Process Intensification and the Whisky Industry

Alan Harper

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HERIOT WATT UNIVERSITY

International Synergies
industrial ecology solutions

Knowledge Transfer Network
Environmental Sustainability

Scottish Funding Council
Promoting further and higher education

The Glen Close Distillery Project

A project of the Heriot-Watt MSc in Sustainable Engineering

Tampering with a malt whisky is like painting a moustache on the Mona Lisa

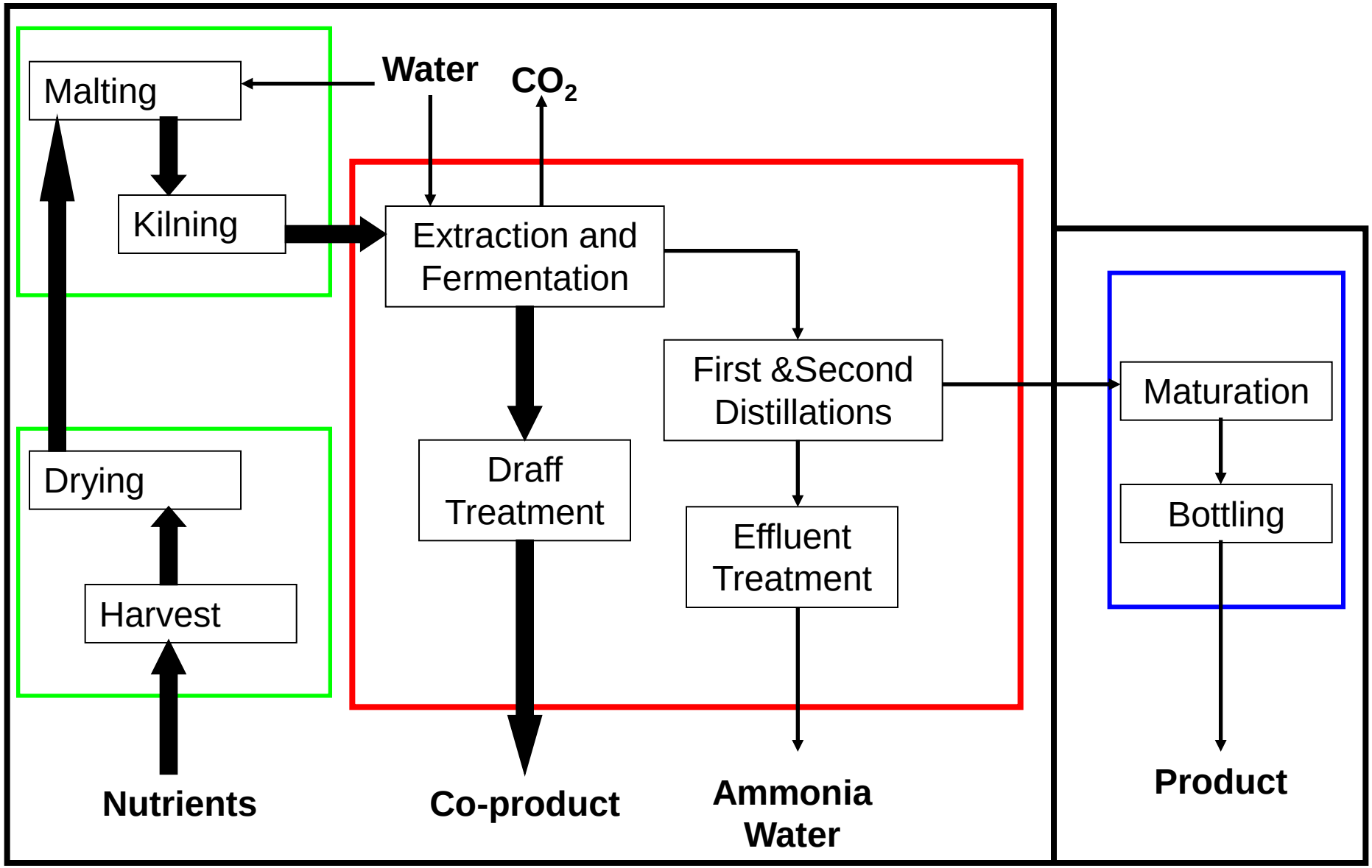
Three Options

1. Make changes that do not affect the qualities of the whisky
2. Design a distillery for a new malt
3. Concentrate on grain distilleries

