

# A feasible application of circular economy: spent grain energy recovery in the beer industry



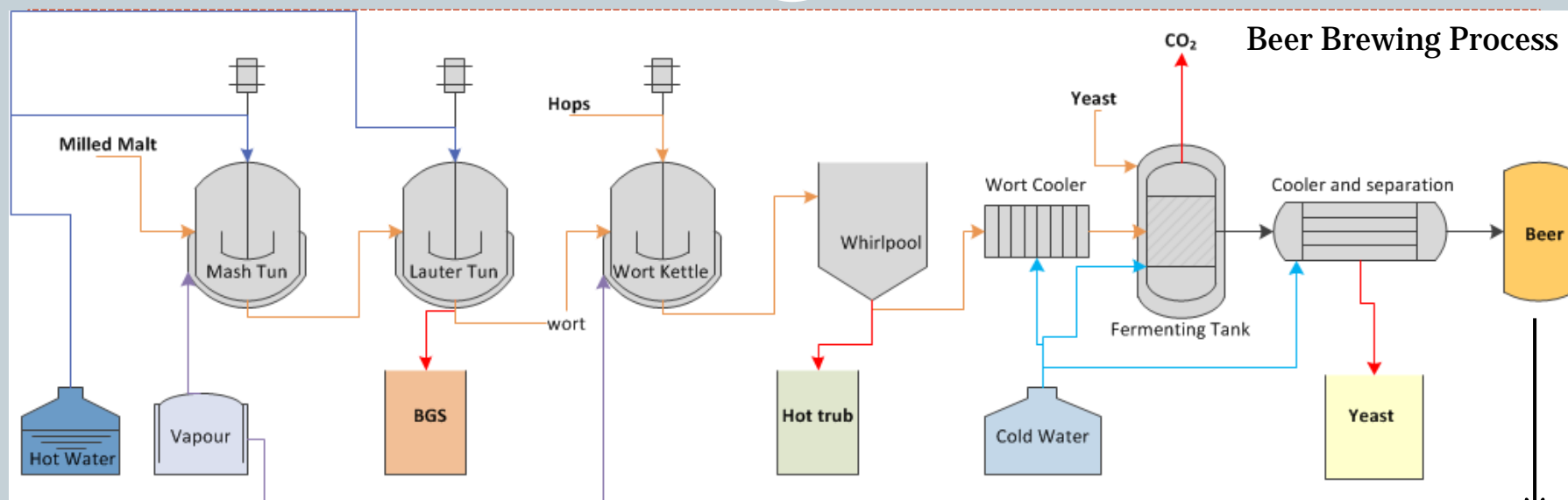
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# Summary



- **Introduction (beer industry, beer residues, energy necessities)**
  - Beer industry
  - Beer residues: BSG
  - Energy requirements
- **Valorization of Beer Spent Grain (BSG)**
- **BSG characterization**
- **Integration of BSG gasification in a craft brewing**
- **Conclusions**



## By-products produced

BSG	20 kg/hl beer
Hot trub	0.3 kg/hl beer
Yeast	0.2 hl/hl beer
CO <sub>2</sub>	3.3 kh/hl beer

85%  
ICS →

## Energy requirements

CO <sub>2</sub> for transfer	0,37 kg/hl beer
Electricity	23.8 kWh/hl beer
Gasoil	31 kWh/hl beer
Total energy	54.8 kWh/hl beer

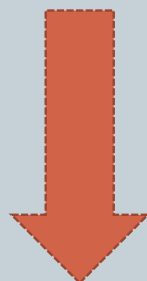


# Introduction

Waste-to-Energy



Gasification of BSG



Diminish waste volume  
Reduce energy from fossil  
fuels



# Valorization of BSG





## Anaerobic digestion

- **Biogas production**
  - Most common
  - ✓ No drying
  - ✗ Long degradation rates/retention time
  - ✗ Technical know-how
  - ✗ High OPEX and CAPEX

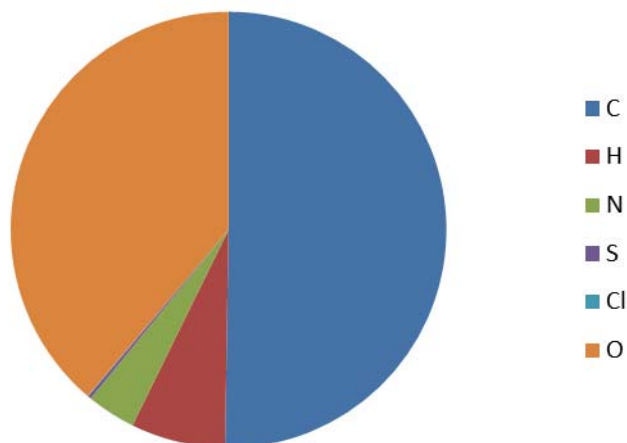
## Combustion/Gasification

- **Combustion**
  - ✓ Good LHV
  - ✗ Drying necessary
  - ✗ Emission (particles, SO<sub>x</sub>, NO<sub>x</sub>)
- **Gasification**
  - ✓ Good LHV
  - ✗ Drying necessary
  - ✓ Versatile
  - ✓ Low environmental impact
  - ✓ High electrical performance

