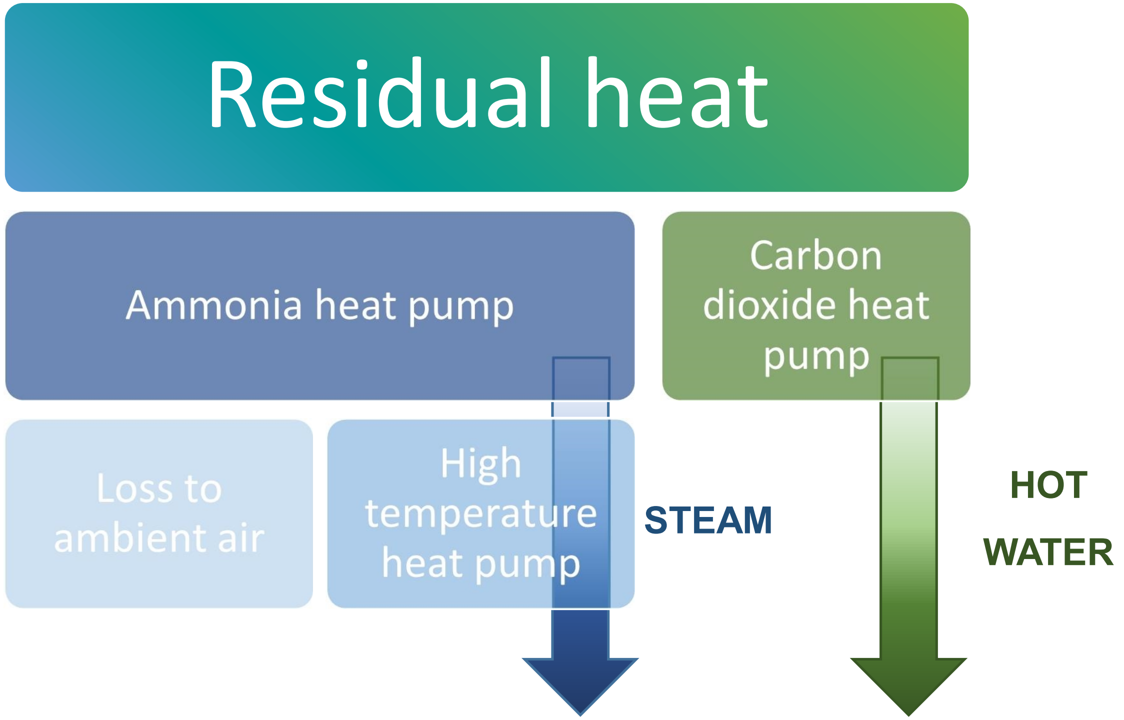
Alternative design: Key points

- Use of heat pumps
- Use of residual heat
- Reduce steam demand
- Eliminate LPG: reduced emissions

Alternative design: Key points

Residual heat is used to produce steam and hot water:

- Steam is produced with a **high temperature heat pump**
- Hot water is produced with a **carbon dioxide heat pump**



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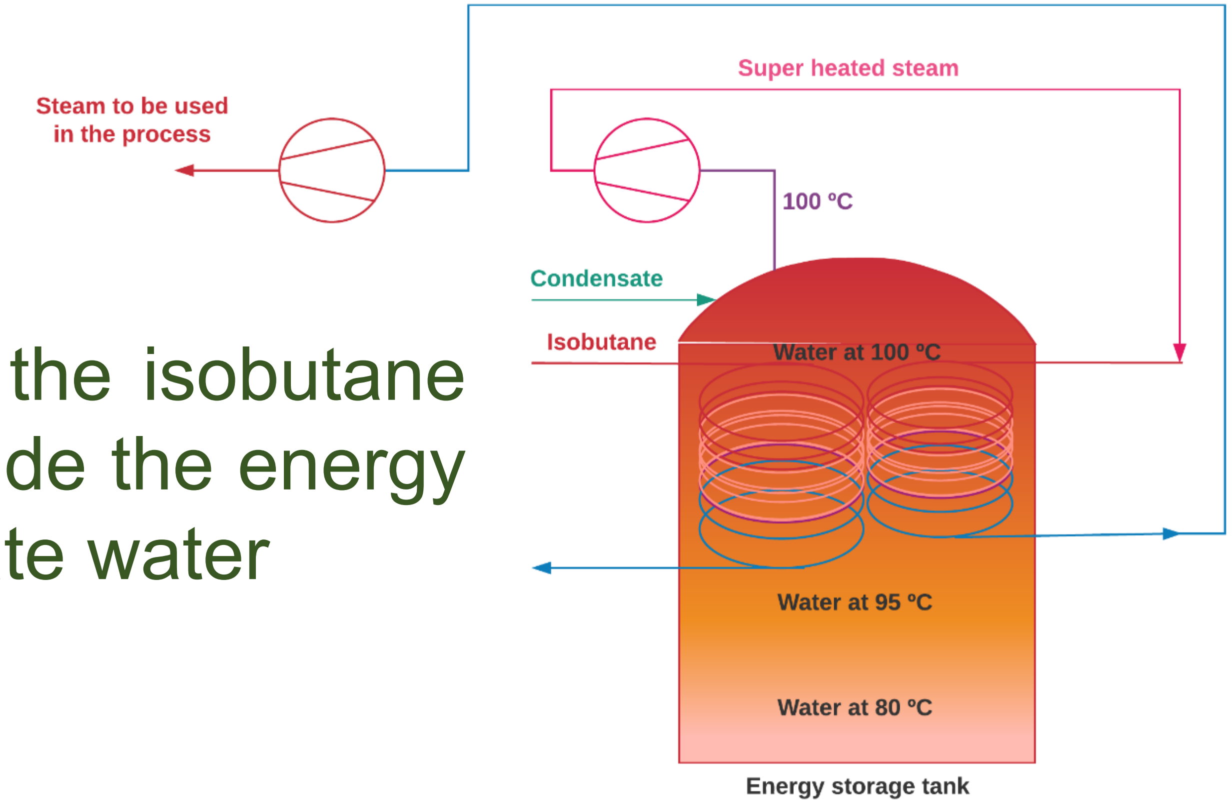
Alternative design. Production of steam

Ammonia – Isobutane heat pump cascade system

Steam is generated at 1 bar and then compressed to 3,5 bar

The condenser of the isobutane cycle is a coild inside the energy storage to evaporate water



Alternative design. Production of hot water

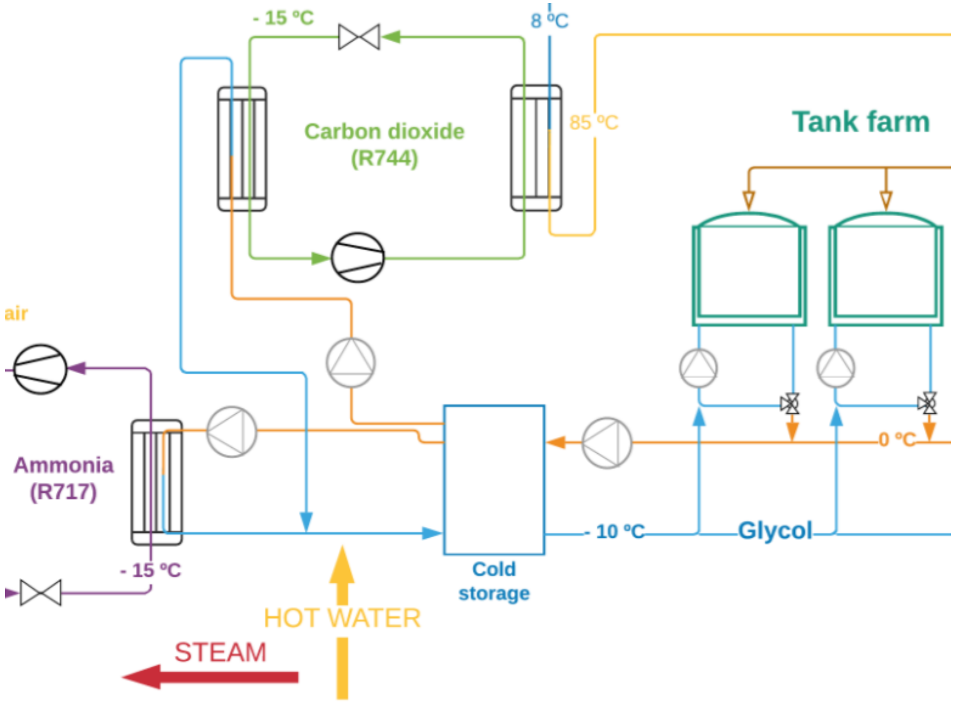
Carbon dioxide heat pump

- Initially it was considered to produce water at 85 ºC (First stages), but it is much more efficient and useful to produce water at 100 ºC (Stage 3)