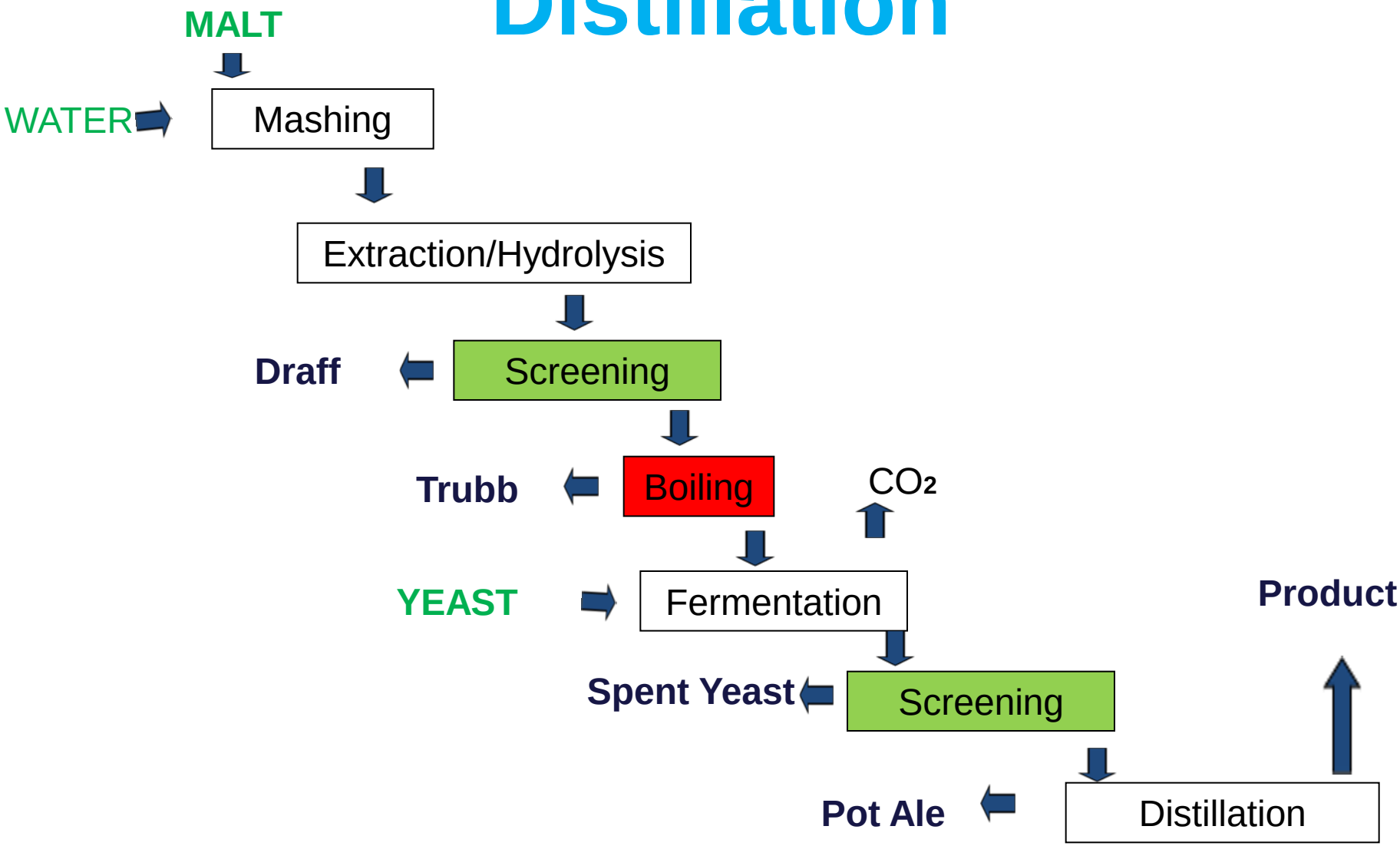
Evaluate suitable technologies for each.