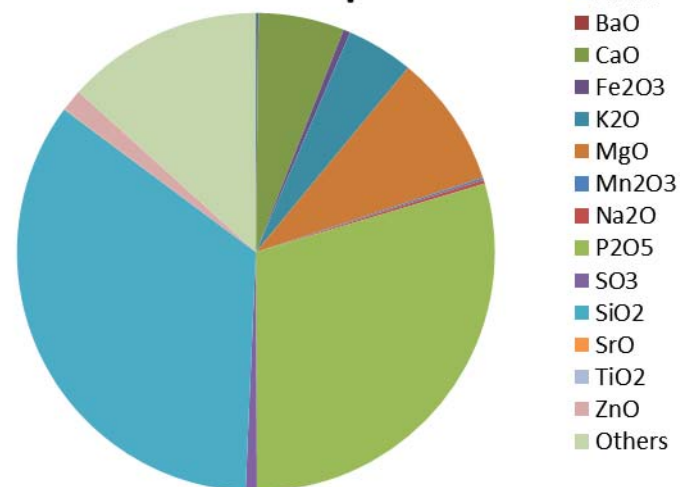
# BSG characterization

Moisture (% b.s.)	Ash (% b.s.)	Volatile Matter (% b.s.)	Fixed Carbon (% b.s.)	LHV (MJ/kg b.s.)
76 	3 	79 	18	19 

