Use of Solar Process Heat – a Challenge in Brewing Technology

Technology Workshop on Solar Process Heat for Industry
Renewable Energy House, Brussels – 15 March 2013

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GEA Brewery Systems
Huppmann Tuchenhagen

Agenda

- State-of-the-art of heat supply in the brewery
- Energy recovery measures / energy storage tank
- Solar thermal energy / installations for hot water preparation
- Solar thermal energy / wort heating with use of new process technologies
- Solar thermal energy / process application mashing
  - Heating of mashing process
  - Mash homogeneity
  - Design of mash kettle
  - Design of agitator
- Integration of solar heat in three HEINEKEN breweries
  - Heating of mash kettle: BRAU Union Österreich, Brewery Göss, Leoben, Austria
  - Heating of tunnel pasteurizer: HEINEKEN Espana, Brewery Valencia, Spain
  - Heating of malt kiln: Sociedade Central de Cervejas e Bebidas, malting plant Vialonga, Portugal
- Outlook on renewable energy supply and CO_2 emission of breweries

State-of-the-art

Beer production with fossil energy sources

Energy input and emissions:

Climate change and global warming

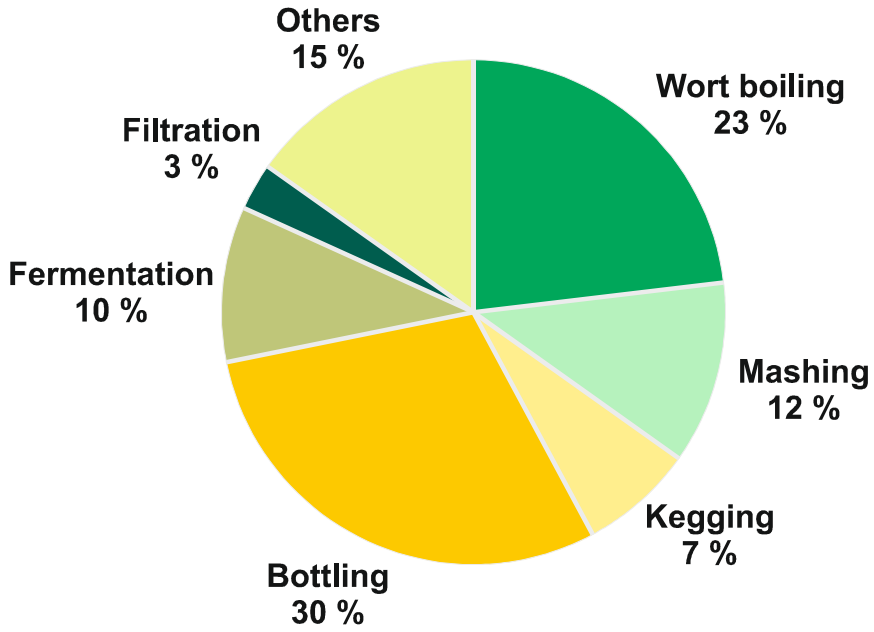
Electric power based on mix of energy sources
7.5 -11.5 kWh/hl

CO_2 emissions based on natural gas and electricity mix, total
9.9 – 14.3 kg/hl
Electric power
4.2 – 6.4 kg/hl
Heat
5.7 – 7.9 kg/hl

Heat from natural gas
23.6 -33.0 kWh/hl

Benchmark for thermal energy consumption

A modern brewery with an energy storage system in the brewhouse and approx. 80 % of sales beer in returnable bottles consumes **19.3 kWh/hl** thermal energy from fossil energy sources.



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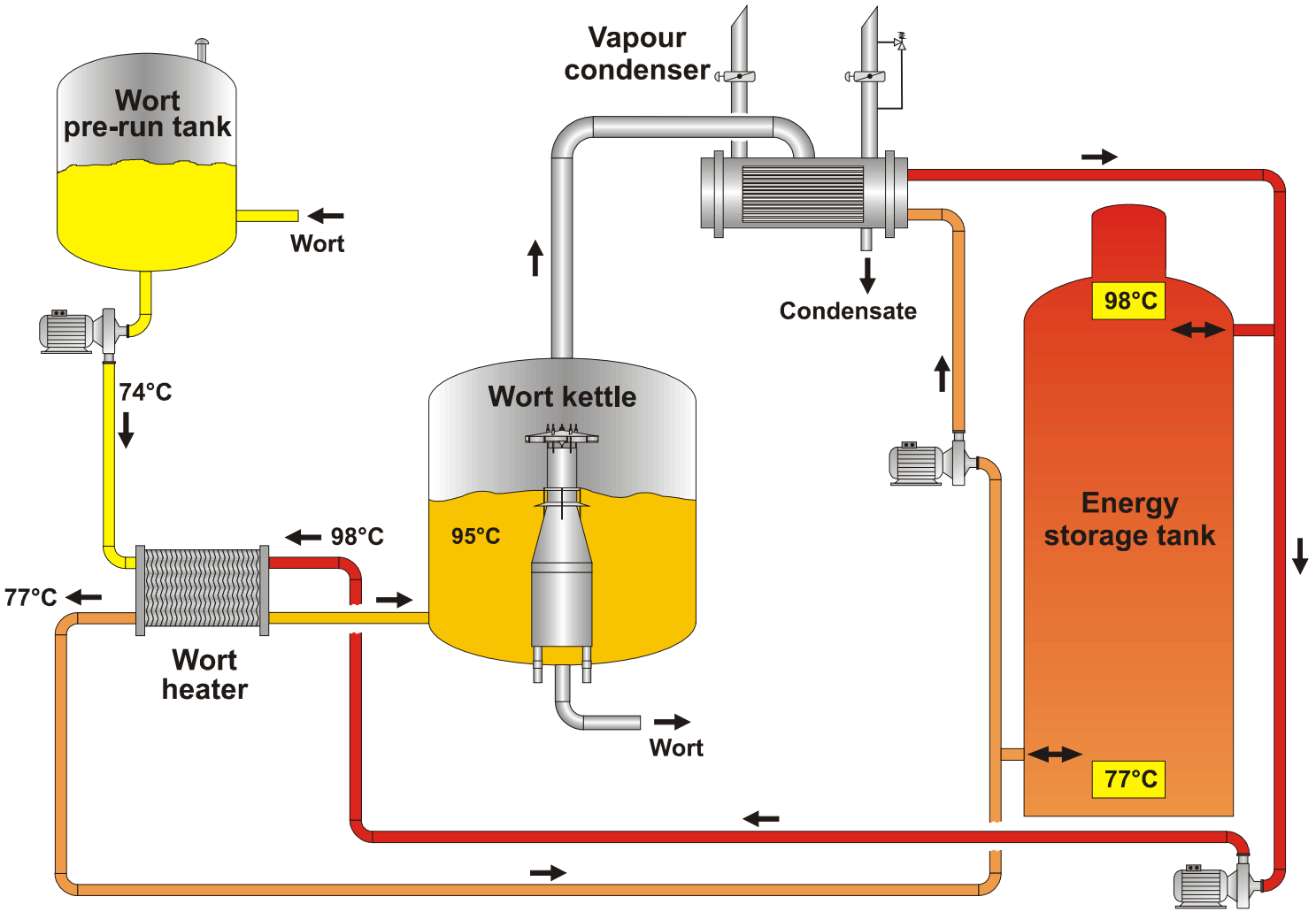
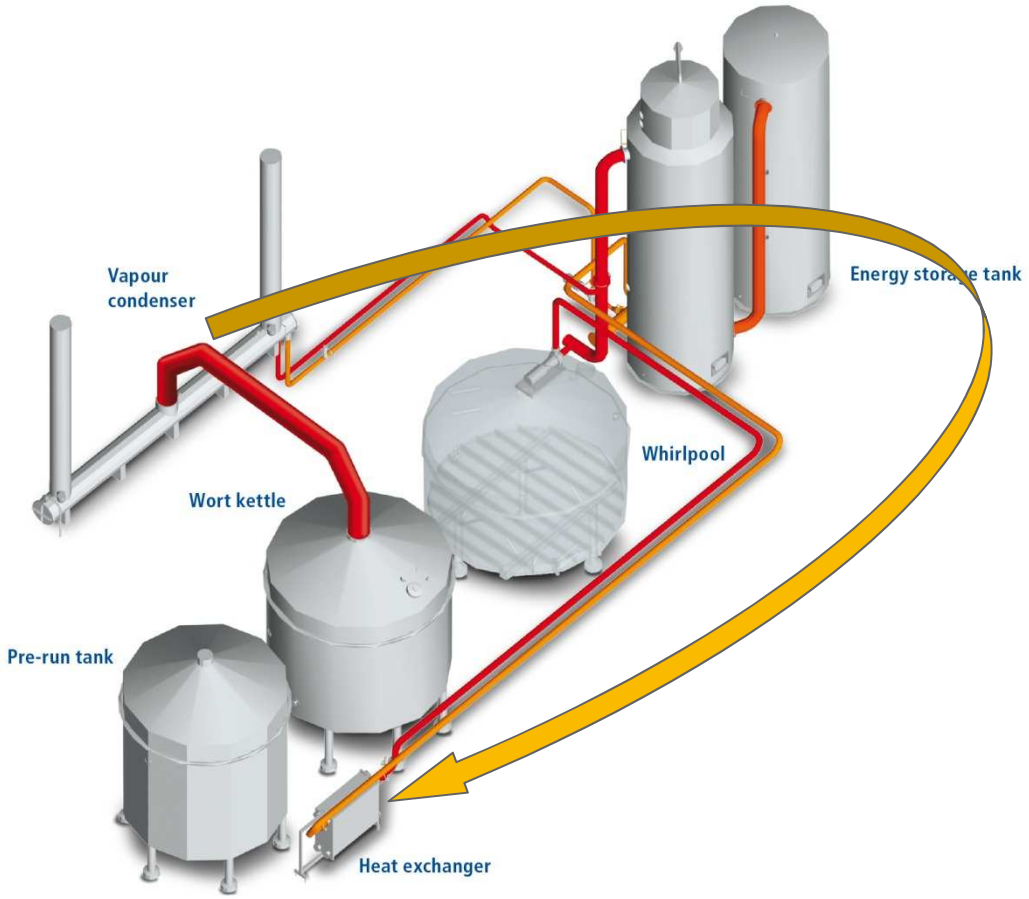
Energy recovery from kettle vapours