Staged innovation

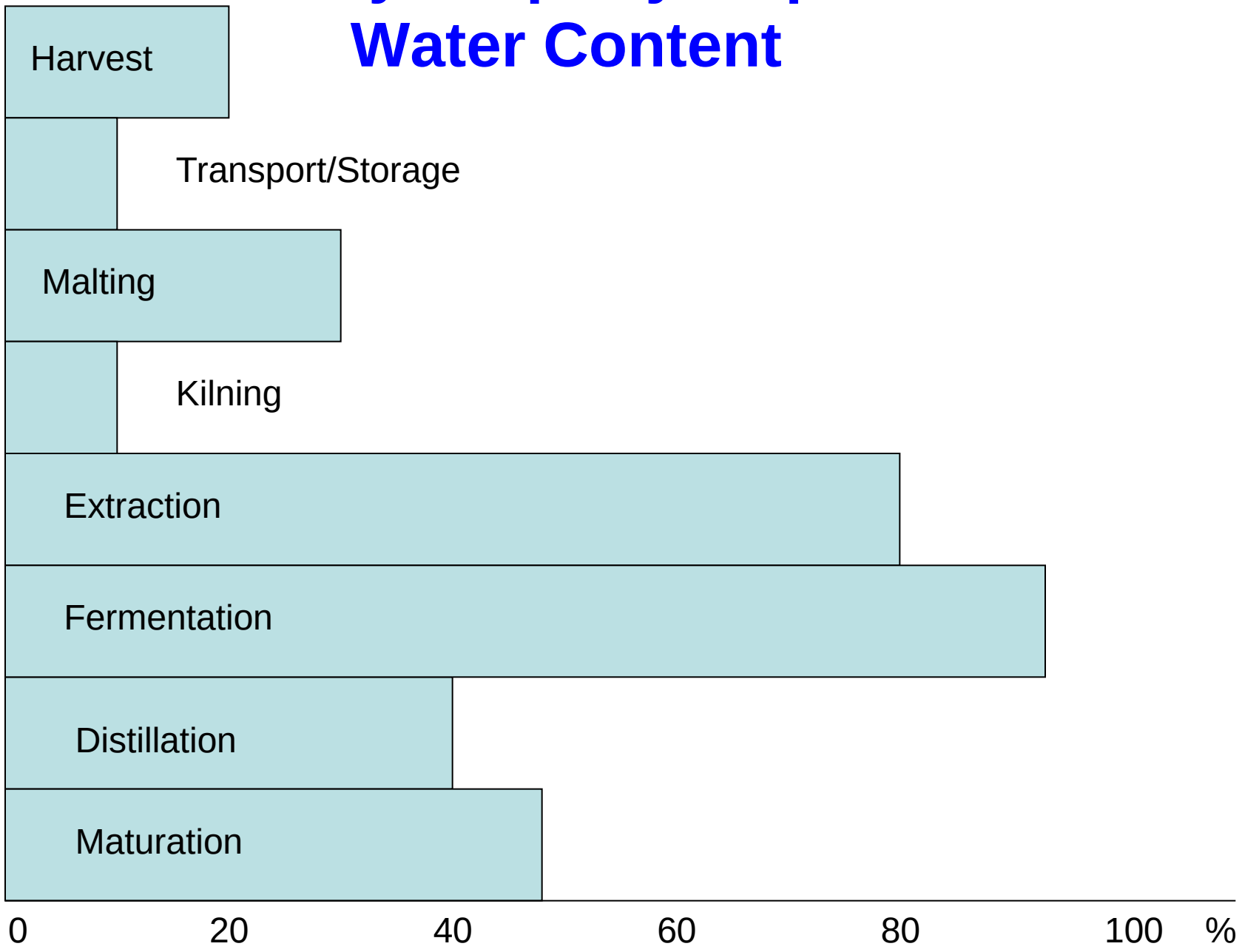
Scope & Boundaries



Generic Brewing and Distillation



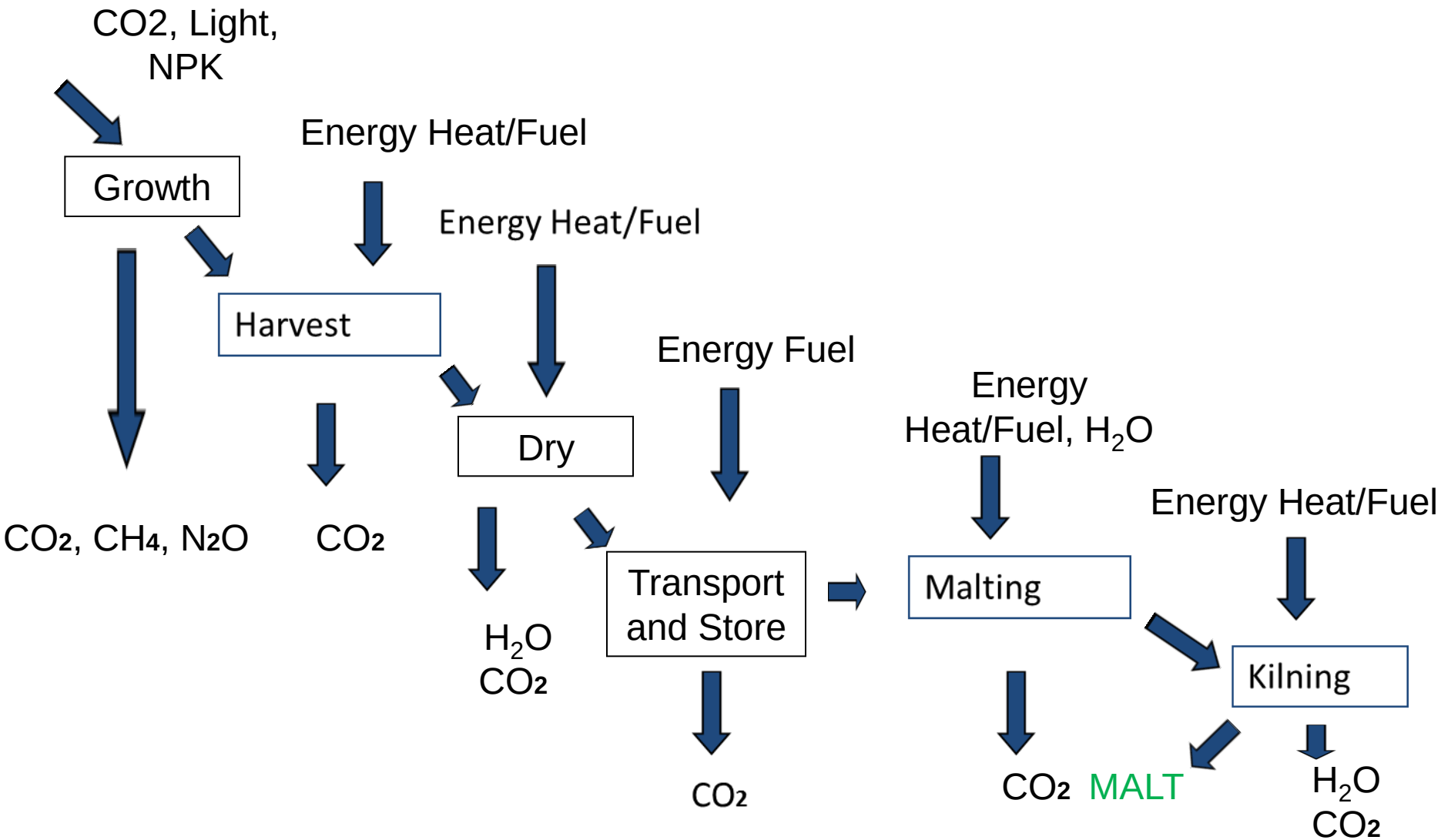
Key Property Map: Water Content



Key Processes

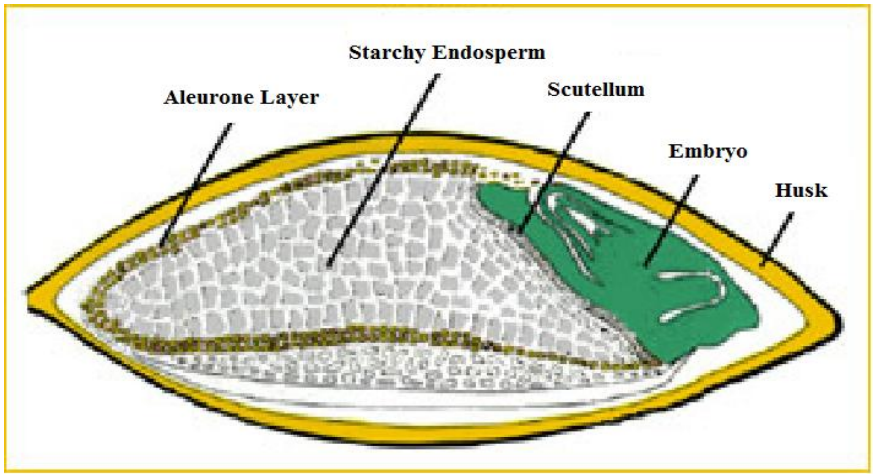
- Malting
  - Steeping
  - Germination
  - Kilning
- Extraction and Hydrolysis
  - Mixing
  - Enzymes
  - Starch
  - Holding
- Distillation
  - Evaporation
  - Condensation

Malting Process



Malting and Kilning

- Malting is the germination of the barley to release enzymes
- Barley is moistened and shoot grows (haulm)
- Haulm is then killed off by kilning in hot air