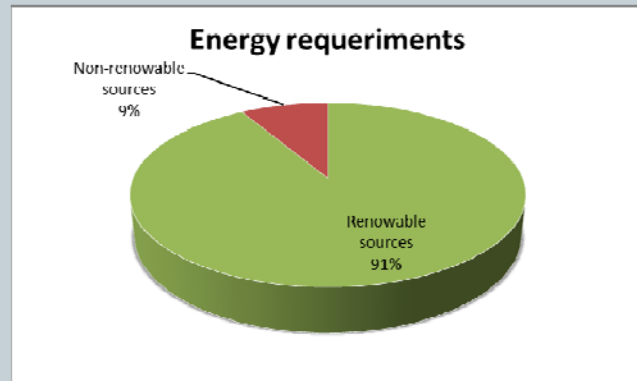
**Ultimate Analysis**



**Ash Composition**



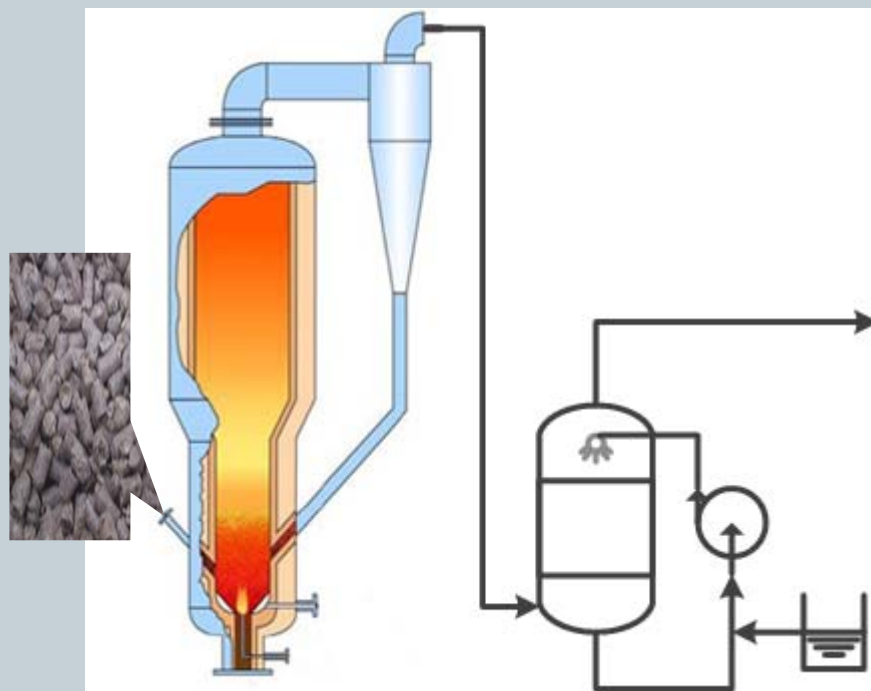
# Pretreatment of BSG



Energy  
from non-  
renewable  
sources:  
192 kJ/kg

Energy consumption = 900 kJ/kg

# Gasification of BSG



**Syngas**

**Boiler**

**Engine**

$$\text{LHV} = 6 \text{ MJ/Nm}^3$$

$$Y_{\text{gas}} = 2.2 \text{ Nm}^3/\text{kg}$$

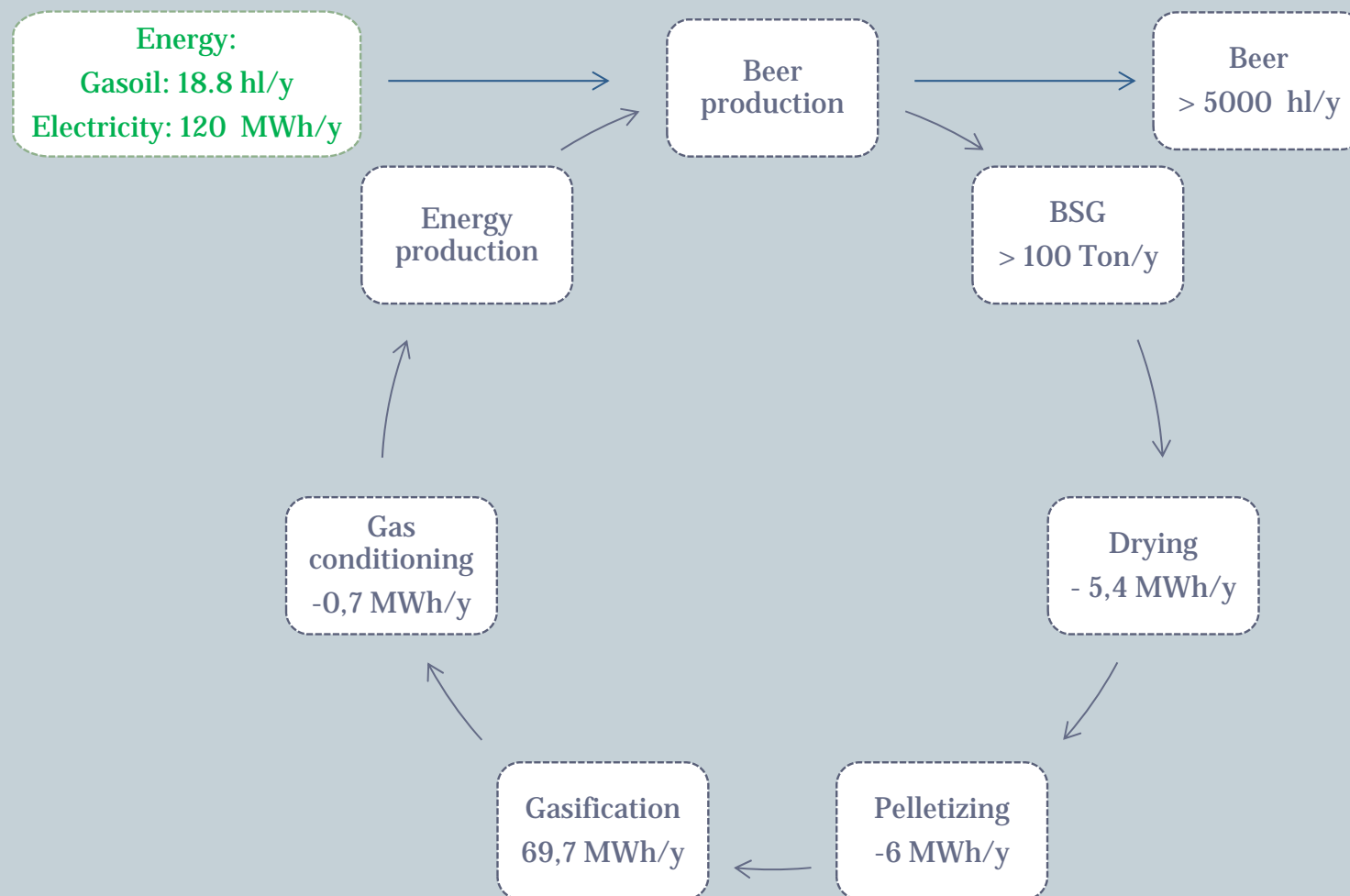
$$\text{Power} = 3.2 \text{ kWh}_{\text{th}}/\text{kg}$$