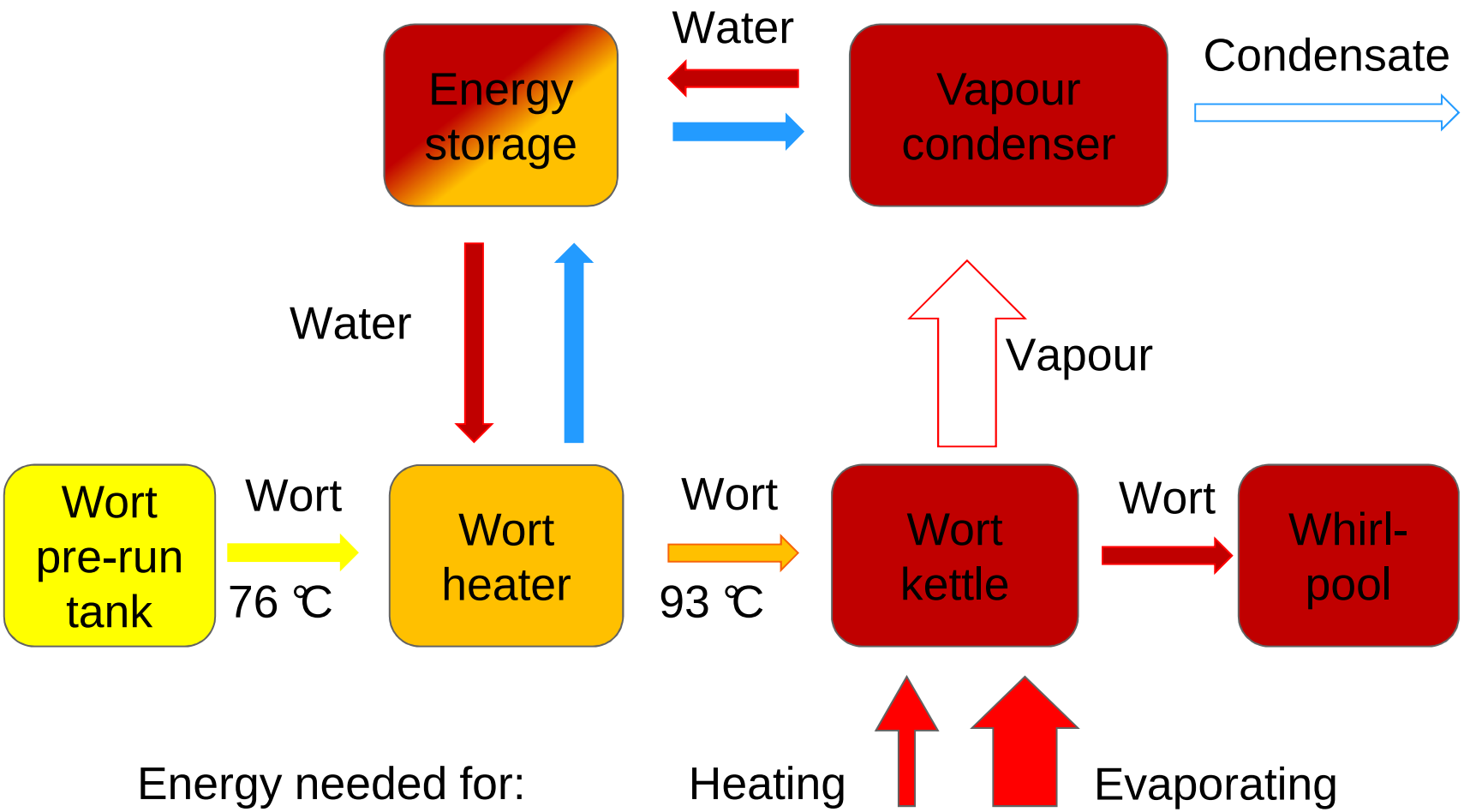


Energy recovery

Transfer of energy from wort boiling to wort heating

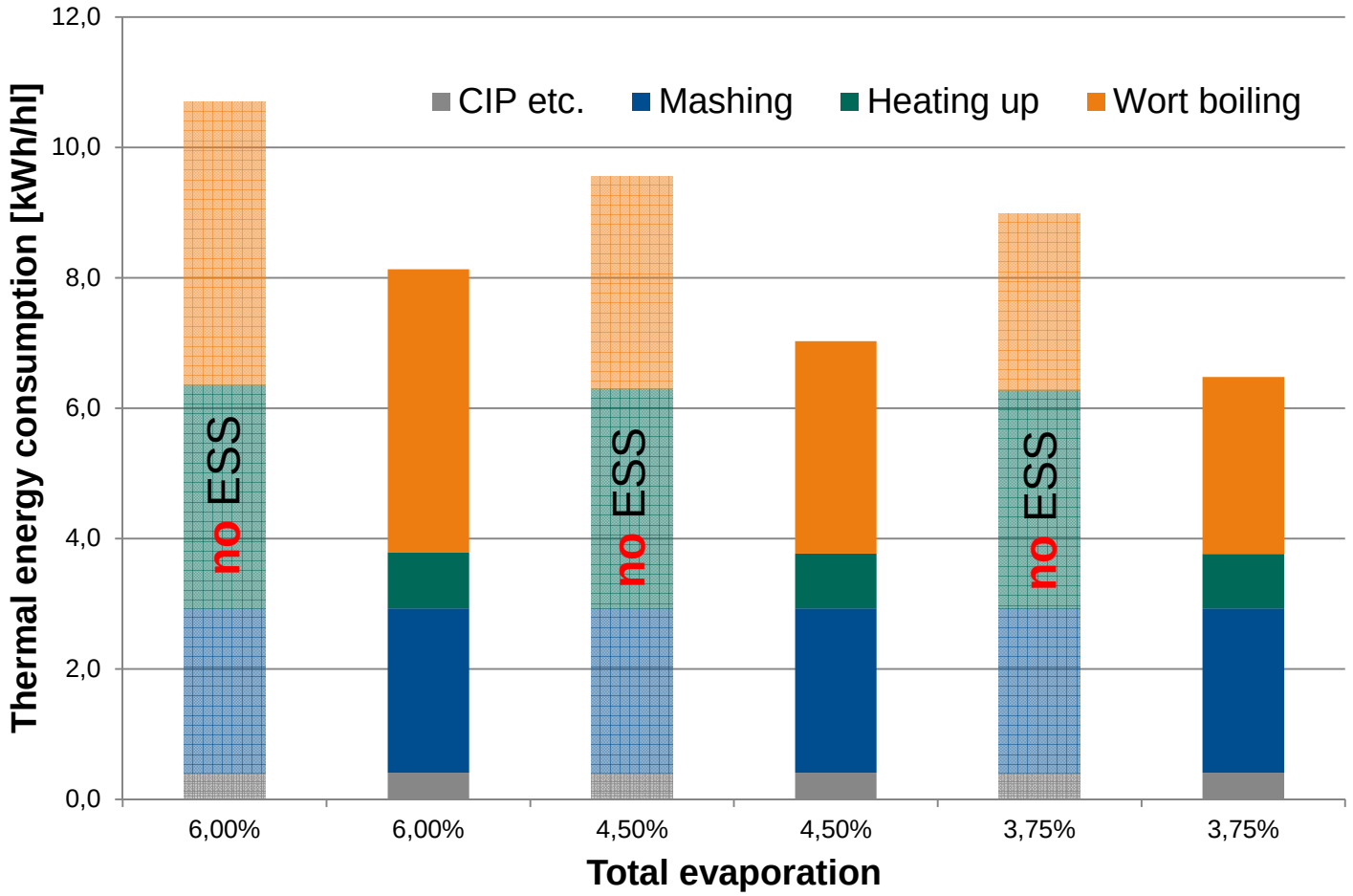


Wort heating process with energy storage system

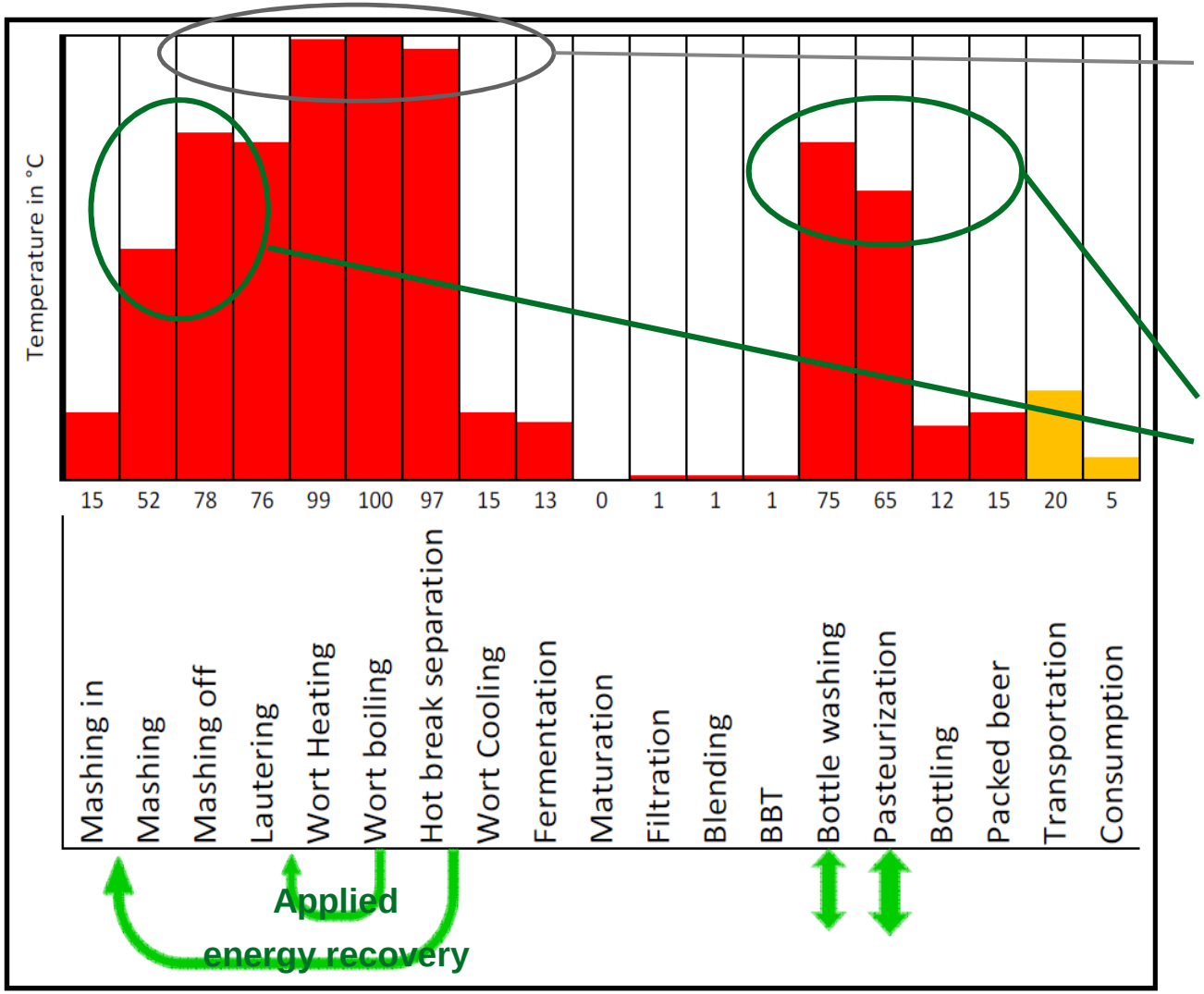


Thermal energy consumption in brewhouse

Energy recovery system – state-of-the-art boiler house



Temperature profile in production and filling



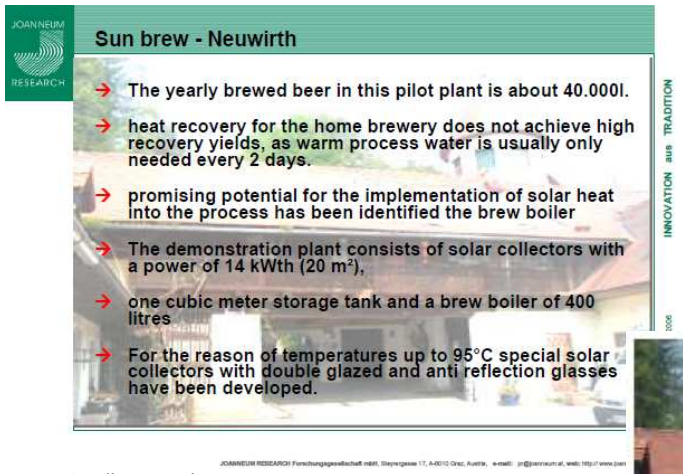
High temperature level:

e.g. with steam (biomass combustion, spent grains)

Medium temperature level:

Ideal for the supply with solar heat, waste heat from the CHP or from a district heating network

Solar thermal energy / installations for hot water preparation



Quelle: www.joanneum.at

SOLAR. UNI-KASSEL.DE

Pilotanlage zur Bereitstellung solarer Prozesswärme bei der Hütt-Brauerei

Hütt
Gebraut für Nordhessen.

Quelle: www.solar.umwelt-uni-kassel.de

Das Hofmühl Solarbier – das umweltfreundliche Bier

Erneuerbare Energien und Bier?
Für Hofmühl ist das keine Frage. Denn ausgezeichneten Geschmack verbinden wir mit einem Beitrag zur Schonung unserer Natur: mit unserem Hofmühl Solarbier. Auf 1.000 Quadratmeter stellt unsere Anlage aus Thermosolarzellen Bier in Spitzenqualität ökologisch her.

Dabei erreichen wir mit der solarthermischen Anlage und der Verwendung von ökologisch erzeugtem Naturstrom aus Wasserkraft einen Anteil von 50 Prozent erneuerbarer Energien. Das sind 25 Prozent mehr, als für die Solarbier®-Auszeichnung überhaupt notwendig wären. Heute schon an morgen denken und als zukunftsorientiertes Unternehmen auch gesellschaftliche Verantwortung übernehmen – dafür steht das Hofmühl Solarbier. Das ist höchster Genuss aus der Kraft der Sonne.