- In parallel to the cascade system

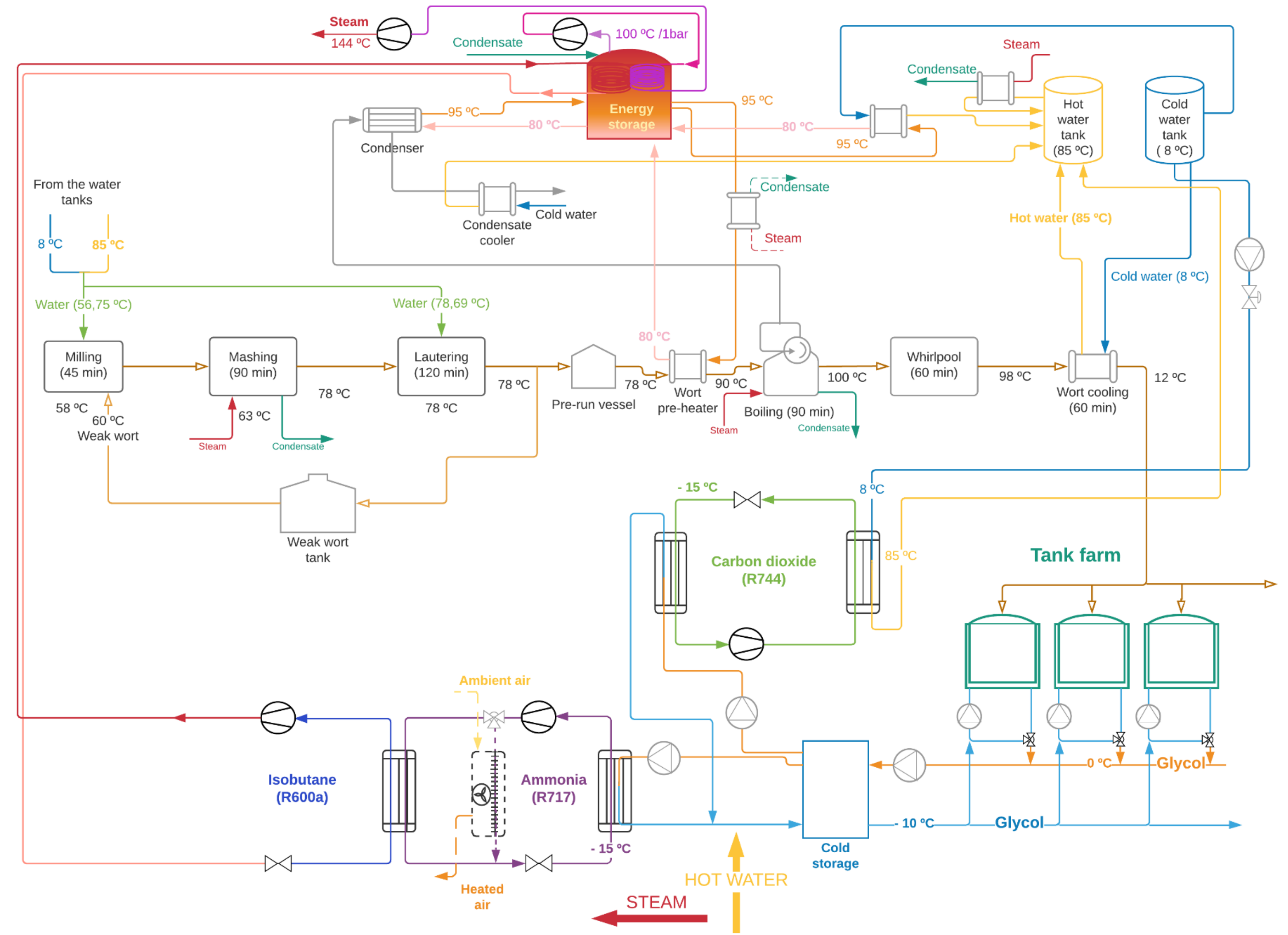
Alternative design: Stage 1

- Only the residual heat from the tank farm is considered
- The heat can be used to produce steam or hot water, or it can be discarded through the ammonia system
- 60 kW, 24/7



Alternative design: Stage 1

Residual heat from the tank farm



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Alternative design: Stage 1

- Maximum production: 36 tons of steam per week or 159 m^3 of water at 85 ºC

Not enough to cover the demands

Need for a second heat source

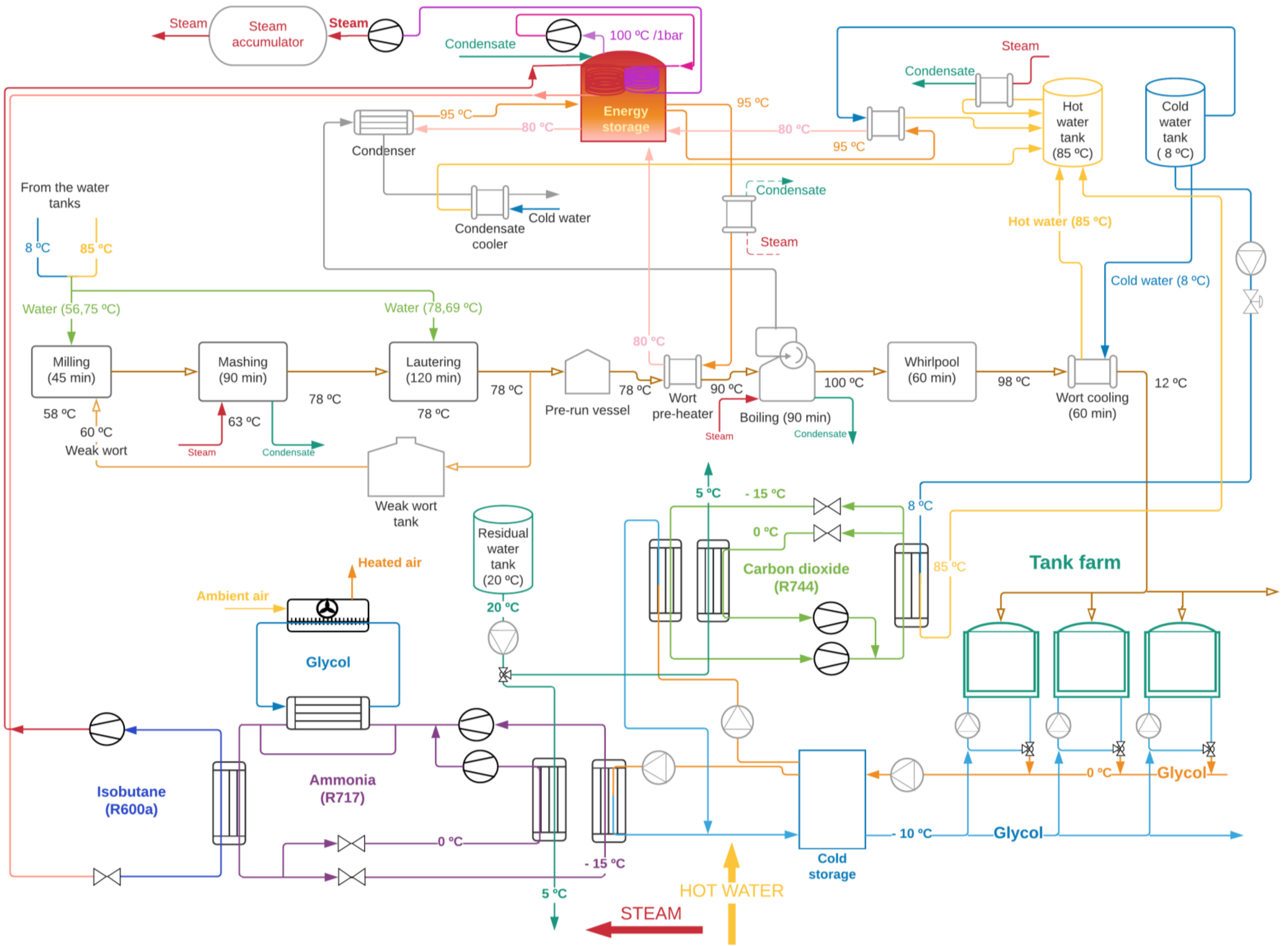
Residual water

Alternative design: Stage 2

- Both the heat from the tank farm and from the residual water are used
- The water is cooled from 20 ºC to 5 ºC
- 60 kW (24/7) + 133,5 kW (5 days/week)
- Parallel cycles