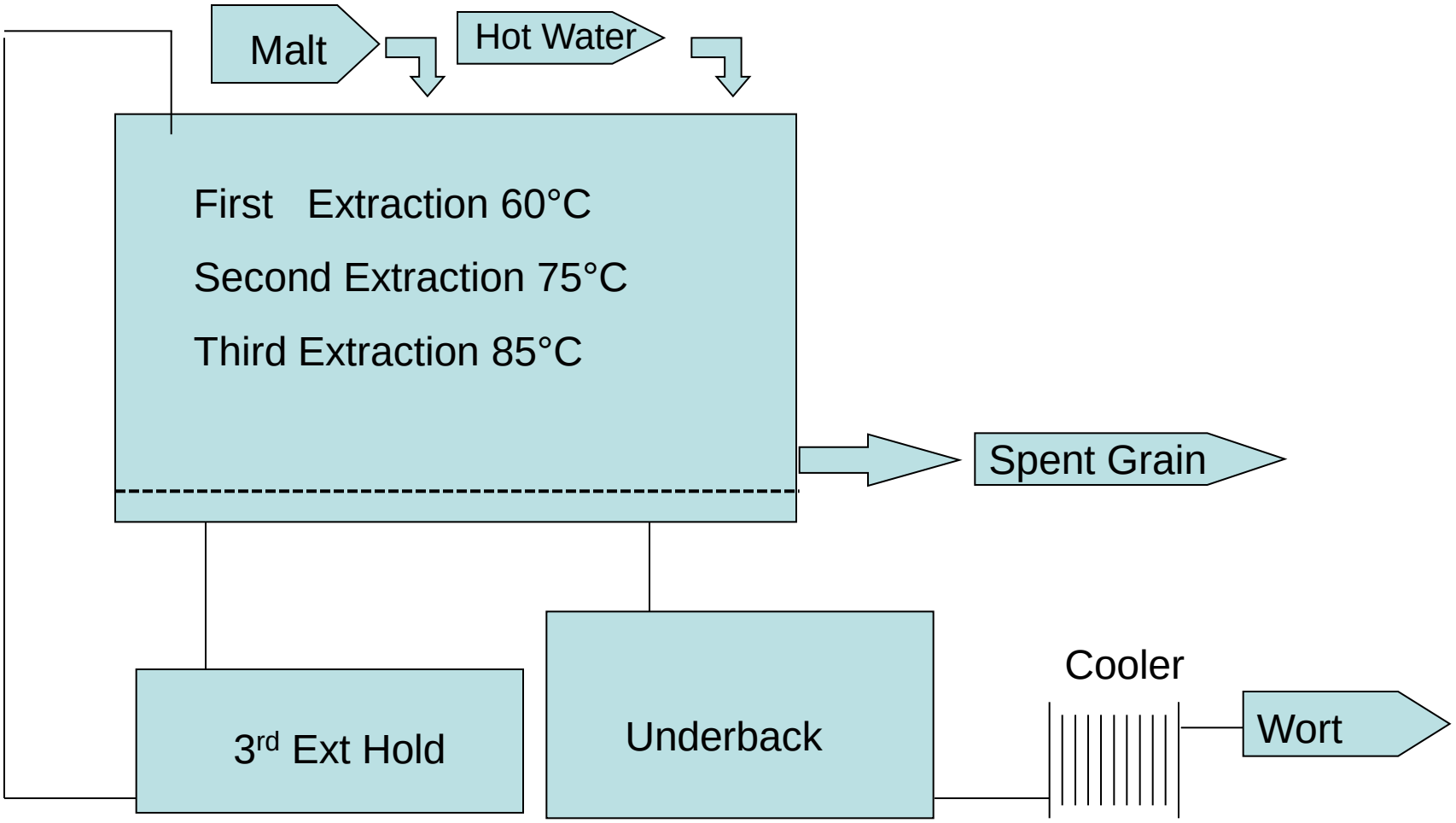


- Green malt (unkilned) has very short shelf life (hours)
- Kilning - large quantities of energy evaporating water
- Can we stop growth without evaporation?
- From key property map: high water levels in haulm
- Water absorbs microwaves….