Quelle: www.hofmuehl.de

Stand der Forschungsförderung Solarthermie in Deutschland

ptJ

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

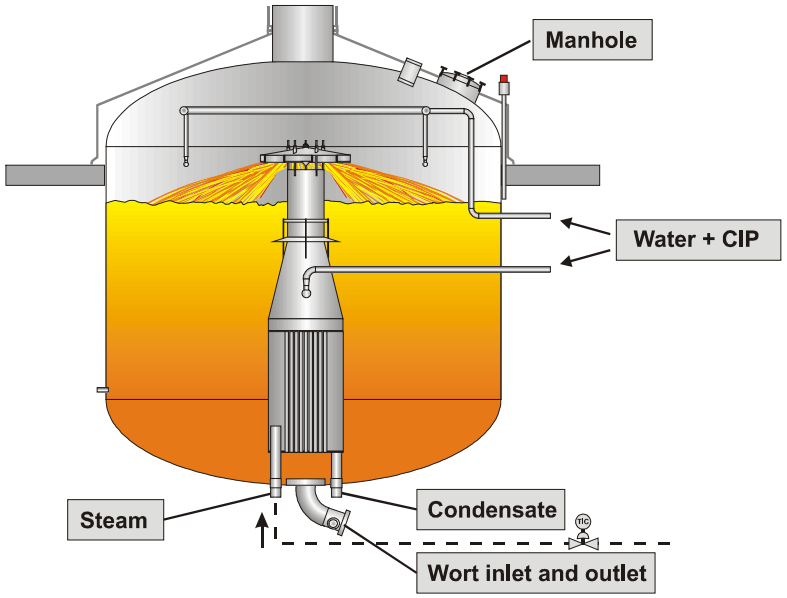
Solarthermie2000plus – ausgewählte Projektbeispiele

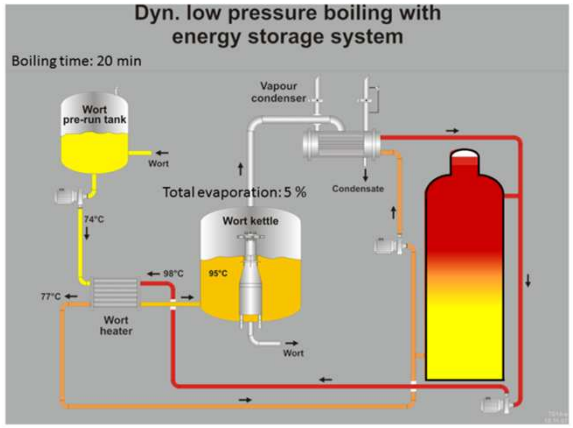
Pilotanlagen – Solare Prozesswärme

- Pilotanlage solare Prozesswärme mit Parabolrinnenkollektoren (P3)
  Metallverarbeitung Ennepetal: 100 m² PTC
  (DLR Köln, Fa. Solitem Aachen, Fa. Alanod Ennepetal, SIJ Jülich, ZfS Hilden)
- Hofmühl- Brauerei Eichstätt: 1.400 m² CPC- VRK
  (Fa. Privatbrauerei Hofmühl Eichstätt, Fa. Krones AG Neutraubling, TU Chemnitz)
- Hütt- Brauerei Kassel- Baunatal: 200 m² FK
  (Fa. Hütt- Brauerei Kassel- Baunatal, Universität Kassel)

Quelle: www.solarthermietechnologie.de

Wort boiling and thermal energy supply

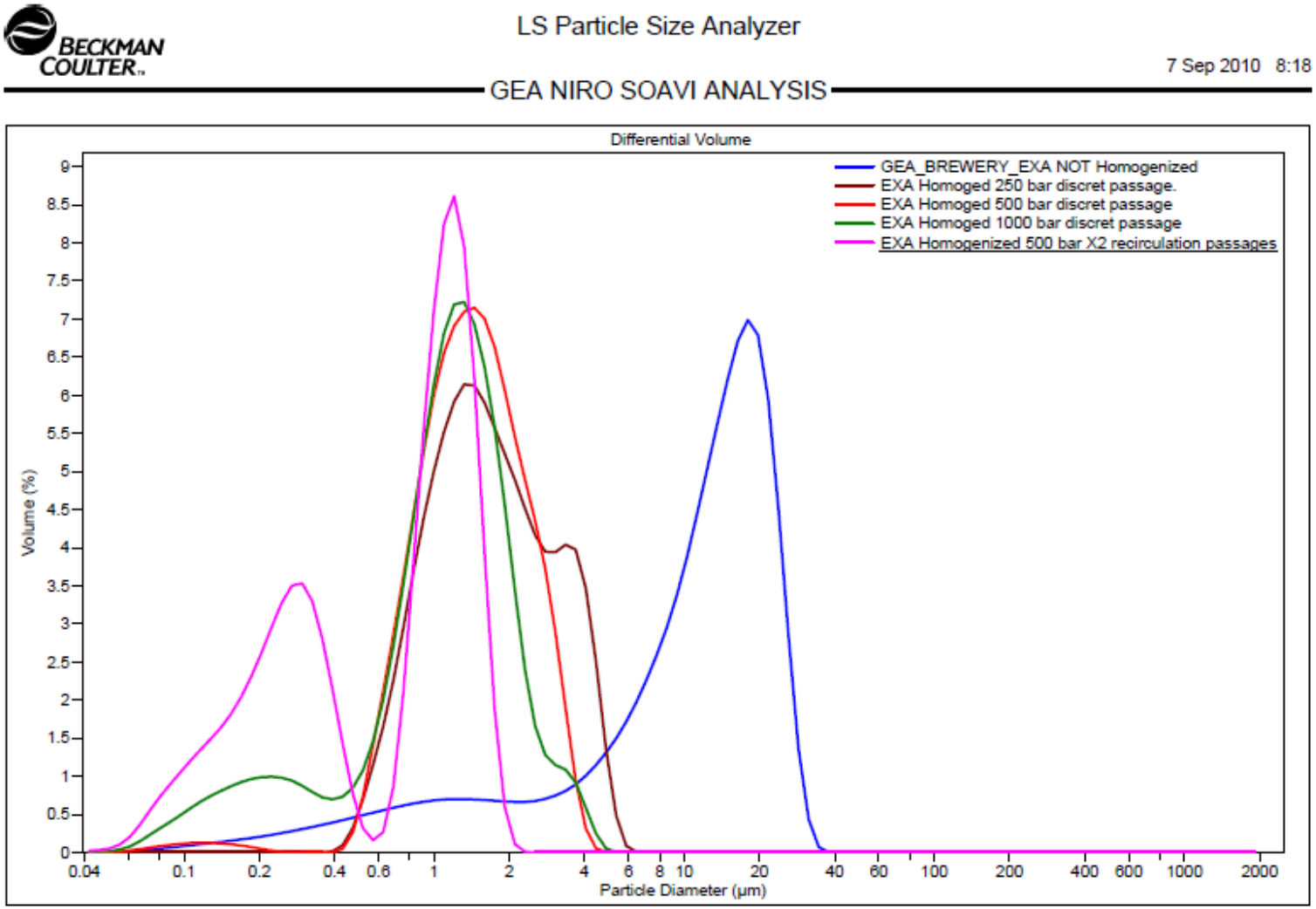




- **Hot holding** requested for chemical reactions like
  - isomerization of hop alpha acids
  - development of aroma substances
  - development of colour (Maillard reaction)
  - dissolution processes
  - protein coagulation
  - inactivation of enzymes
  - sterilisation
- **Evaporation** for removal of undesired aroma substances like
  - DMS (sulfur compound)
  - from lipid metabolism
  - from hop flavour

Controlled isomerization of hop alpha acids
Design of pilot plant

Controlled isomerization of hop alpha acids
Homogenization / Particle size reduction



Controlled isomerization of hop alpha acids
Hop extract suspension / Pictures

Left sample: dispersed HoEx suspension from CO_2 and ethanol extract

Sample in the middle: homogenized HoEx suspension from CO_2 and ethanol extract

Right sample: homogenized and isomerized HoEx suspension

(Mixture for suspension of 35 % ethanol extract and 65 % CO_2 extract)

Controlled isomerization of hop alpha acids
Energy demand and calculation of profitability

Saved cost for energy when wort boiling is adjusted:

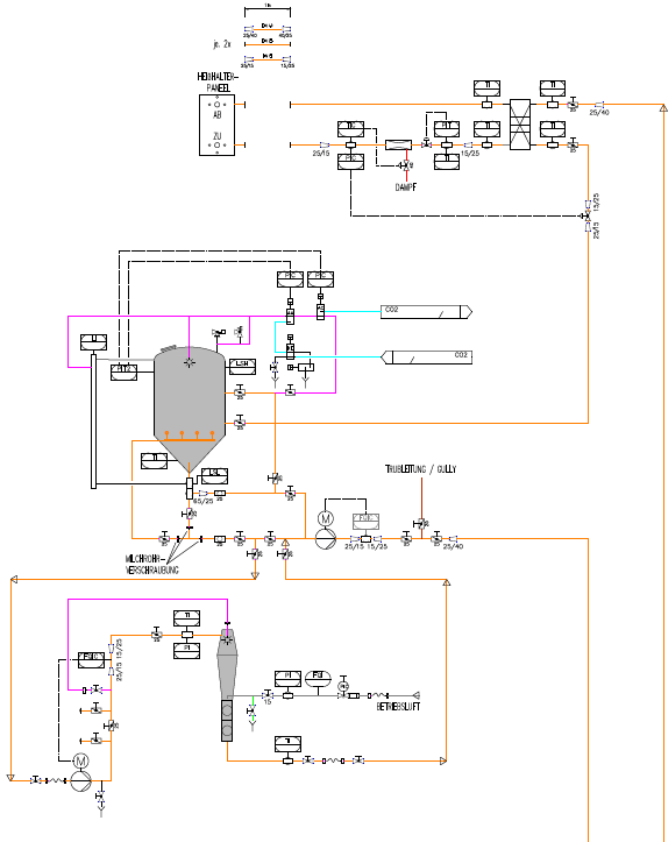
- Isomerization during boiling no longer required, this means possible reduction of boiling time and total evaporation of at least 50 %
- Assumption for cost savings for thermal energy consumption:
  - Energy costs 4 ct/kWh natural gas
  - **Total evaporation 2.2 % instead of 4.5 % - <u>less energy recovery for wort pre heating!</u>**
  - **Specific use of thermal energy for boiling < 1,5 kWh/hl instead of 3 kWh/hl wort**
  - Total degree of efficiency for supply of thermal energy at wort kettle 90 %
  - Savings 6.7 ct/hl wort
  - **Possible savings for 2 million hl wort production:** approx. 134,000 €
  - Annual energy cost for heating the HoEx suspension: approx. 5,000 €

(only 1 % of the yearly wort production volume to be heated for the isomerization process)

- **Annual energy cost net savings: approx. 129,000 €**
- **<u>Compensation of less energy recovery with solar thermal heat!</u>**