$$E_{\text{consumed}} = 1 \text{ kWh}_{\text{th}}/\text{kg}$$

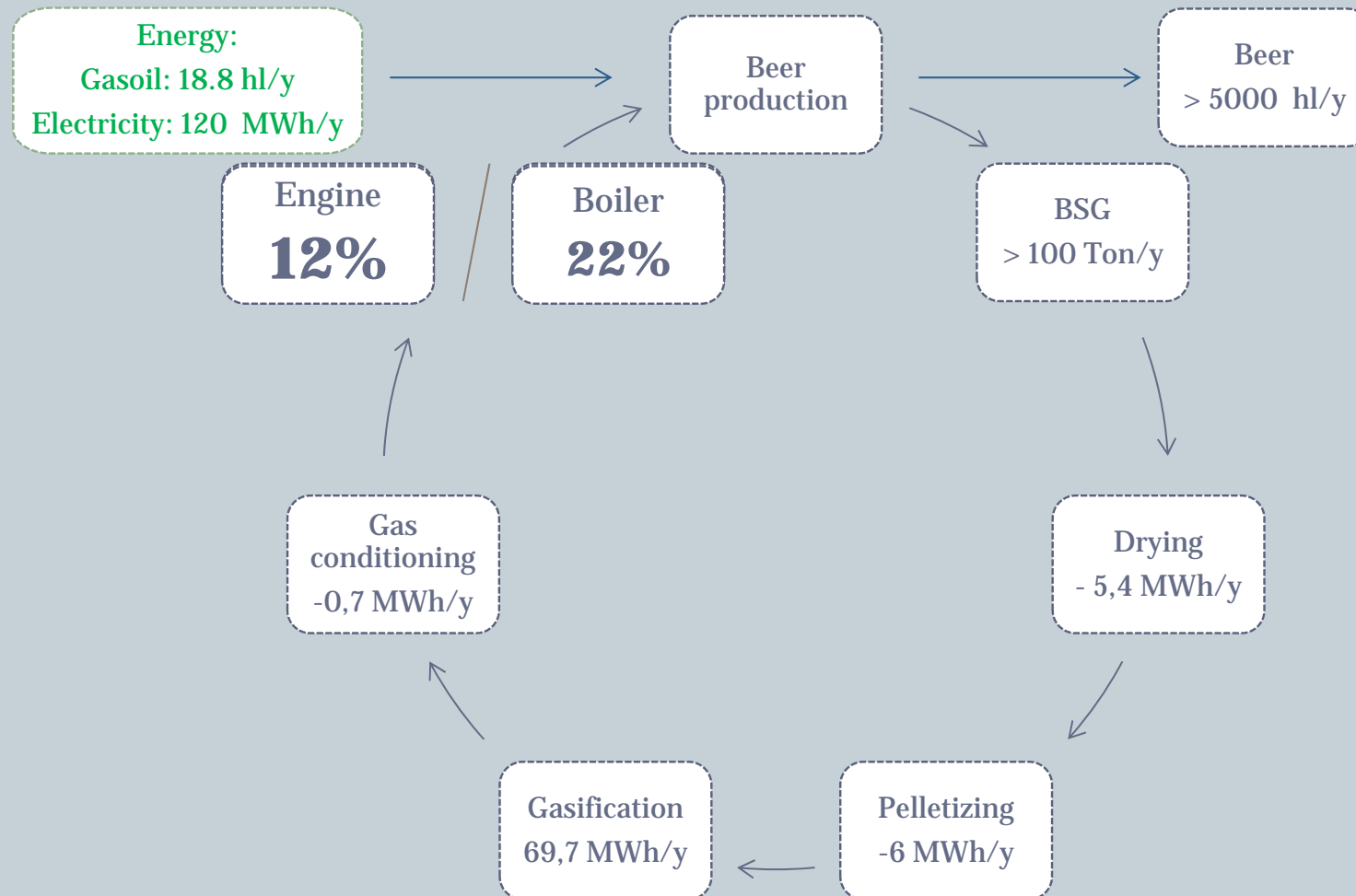
$$E_{\text{consumed}} = 0.03 \text{ kWh}_{\text{th}}/\text{kg}$$



# Integrated solution



# Integrated solution



# Conclusions



- Reduce of fossil fuels (12 - 22 %)
- Avoid CO2 emissions
- Help to mitigate climate change
- Reduce the waste volume

# Thank you for your attention



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