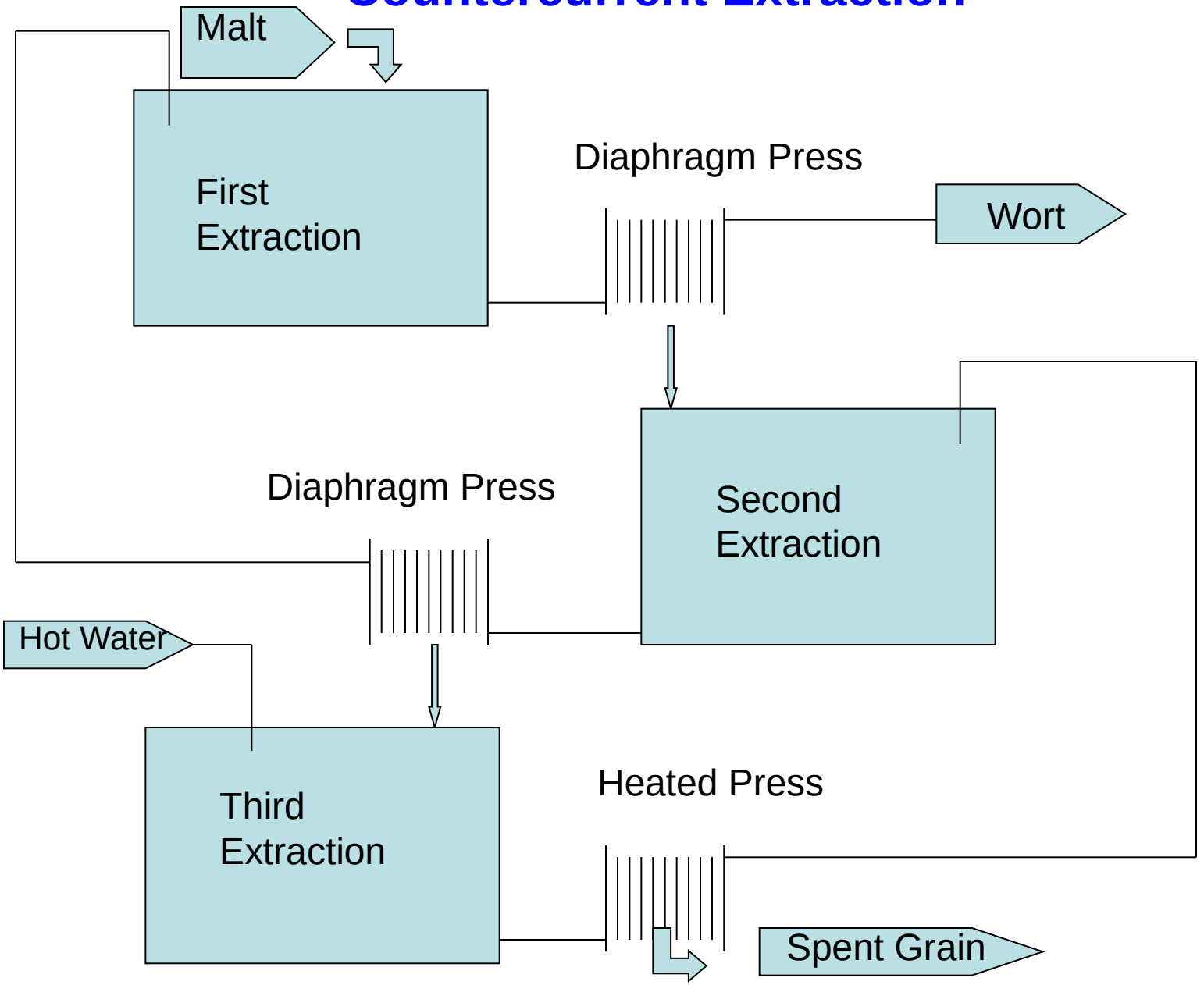
Extraction of Enzymes and Carbohydrates

- ‘the Grain, the whole Grain and Nothing but the Grain’
- Carbohydrates from barley, wheat or maize
- Enzymes from malted barley
- Enzymes denature
  - with temperature
  - pseudo first order kinetics