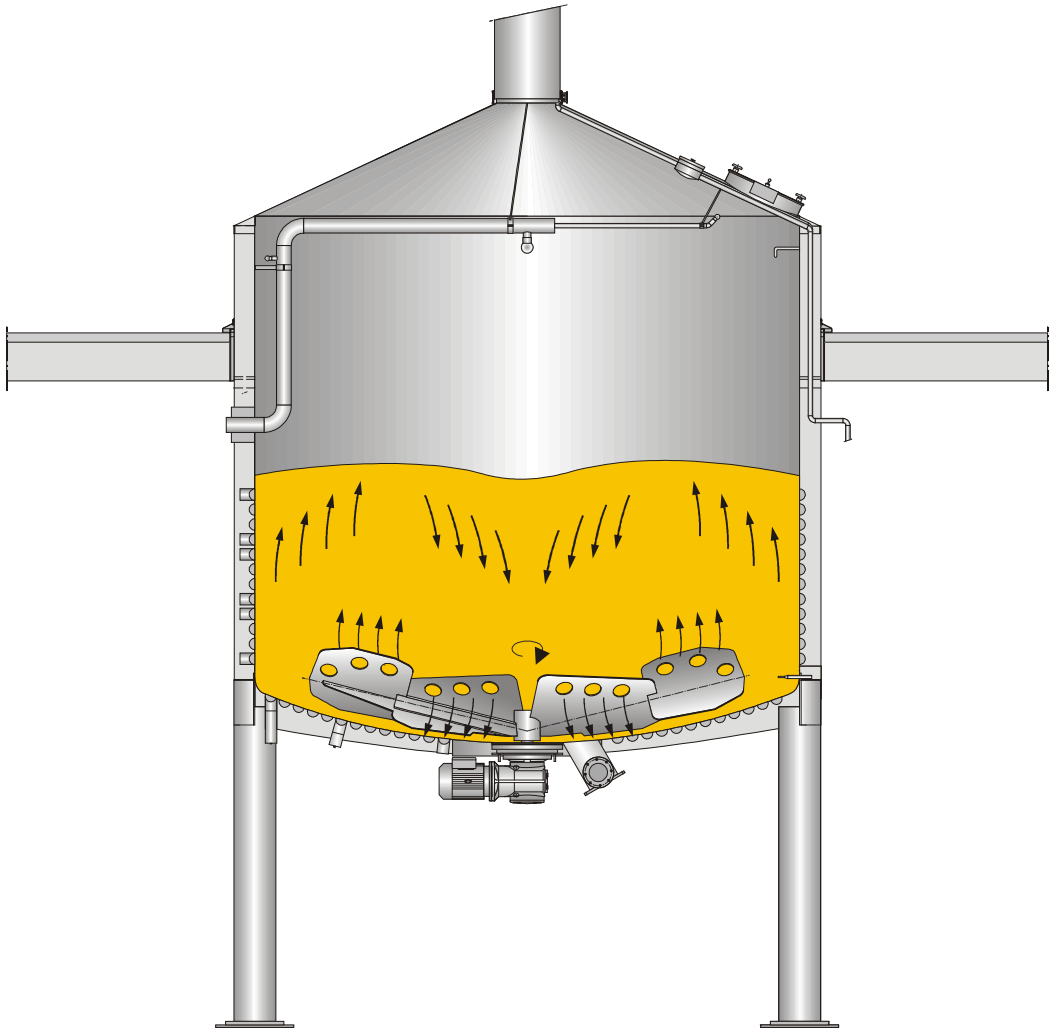
High-Temperature wort boiling (HTW boiling)

- **Regular boiling** condition at about 100 ℃ to 105 ℃ for 60 – 90 min.
- Atmospheric or at low pressure
- Evaporation rate between 4 – 6 % with modern boiling systems
- Energy recovery with vapour condensor and pre heating of wort during transfer in kettle
- **HTW** at about 128 – 135 ℃
- Holding time about 2 – 4 min
- Heating of wort with direct steam injection
- Use of HTW-HEX for energy transfer
- Pre heating of wort during transfer in kettle with **solar energy**
- Only for heat losses by HTW-HEX primary energy (e.g. life steam) is requested to realize the max. process temperature of 128 - 135 ℃



Solar thermal energy / process application mashing

Mash kettle



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Flow patterns in the mash vessel

The target of stirring in the mash vessel is:

- Optimum enzyme-substrate contact
- Homogeneous temperature distribution in the mash
- Fast mash heating
- Minimal fouling of the heating surface
- Processing with little oxygen uptake

Agitator paddle for optimal flow

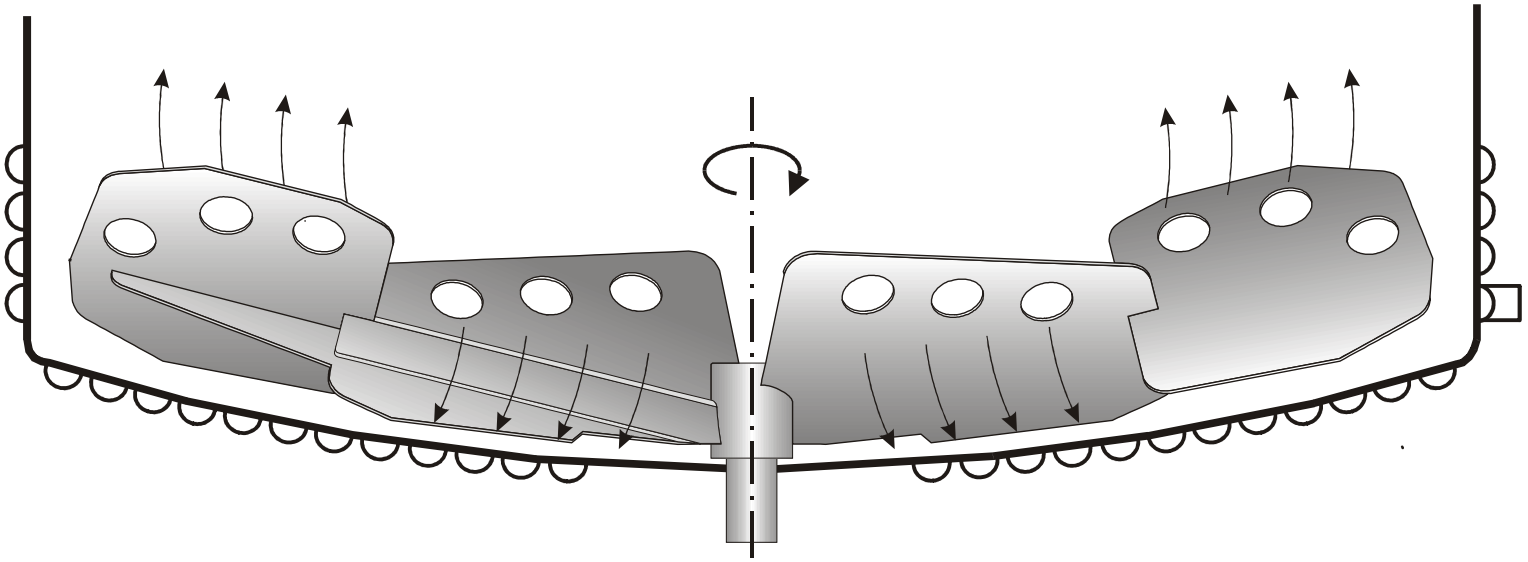
Slow agitator speeds possible

- Tip speed < 3 m/s
- Low shear forces
- Reduced oxygen uptake

Support of convection with inclined agitator blades arranged in opposite direction

- Circular movement and “folding” of the mash
- Optimal mixing in the dead zone behind the blade due to holes in the blade
- Inner blade area pushes the mash downwards to the bottom
- Outer blade area lifts the mash upwards at the heated shells

Agitator paddle



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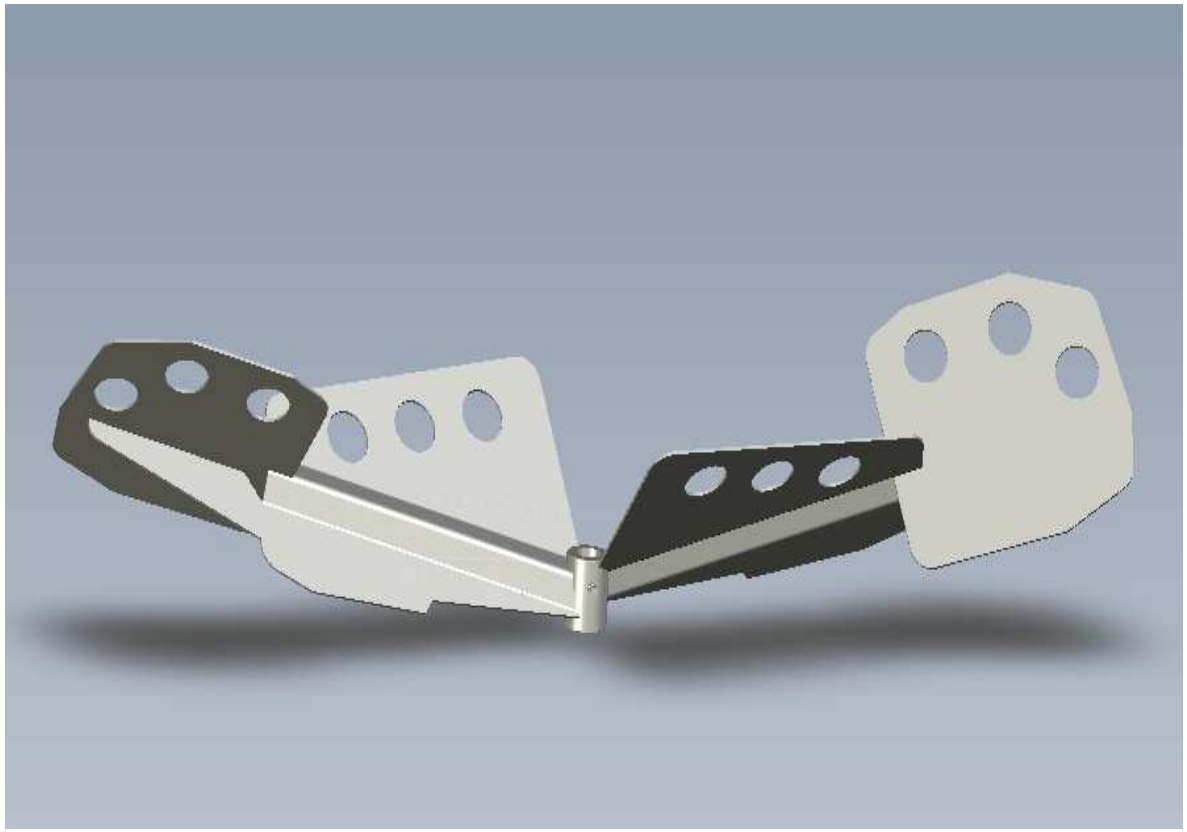
Agitator variations for CFD simulations

GEA Brewery Systems Huppmann agitator (mash vessel Kulmbach)