Alternative design: Stage 2

Tank farm + Residual water



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Alternative design: Stage 2

	Heat available at source (kW)	Days of availability per week	Maximum steam generation (kg/week)
Tank farm (0 ºC)	60	7	36.187
Residual water (20 ºC)	133,5	5	52.344
Total	-	-	**88.531**

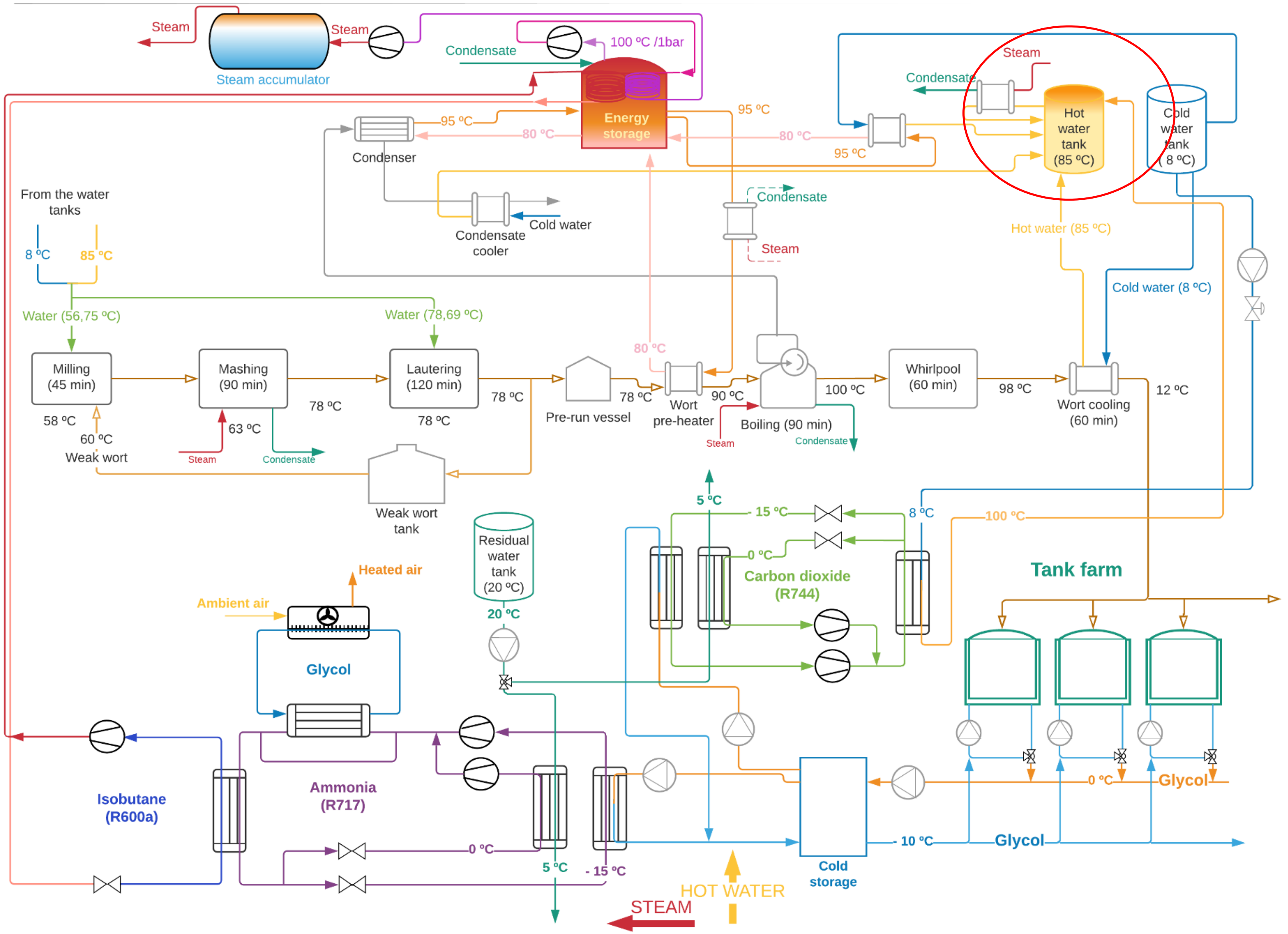
Weekly demand	Steam (kg)
Brewing process	23.142
Beer CIP	7.402
Soft drinks CIP	29.849
Total	**60.393**

- Enough to cover the demands
- Very inefficient: better to produce water at 100 ºC for the CIP and eliminate steam