Extraction of Enzymes and Carbohydrates: Traditional Malt Process



Extraction of Enzymes and Carbohydrates: Countercurrent Extraction



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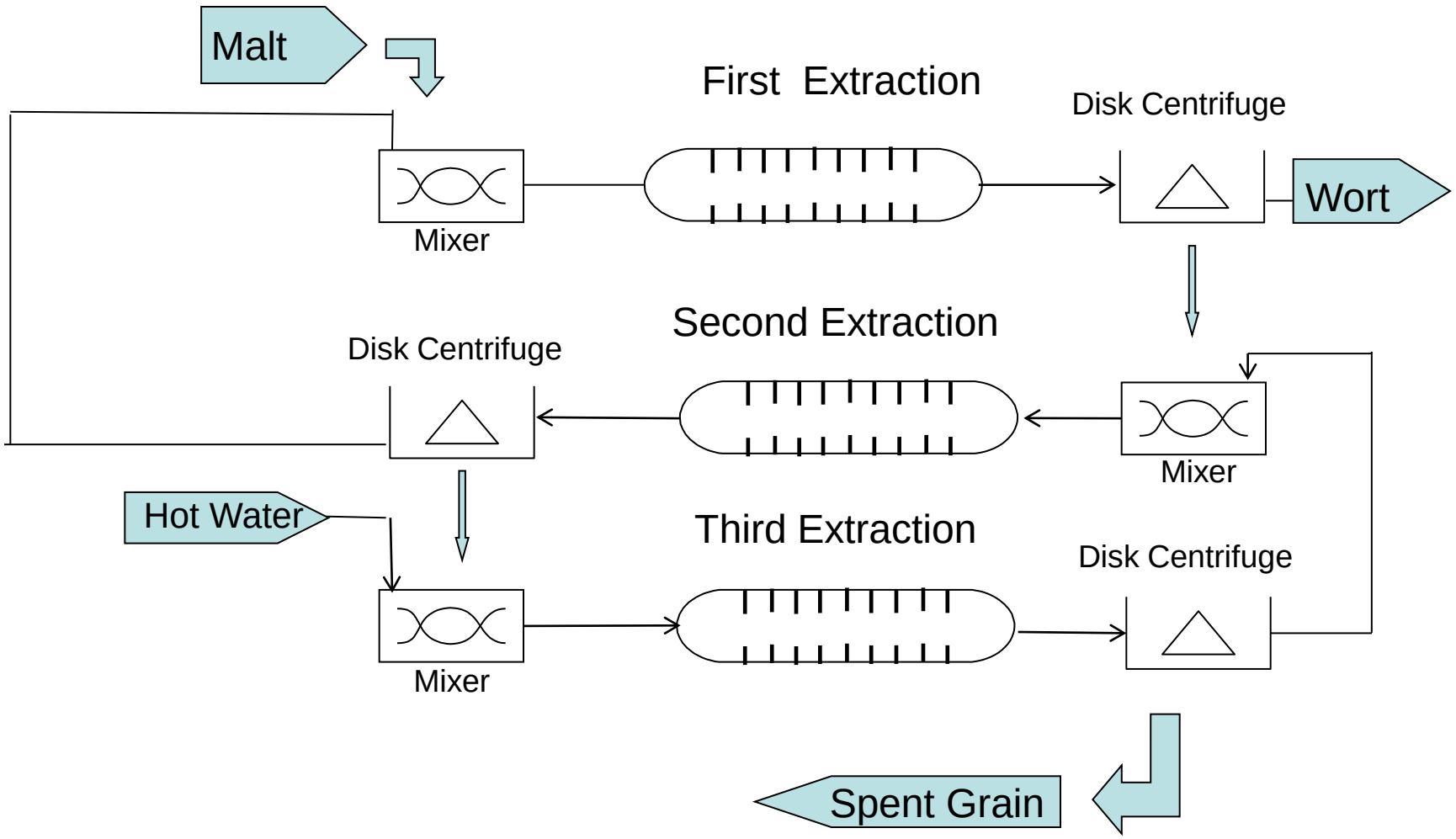