Type: axial

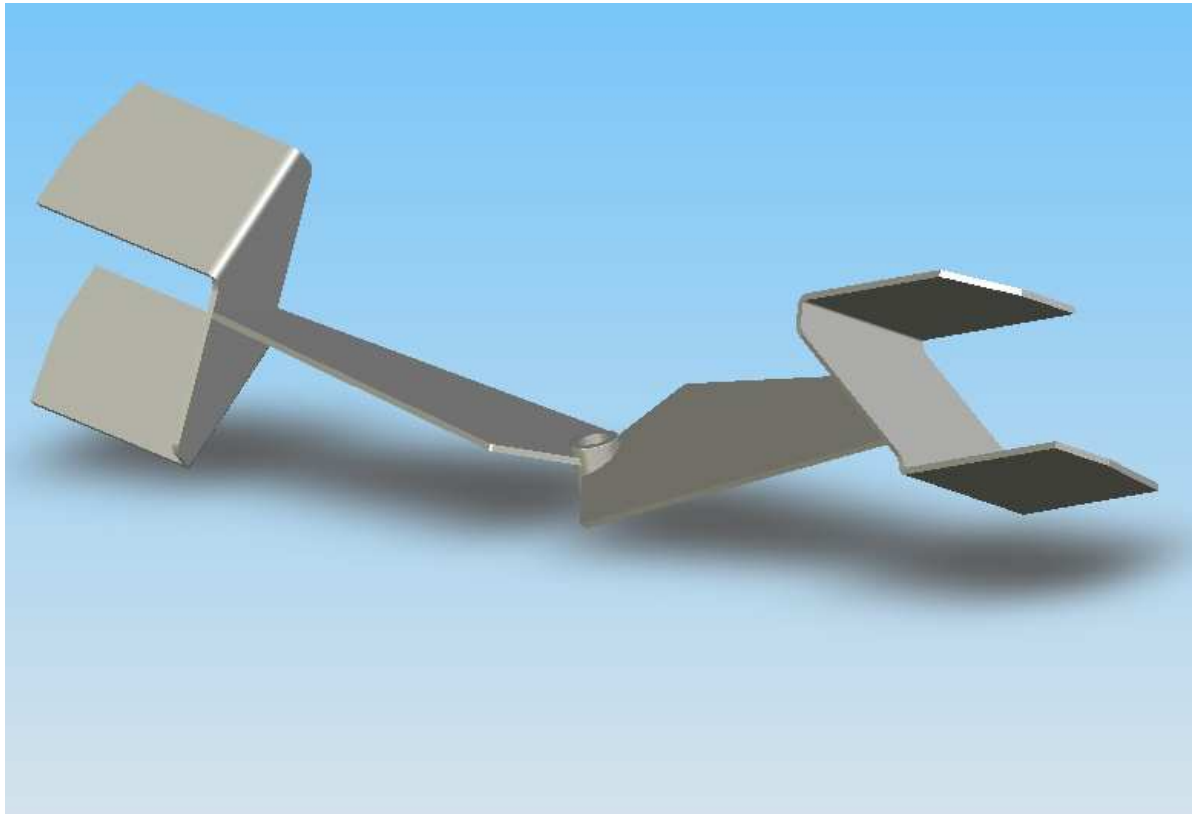
d = 3.8 m

d/D = 0.86

v_u*d = 11.34

Agitator variations for CFD simulations

Intermig agitator (mash vessel Kulmbach) – make: Ekato



Type: axial

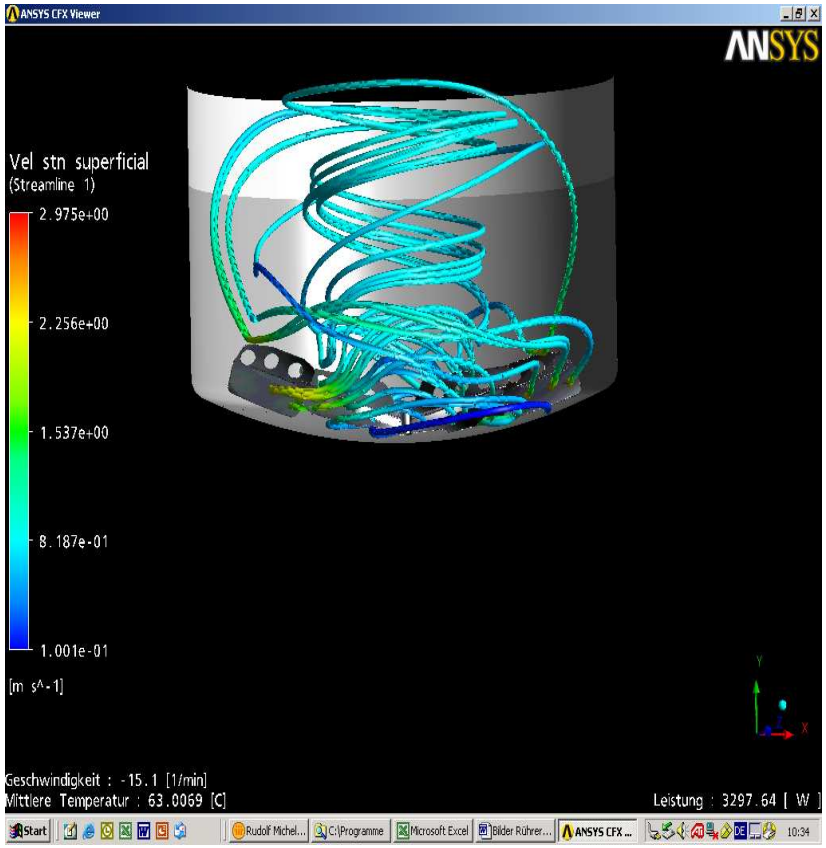
d = 3.8 m

d/D = 0.86

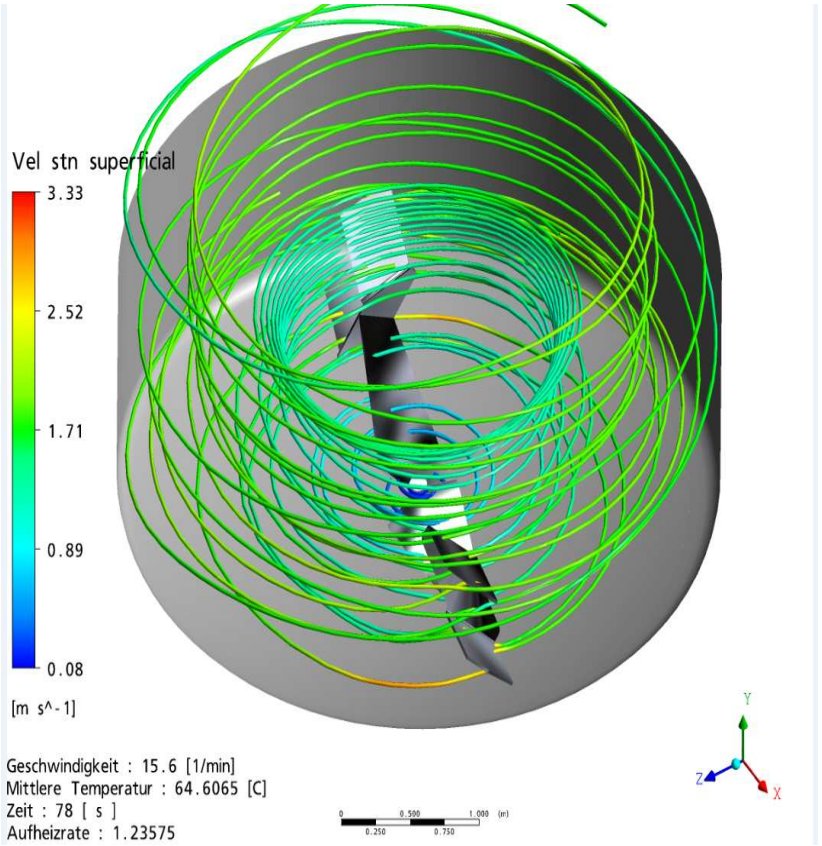
v_u*d = 11.34

CFD simulation of the flow patterns

Huppmann agitator

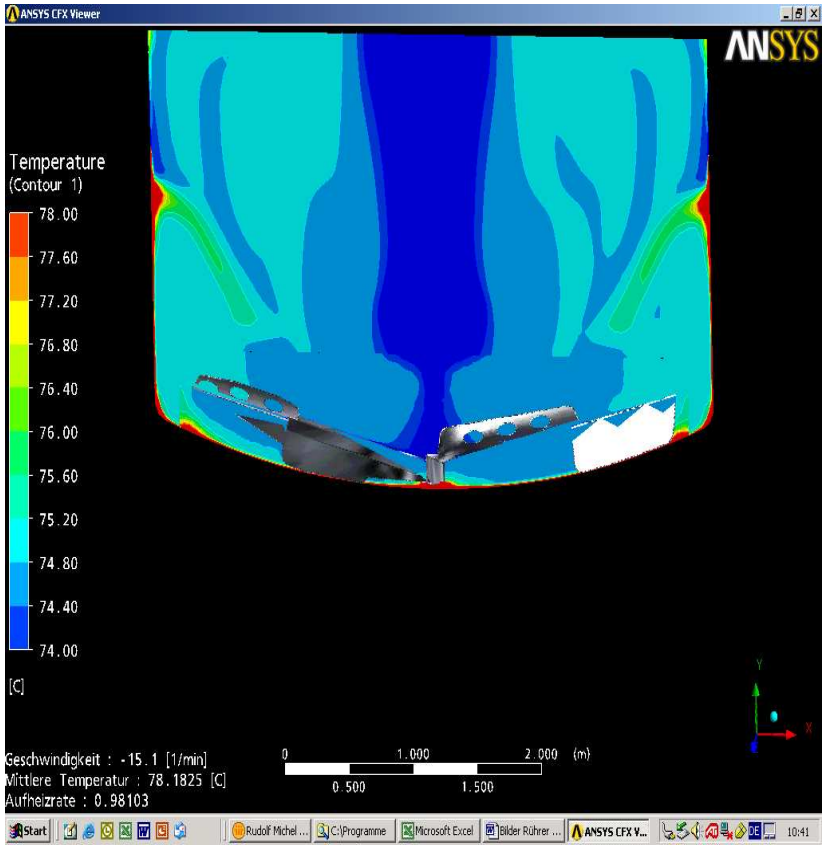


Intermig agitator

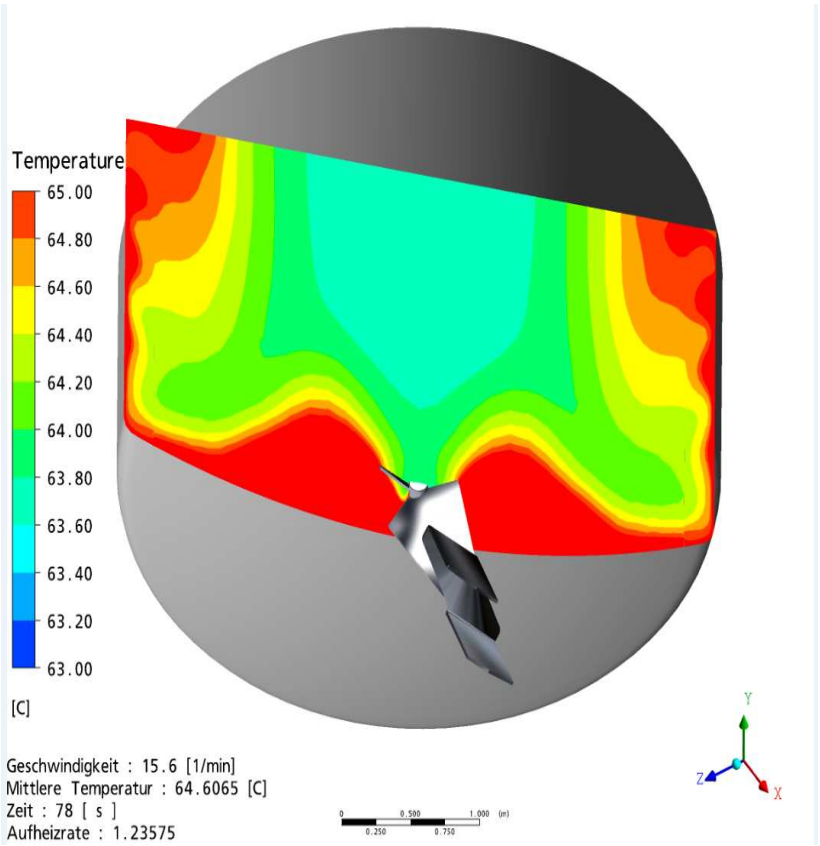


CFD simulation of heating

Huppmann agitator



Intermig agitator



Project SolarBrew

Source: AEE Intec

SolarBrew: Solar Brewing the Future

EU FP7 (2012 – 2015)

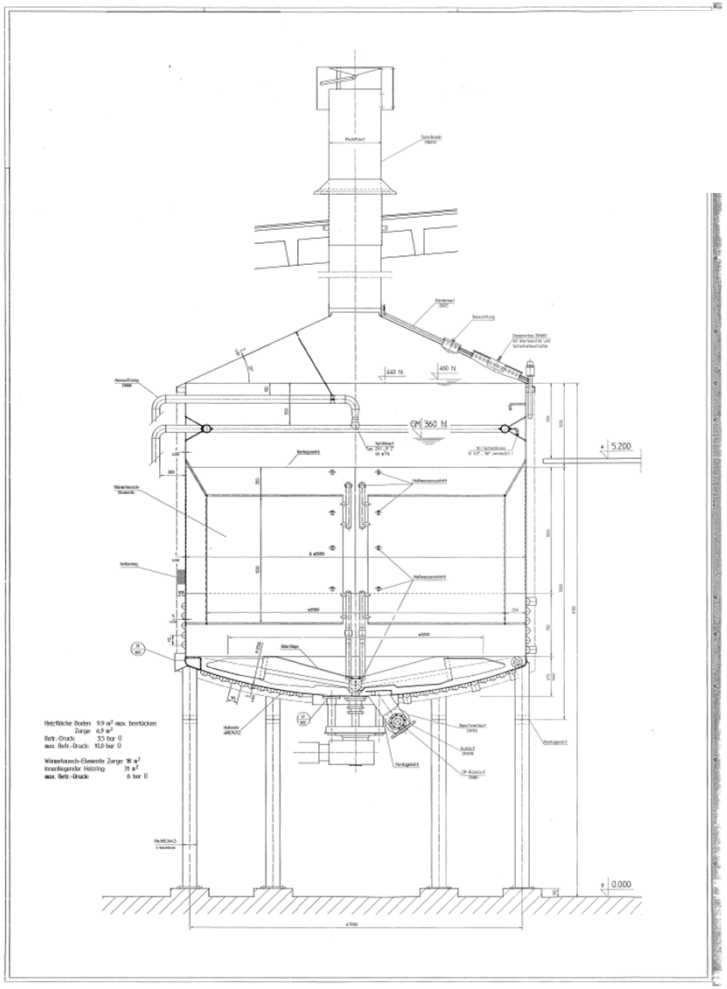
Project no. 295660

SEVENTH FRAMEWORK PROGRAMME

- Demonstration of the technical and economic feasibility of three large solar thermal systems with a capacity > 1MW_{th} in the brewing industry.
- Energy efficiency increase and solar heat integration for processes at process temperatures < 80 °C
- In total > 5$MW_{p,th}$ at the 3 mentioned locations
- "Green Brewery Sector Concept"
  → Provision of information to interested breweries