Alternative design: Stage 3

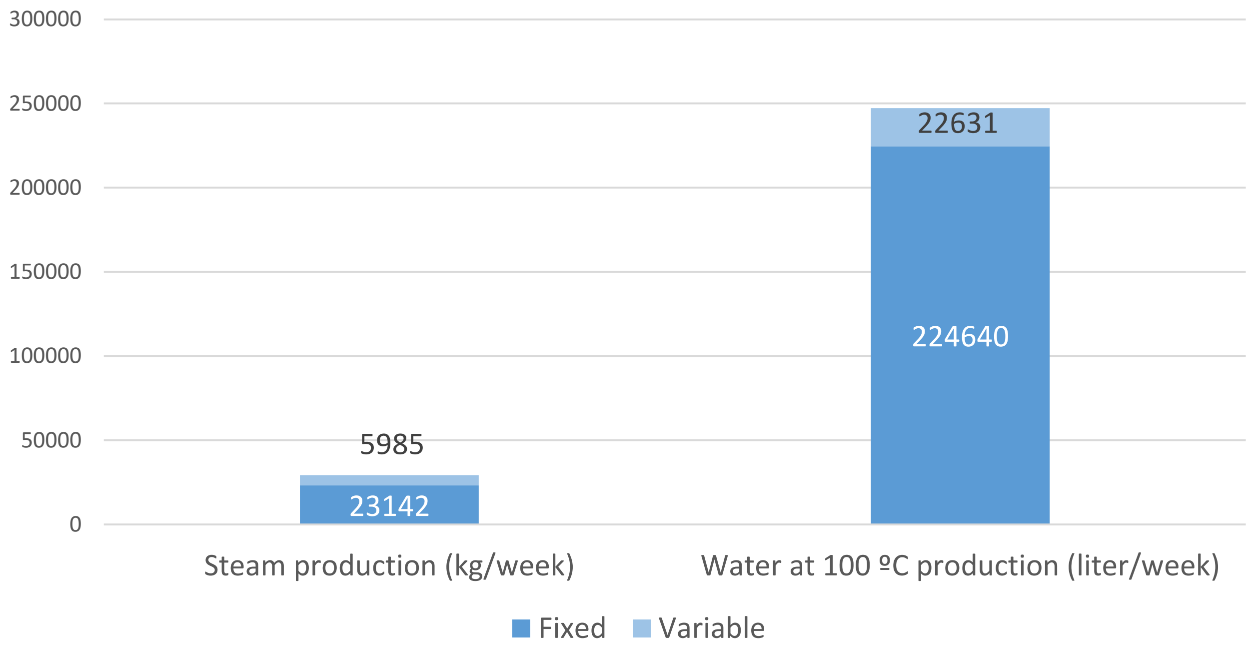
Tank farm + Residual water

Steam + Water at 100 ºC



Alternative design: Stage 3

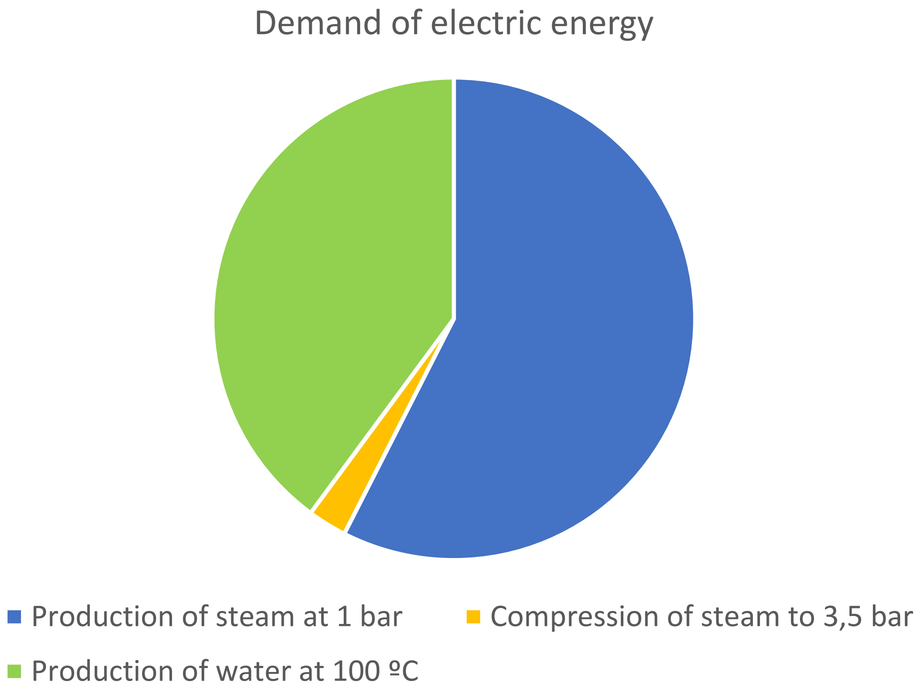
Weekly demand	Steam (kg)		Water at 100 ºC (liters)
Brewing process	**23.142**		0
Beer CIP	7.402	or	44.640
Soft drinks CIP	29.849	or	180.000
Maximum total	60.393		**224.640**
Maximum weekly generation	**88.531**	**or**	**334.783**

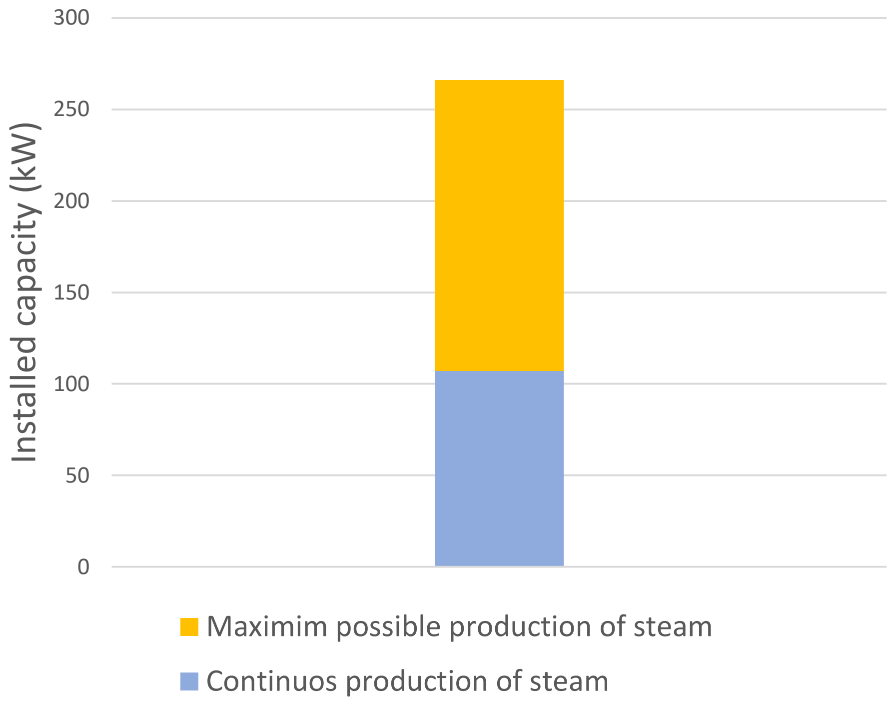


- 62% steam demand

Electricity consumption

Alternative design: Stage 3





Electricity consumption:

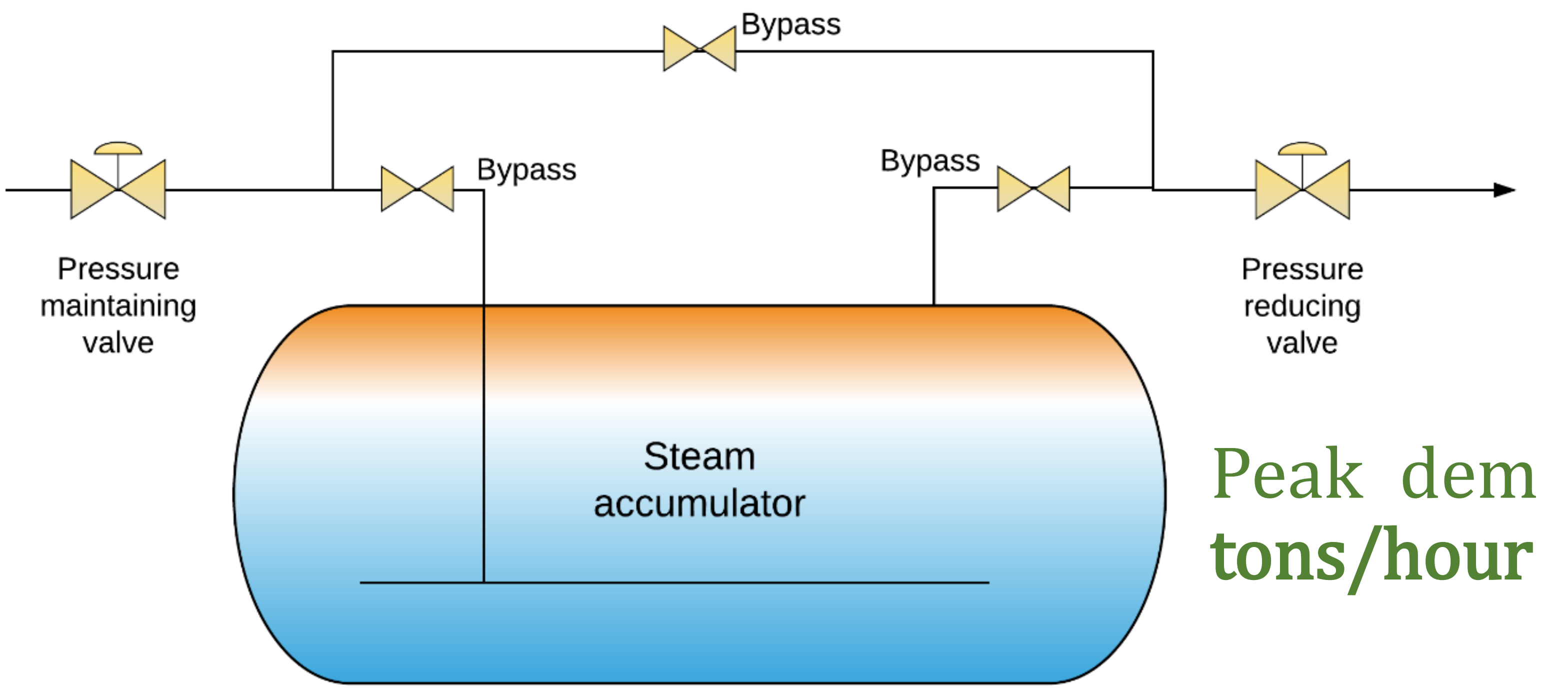
~ 727 MWh/year

Installed capacity:

266 kW (Maximum production of steam, 650 kg/hour)

107 kW (Continuous production of steam, 137 kg/hour)

Alternative design: Stage 3



Peak demand of **1,7 tons/hour**

Capacity of the steam accumulator:

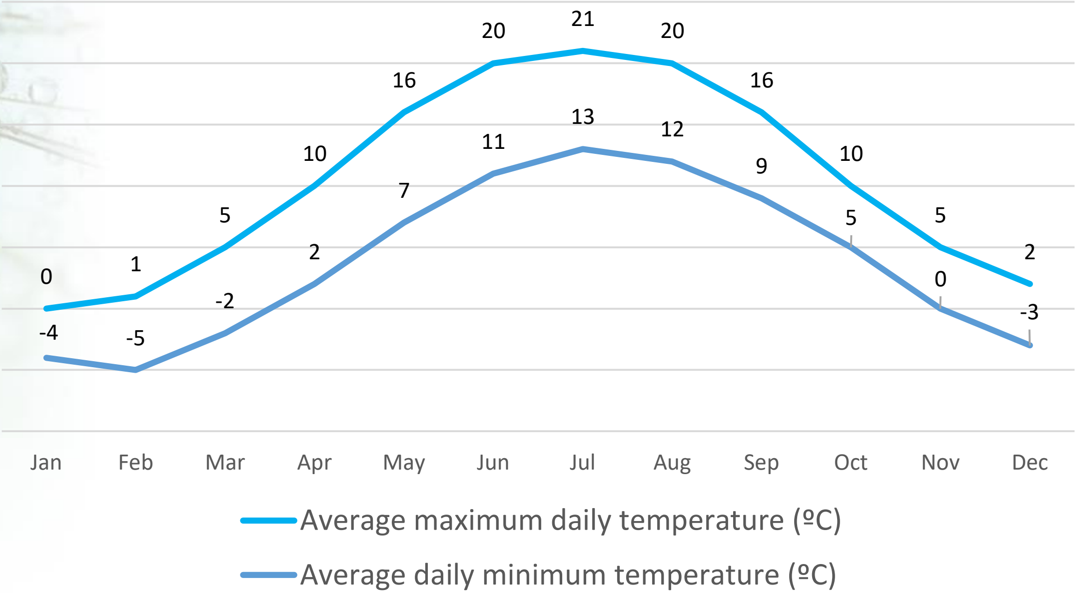
5 tons (Maximum production of steam)