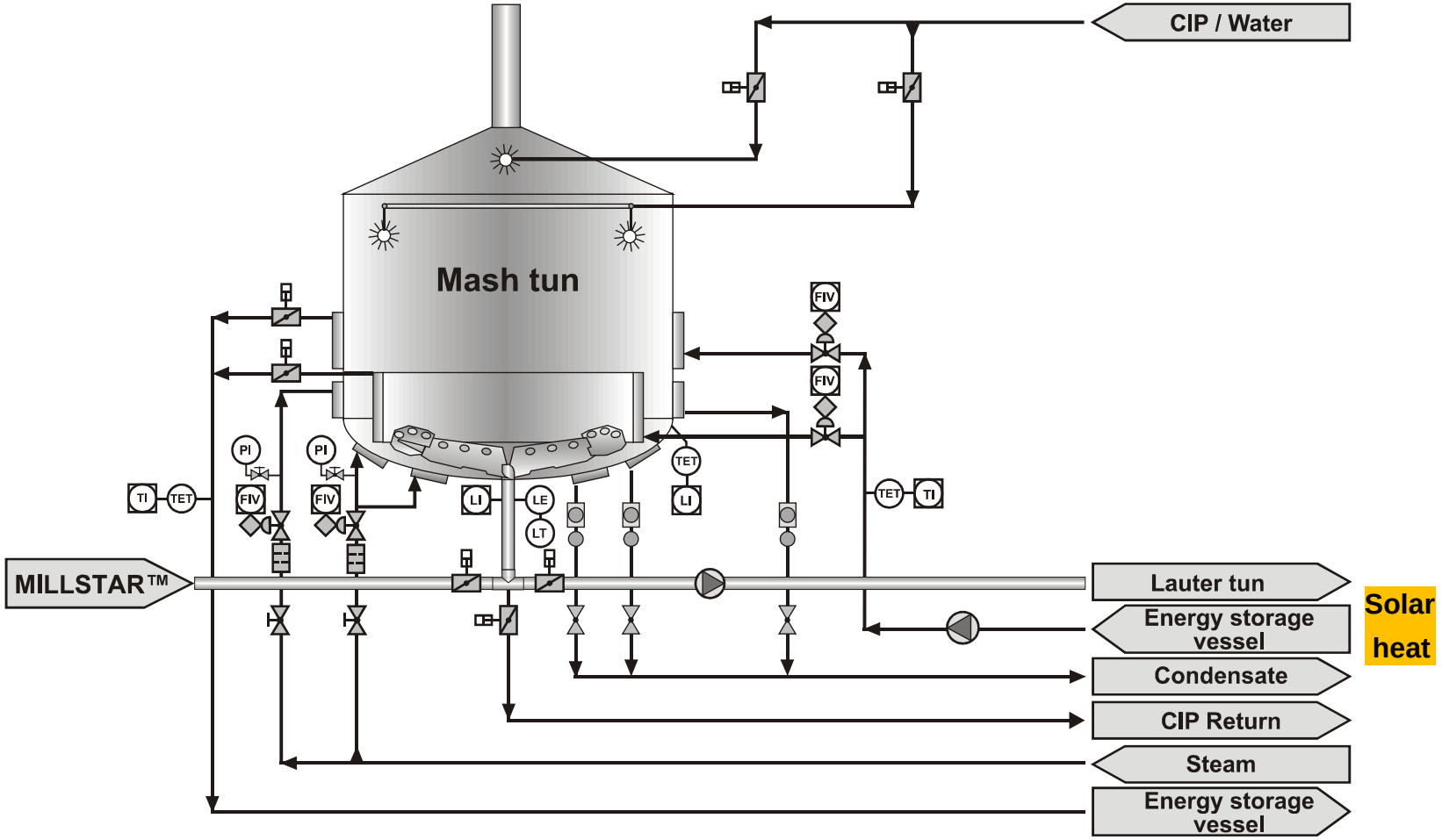
Heating of mash vessels

With solar heated hot water



- Installation of a mash vessel with hot water heating from the energy storage tank in a well-known large brewery in Germany (1994)
- Technical realization according to the drawing, a project from 1992
- Energy storage tank filled with energy from vapour condenser or CHP
- Hot water supply from an energy storage tank, which is connected with the solar thermal hot water circuit
- Heating surfaces in the shell and/or as additional heating surface in the vessel designed as dimple plates/ templates
- Back-up heating surfaces on the vessel bottom for saturated steam

Mash tun



With additional heating surface for optional use of energy storage water.

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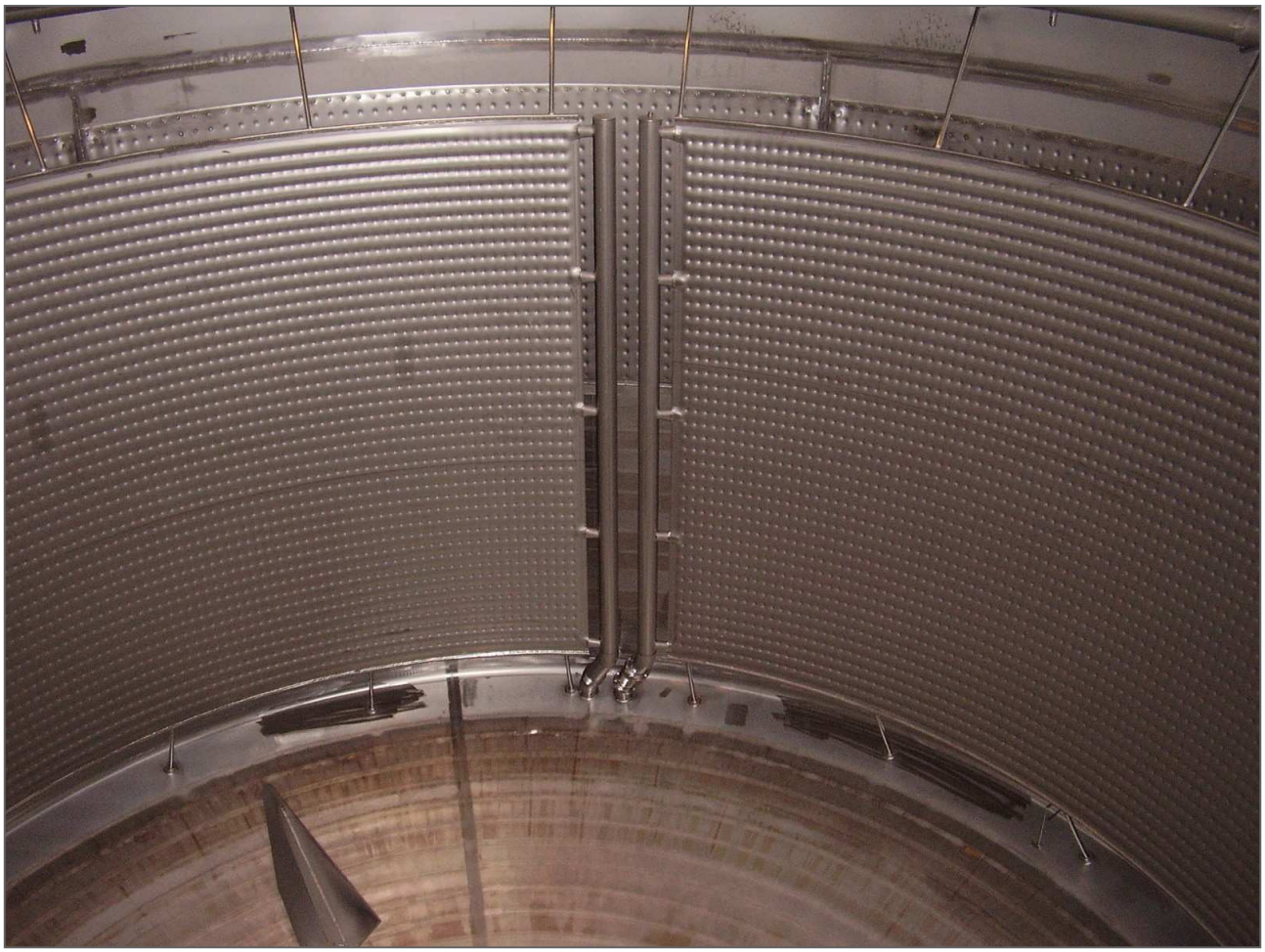
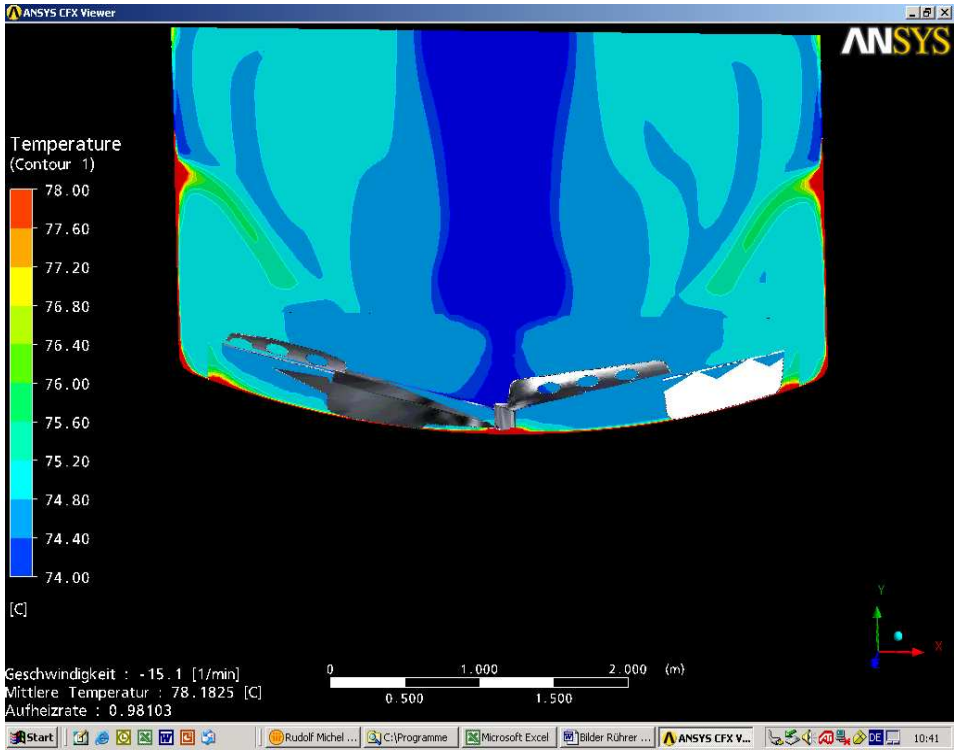
Heating of mash vessels

With solar heated hot water / Installation of templates



CFD simulation – GEA Brewery Systems agitator
Homogeneity during mash heating process

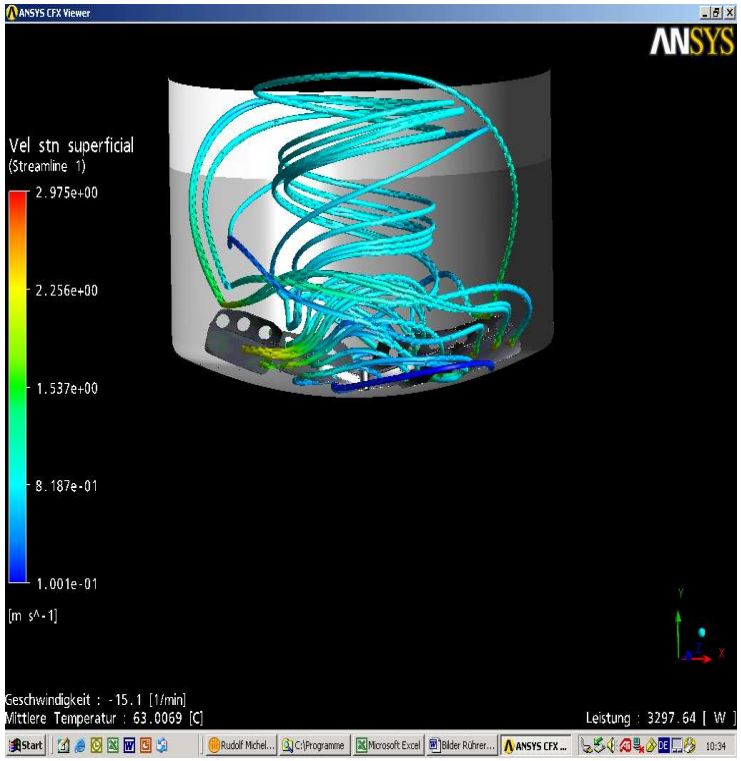
- **Heating with steam:**
- Heating capacity: 0.981 K/min
- Product temperature: 78.1 ℃
- Wall temperature outside: 150 ℃
- Steam pressure: 3.7 bar g
- Heating zones: Shell and bottom



- **General heating criteria:**
- Fast heat removal from the heat surfaces required
- Homogeneous temperature distribution more important than high heating capacity (> 0.8 K/min)
- Avoidance of cold zones with reduced enzyme activity in the mash
- With **solar heat,** a heating capacity of **0.5 K/min** is defined

CFD simulation
Flow patterns of different agitators

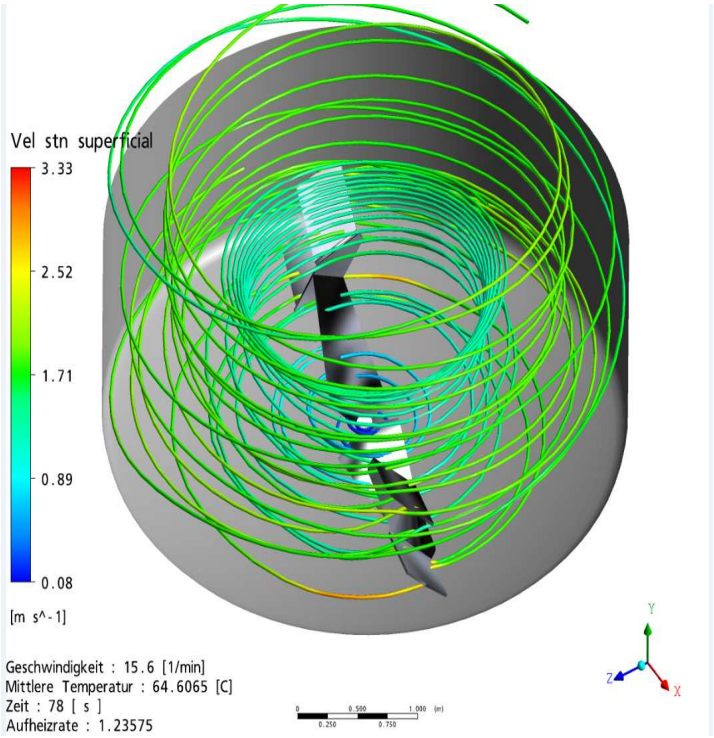
GEA Brewery Systems agitator



Agitation:

- Good mash mixing
- Homogeneous mash and temperature

Intermig agitator



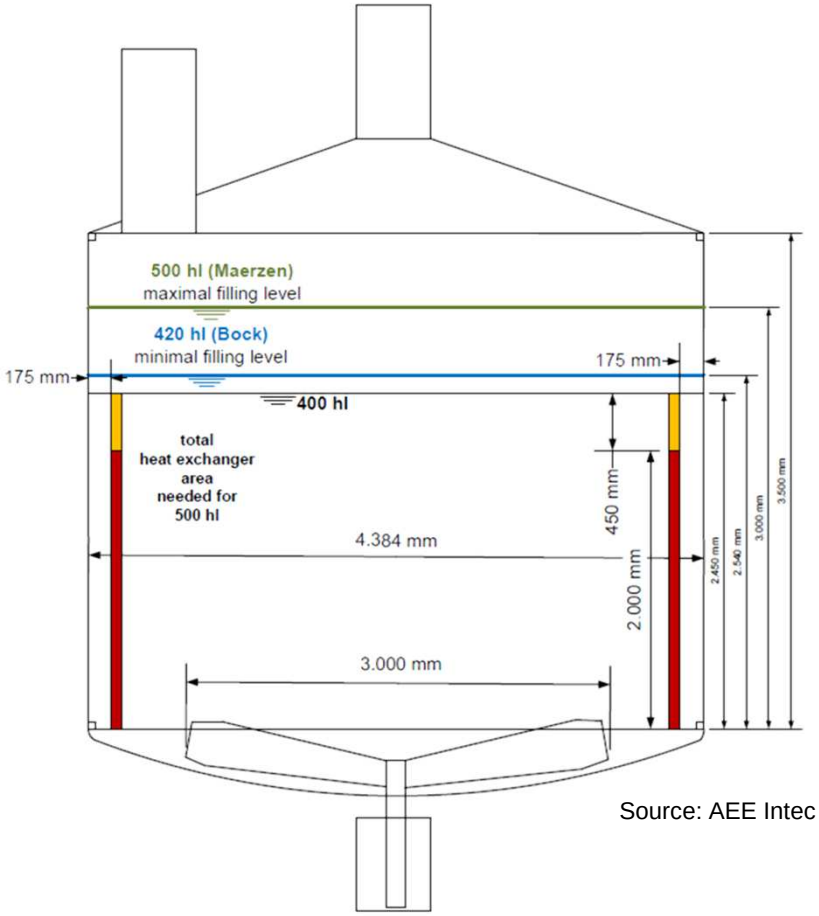
Agitation:

- Restricted mash mixing
- Inhomogeneous mash, cold core zone

Brewery Göss – Leoben, Austria

Integration of solar heat for two existing, formerly steam-heated mash vessels

- 20-27 brews/week
  - Mash volume 420-500 hl/brew
- Installation of “templates“ as additional heating surfaces for solar heat