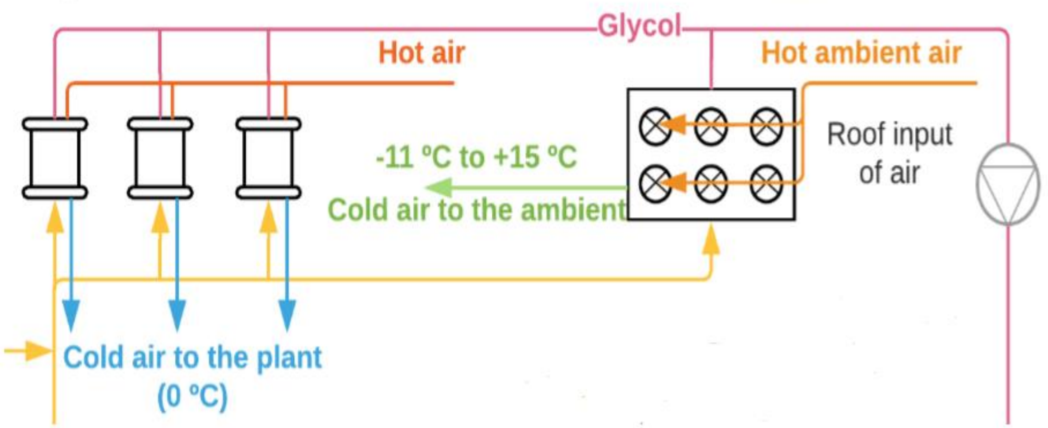
12 tons (Continuous production of steam)

Alternative design: Additional options

- Heat from the cooling of the plant in the summer
- Heat from the ambient air in the winter: through the roof
- Use of glycol

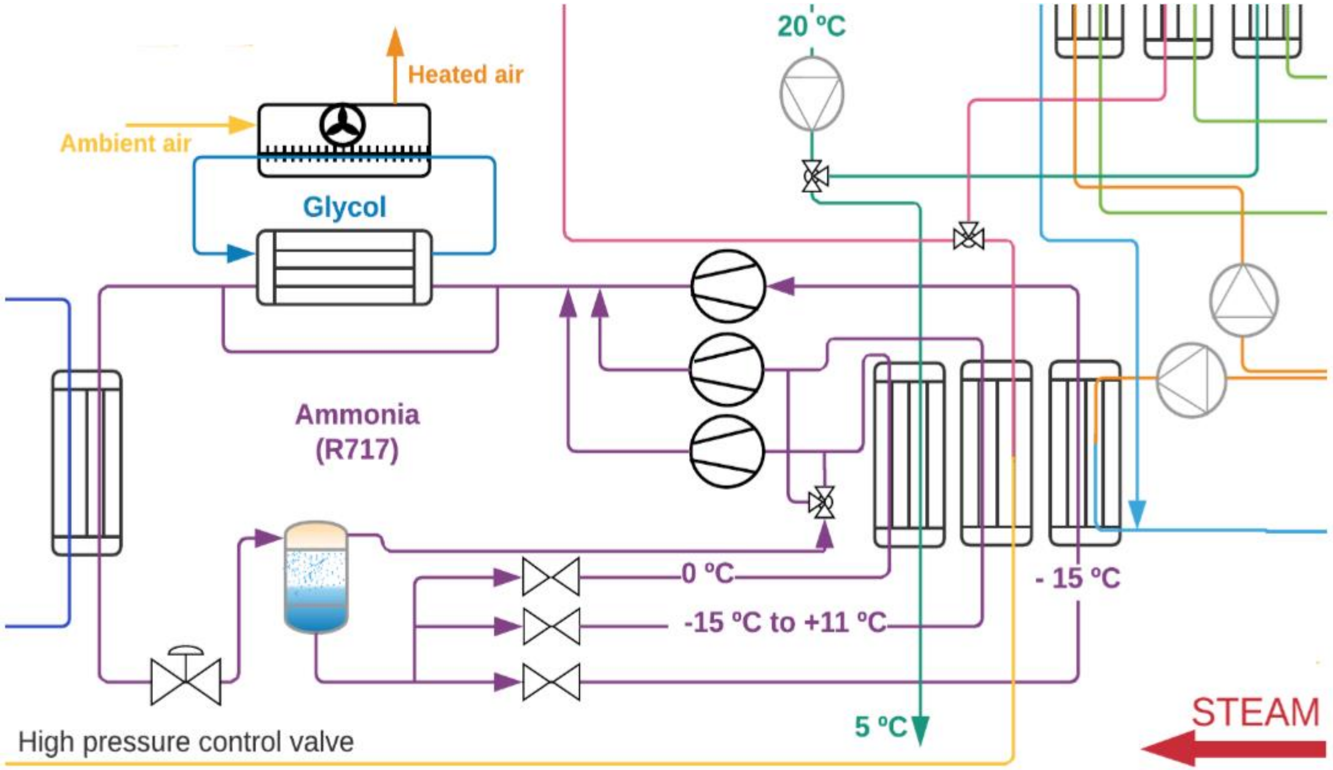
Theoretical: To cover other necessities of the plant or as an alternative





Alternative design: Additional options

- 3 Parallel cycles
- Variable evaporation temperature



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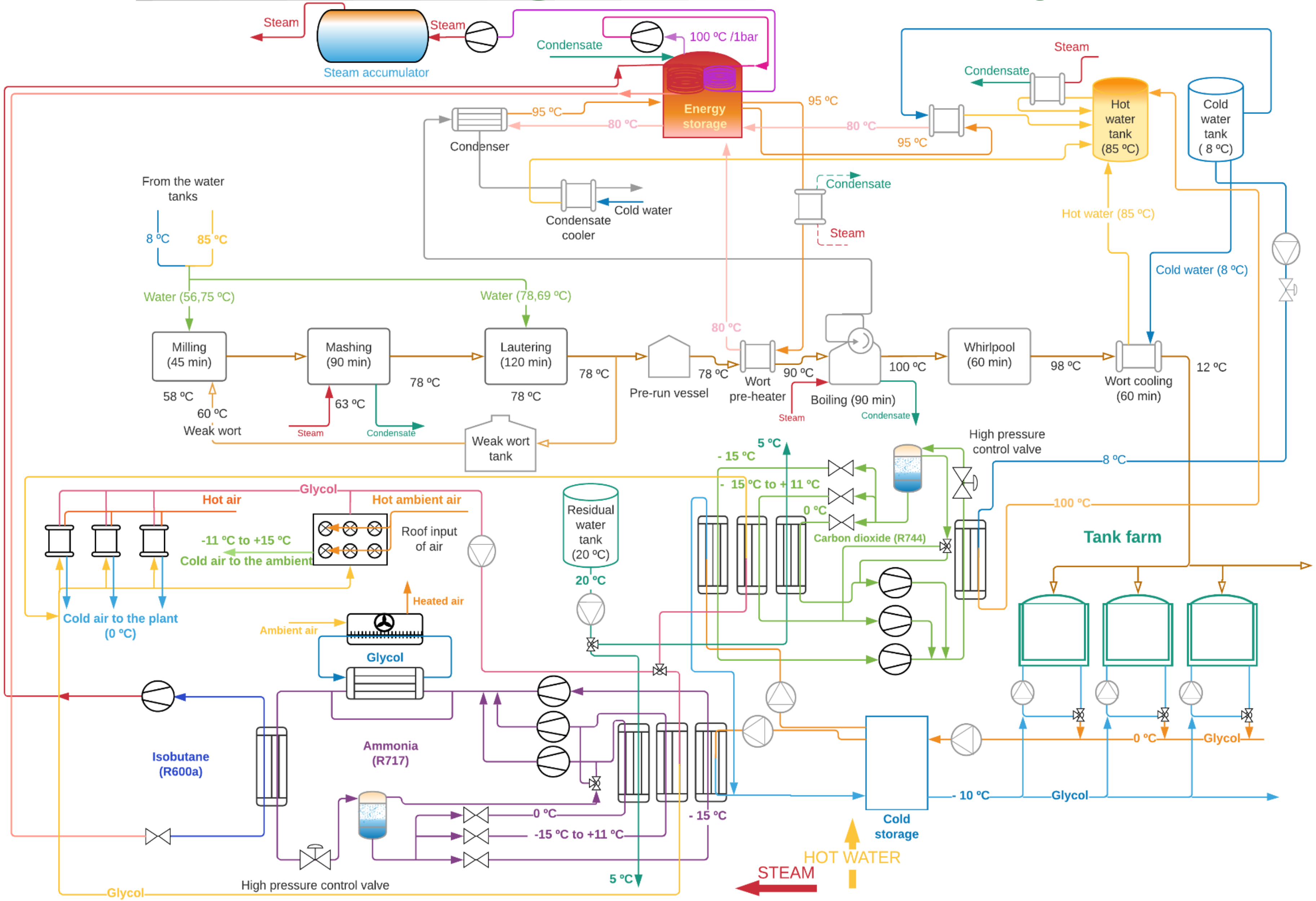
Alternative design: Additional options