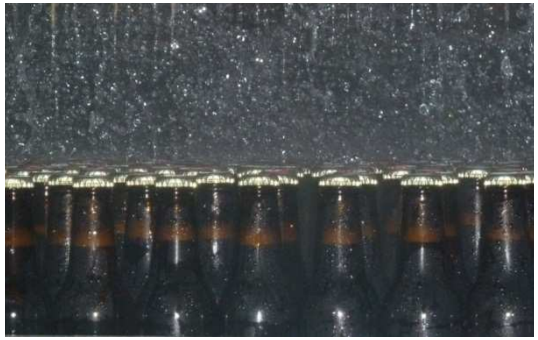
Source: AEE Intec

Brewery Valencia – Spain

Pasteurizer 1 for cans

Pasteurizer 2 for bottles

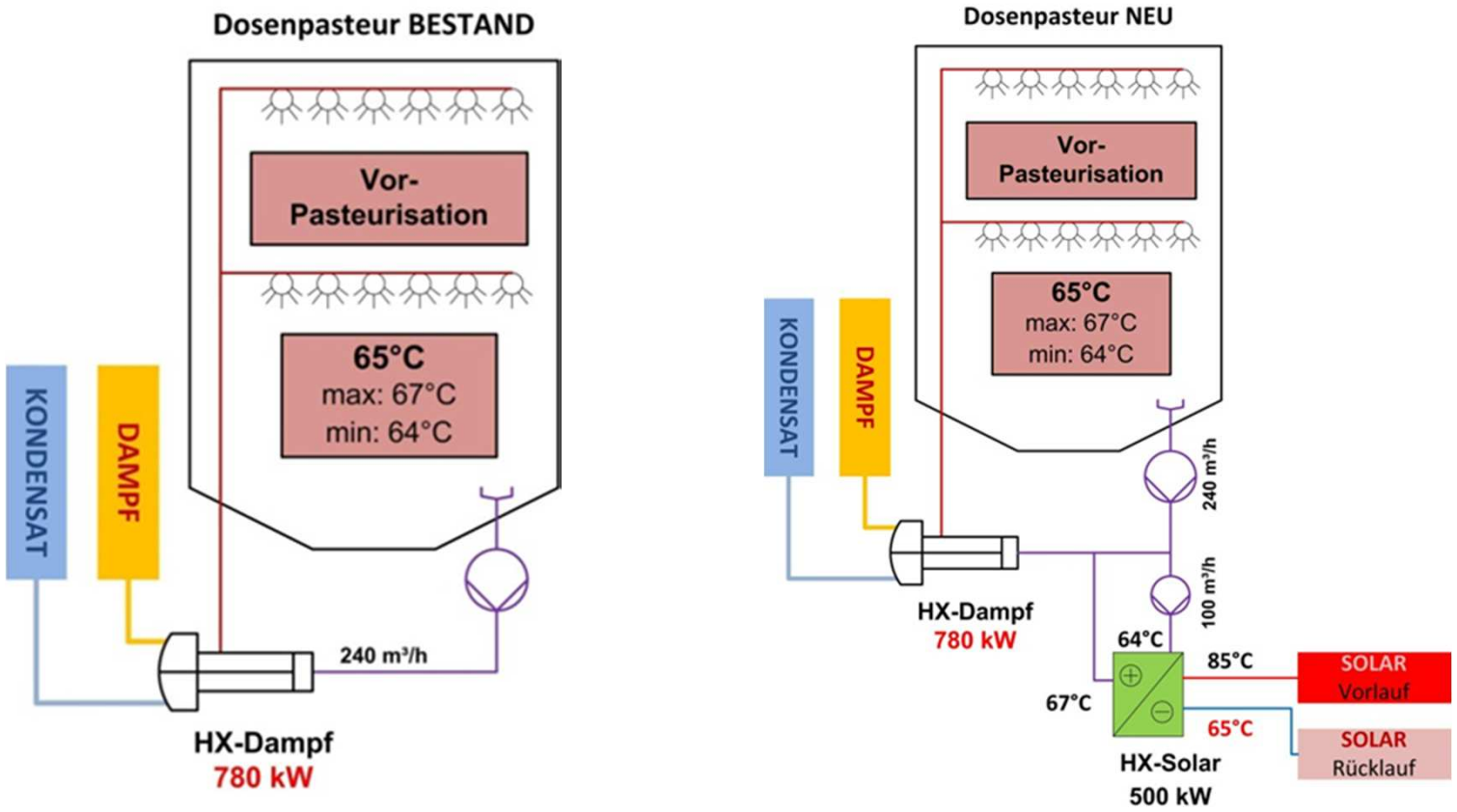
Existing steam heat exchanger



Spraying of bottles

Solar heat for tunnel pasteurizer

Comparison of existent and improved heating system



Source: AEE Intec

Malting plant Vialonga – Portugal

Process description

1) Withering phase

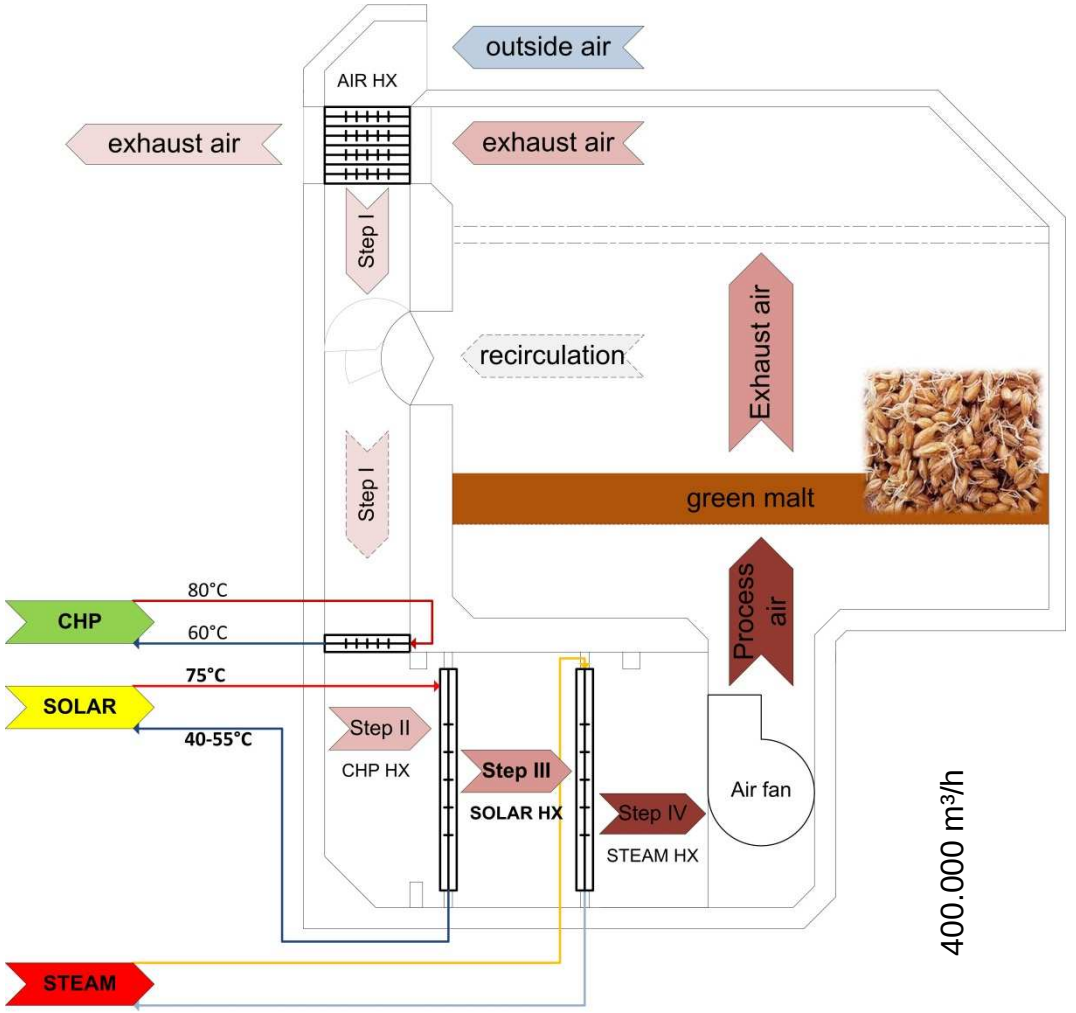
- Drying to about 18 % H_2O at 50 ℃-65 ℃
  - Duration: about 10-12 hours
  - Use of **SOLAR HEAT**

2) Heating phase

- Drying to about 9 % H_2O at 70 ℃-80 ℃
  - **No SOLAR HEAT**

3) Curing phase

- Drying to about 4-5 % H_2O at about 80 ℃-85 ℃
  - Recirculating air operation
  - Duration: about 4 hours
  - **No SOLAR HEAT**



Source: AEE Intec

Malting plant Vialonga – Portugal

Integration of solar heat

New heat exchanger hot water/air

Step I

Existent hot water HEX (CHP exhaust gas energy)

Step II

Existing steam HEX

Step III

Step II

Step IV

400,000 m³/h

Source: AEE Intec

Summary: use of solar thermal energy in breweries

- Examples for use of solar heated water of about 95 °C:

(1) Heating of brewing or process water

(2) Mash heating

(3) Wort heating
  - e.g. in combination with high temperature wort boiling system
  - or with controlled isomerization technology

(4) Heating of bottle washing machines

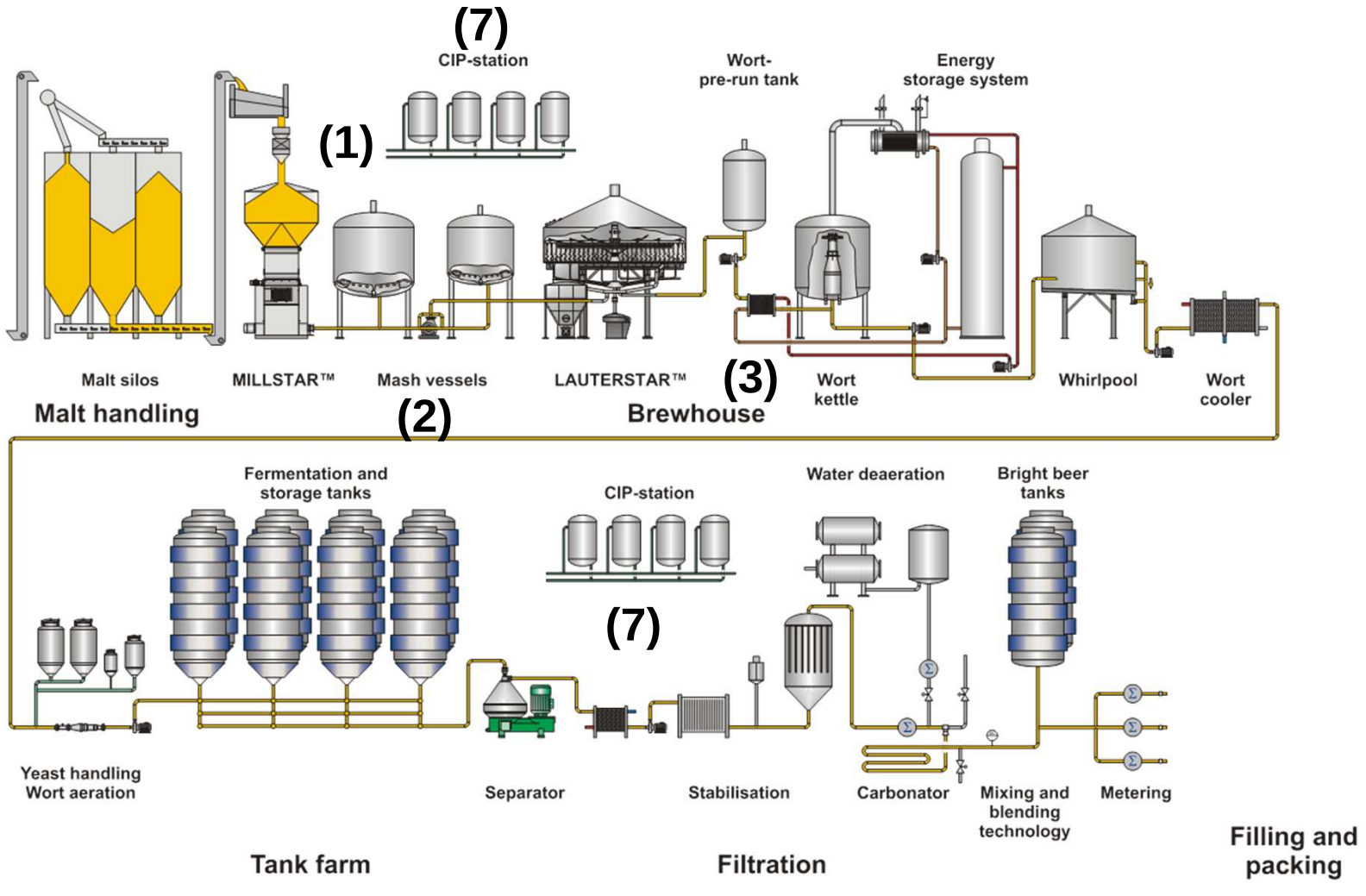
(5) Heating of tunnel pasteurizer

(6) Use in refrigeration plant for absorption cooler
  - e.g. project in African brewery with Thermax cooler

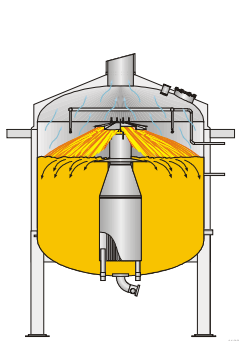
(7) Heating of CIP media (caustic, hot water)
  - e.g. in brewhouse, cellar or packaging plant

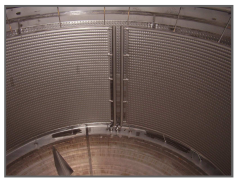
(8) Heating of boiler feeding water

Summary: use of solar thermal energy in breweries



Overview of heat network system





Medium temp. level brewhouse

Medium temperature level filling area

Hot water network RL 75 ℃

Absorption refrigeration plant chilled water

High temp. level brewhouse

Hot water network VL 95 ℃

CHP CHPC

HW

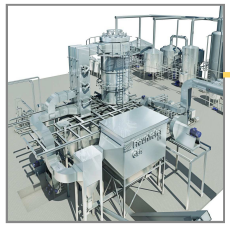
Electricity

Steam

Biomass combustion spent grains

Solar thermal system

Compressor refrigeration plant ammonia



Spent grains press water

HW

Anaerobic waste water treatment biogas

Biogas

Compressed air compressor

HEAT-STER™

Assumption of ideal consumption figures of a “Green Brewery”

Energy demand and use of renewable energy in the brewery, output 1 million hl sales beer

Fresh water
3.5 hl/hl

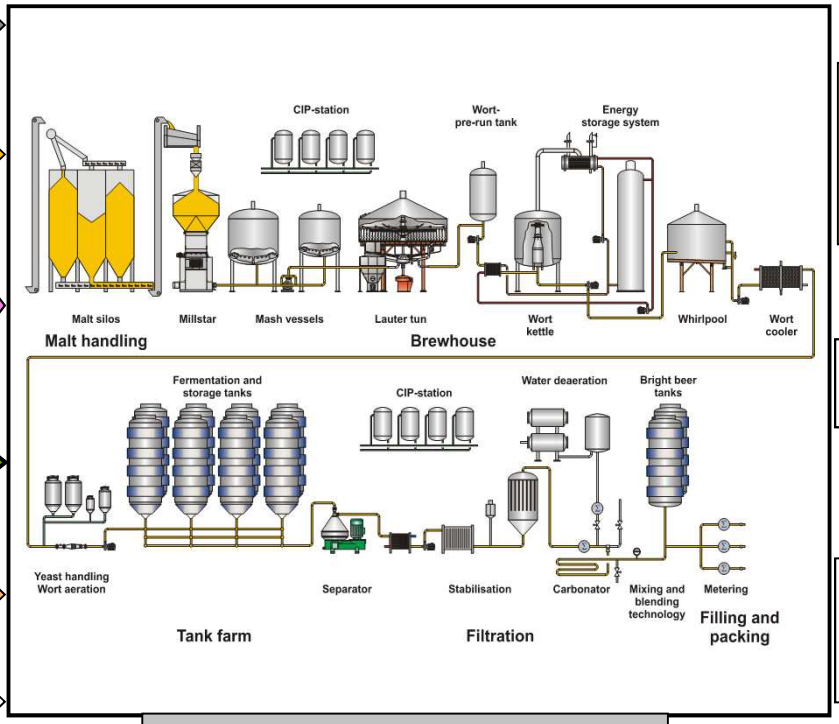
Thermal energy
20% solar system 3.9 kWh/hl

Thermal energy
5 % biogas 1.0 kWh/hl

Thermal energy
75 % spent grains combustion 14.4 kWh/hl

Electricity: Biogas 0,8 kWh/hl
External supply 5.5 kWh/hl

Kieselguhr
0 to 100 g/hl



Solid waste

Glass	0.3 kg/hl
Paper	0.14 kg/hl
Carton	0.04 kg/hl
Wood	0.017 kg/hl
Plastic	0.01 kg/hl
Metal	0.01 kg/hl

Benchmark thermal energy:
19.3 kWh/hl (chart 4)

CO_2 emissions

Total	**3.1 kg/hl**
Biogas	0.0 kg/hl
Electricity (mix)	3.1 kg/hl

Waste water
2.2 hl/hl

By-products
Yeast / deposits 1.7 to 2.9 kg/hl
Kieselguhr 0.0 to 0.5 kg/hl

Source of original data:
The Brewers of Europe, 2002

Contact

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Thank you for your kind attention!


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