Tank farm + Residual water + Air



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Results

Environmental considerations → Operating costs → Final considerations

❖ Air is not considered as a heat source for this stage, only as a possible alternative

Results: Environmental impact

- Different sources for the electricity:

General mix
- 31 gCO_2/kWh
- 22,5 tons of CO_2 per year

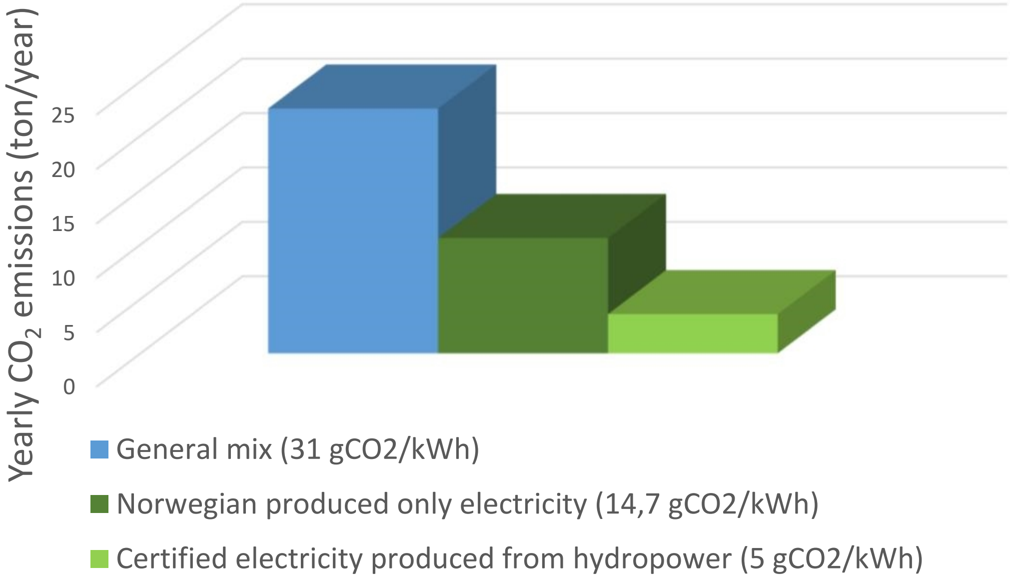
Norwegian produced
- 14,7 gCO_2/kWh
- 10,7 tons of CO_2 per year

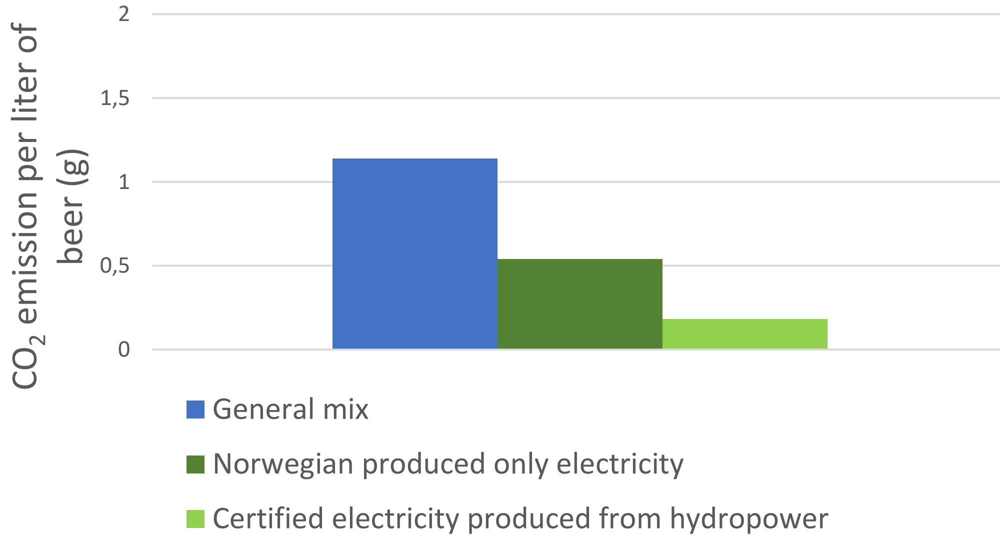
From hydropower
- 5 gCO_2/kWh
- 3,5 tons of CO_2 per year

Guarantee of Origin

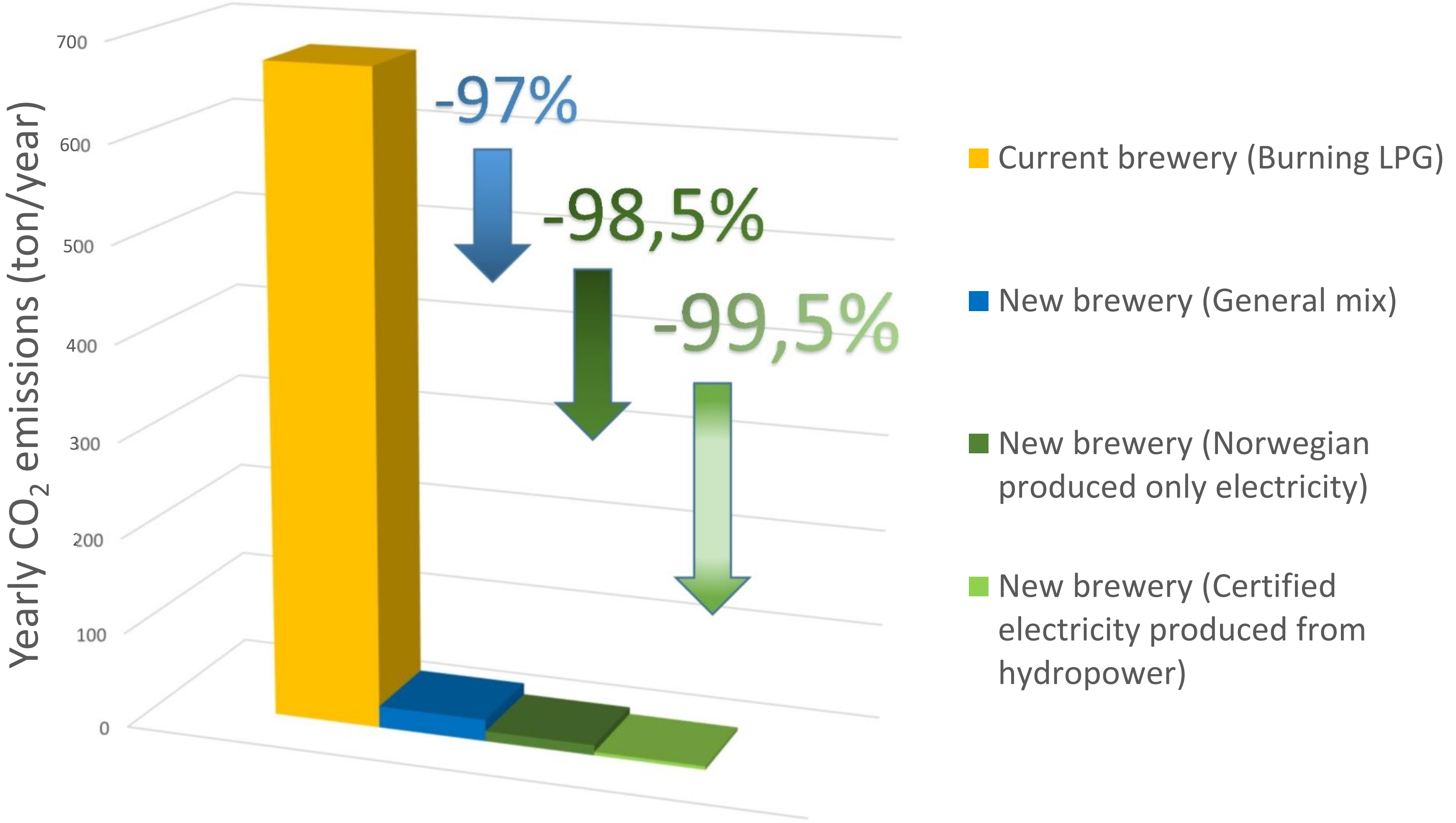
Results: Environmental impact

	CO_2 emissions per liter of beer (g)	CO_2 total yearly emissions (t)
Current brewery (Burning LPG)	25	685
New brewery (General mix)	1,1	22
New brewery (Norwegian produced only electricity)	0,5	10
New brewery (Certified electricity produced from hydropower)	0,2	3,5





Results: Environmental impact

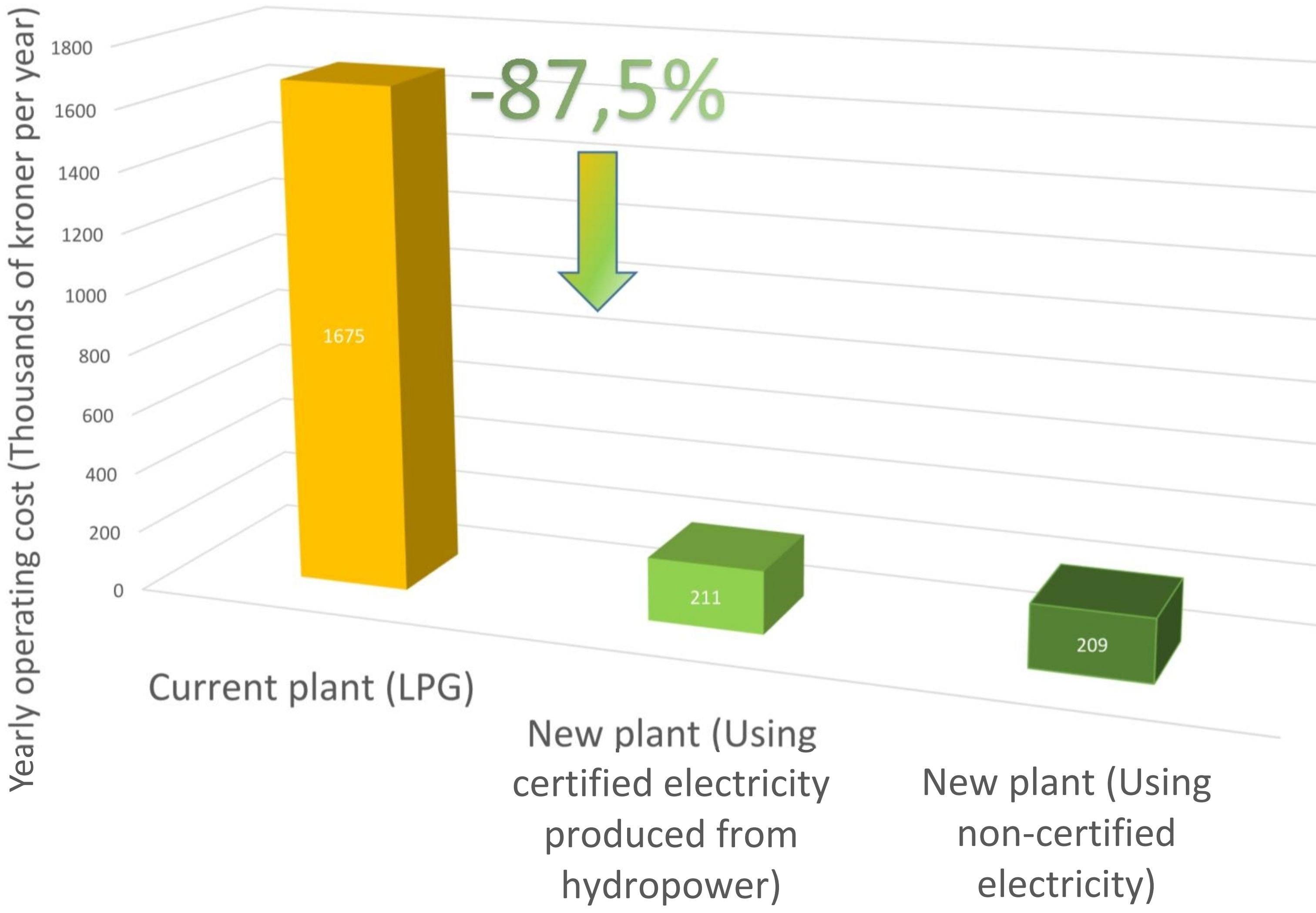


Results: Operating costs

With GOs: 211 k kroner/year

$\pm 1\%$

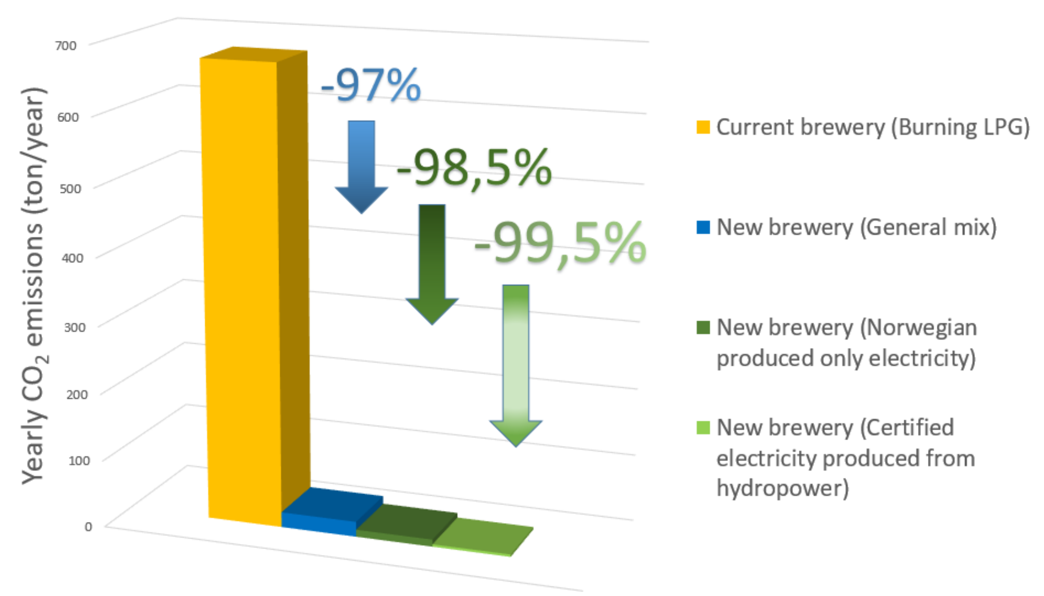
Without GOs: 209 k kroner/year

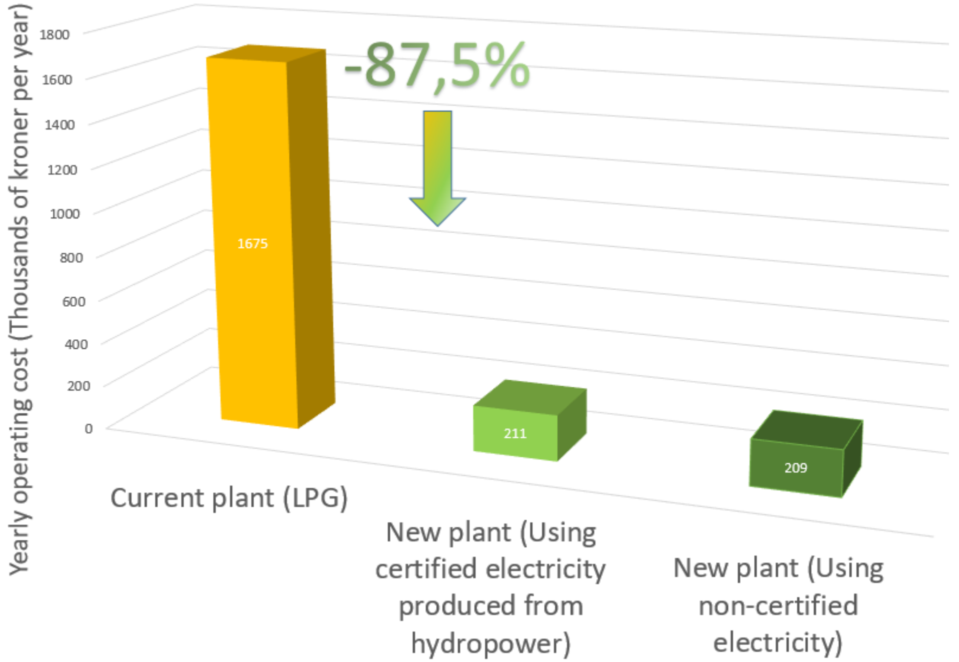


Results: Final considerations

✓ The use of residual heat from the tank farm and from the residual water offers almost a complete elimination of the CO_2 emissions and a great reduction of the operating costs

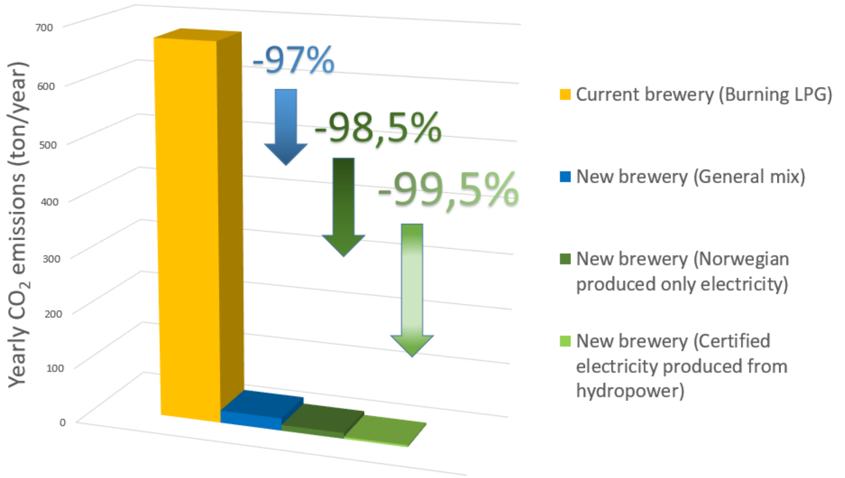
✓ Steam is not necessary for the CIP systems, and production of water at 100 ºC is much more efficient

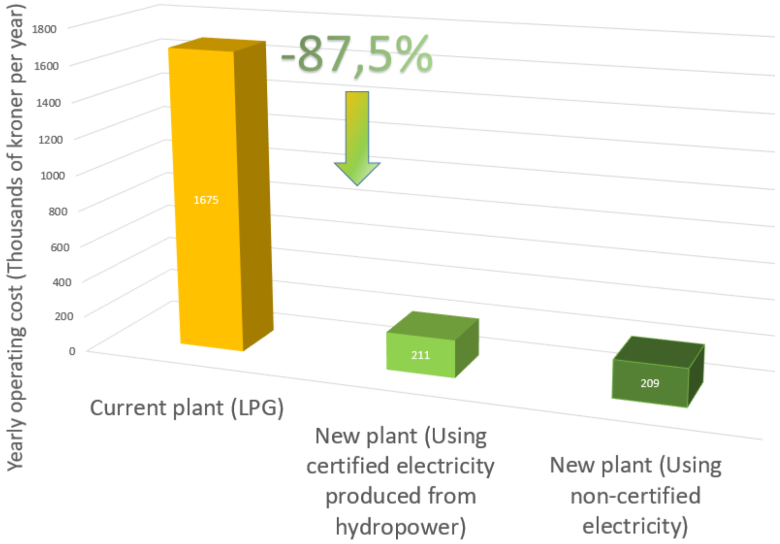




Results: Final considerations

- ✓ GOs reduce emissions to 1/6 with an increase of only 1% of the cost
- ✓ If used with a Green label, it can greatly impact how the consumers value the brand
- ✓ Marketing should play an important role in this scenario to gain the macimum competitive advantage





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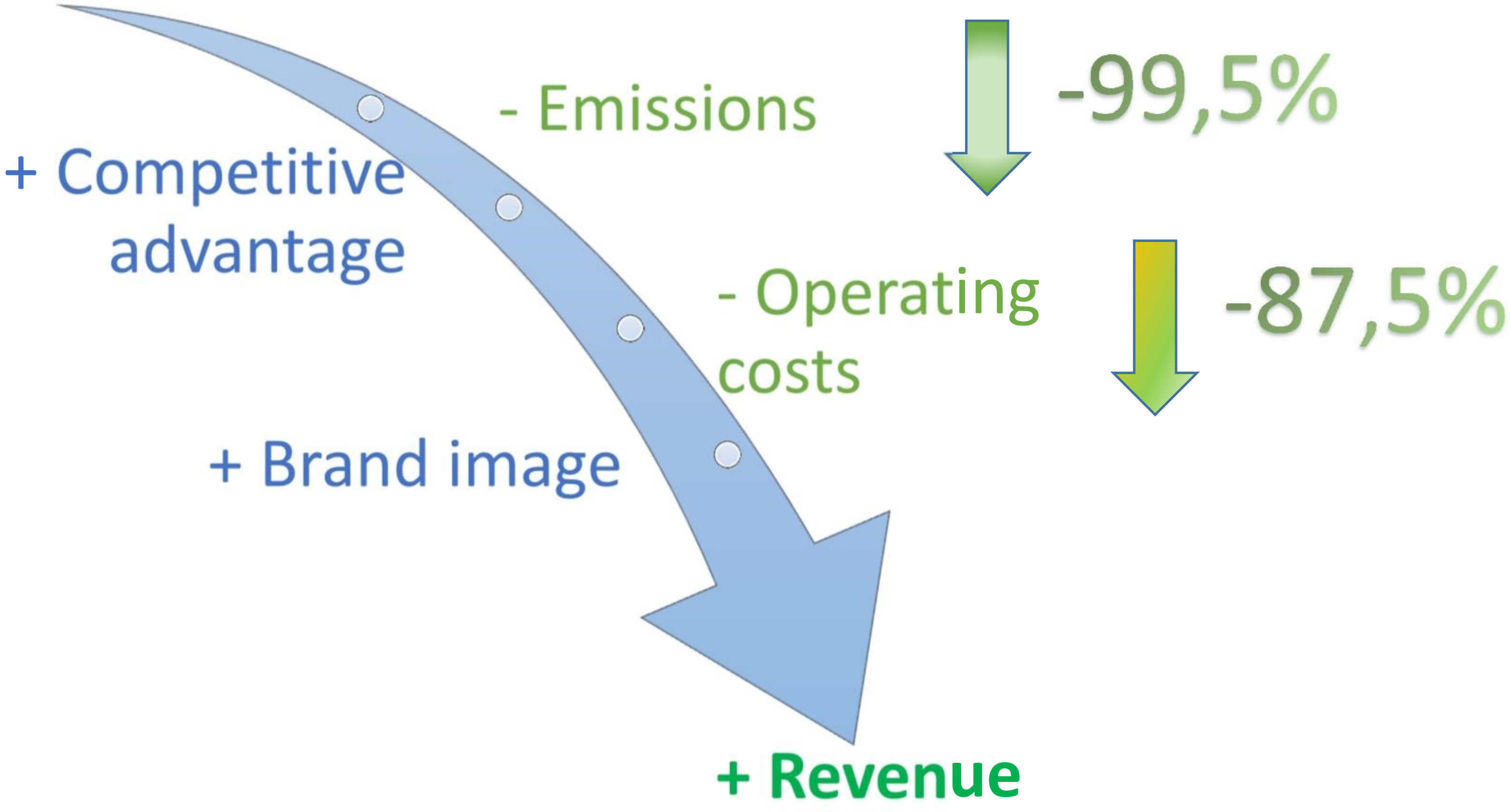
Results: Final considerations

Use of residual heat from the tank farm and from the residual water



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