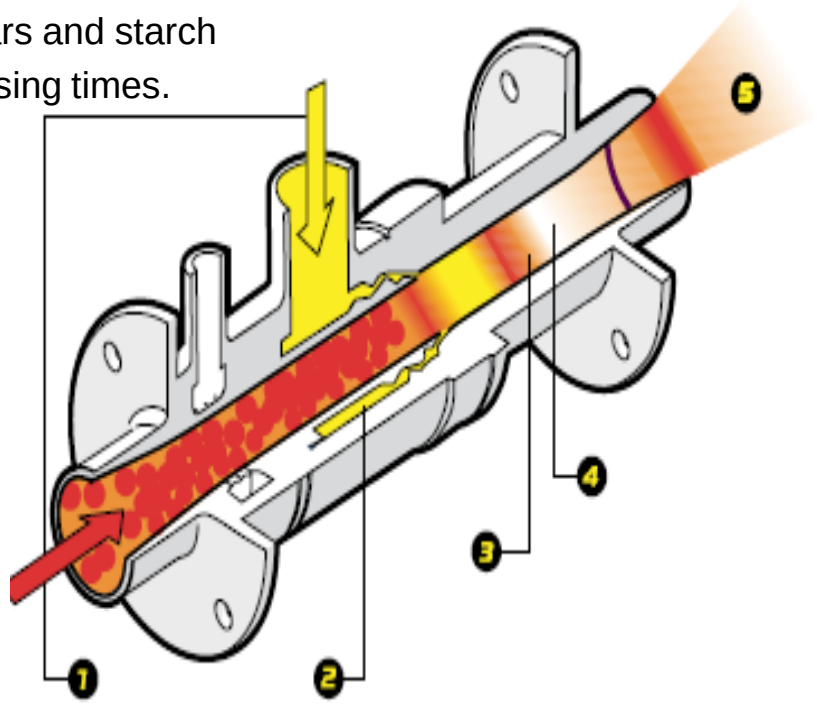


PDX Ethanol Reactor System

- steam is injected at supersonic velocity into the process slurry
- energy is transferred as kinetic energy rather than heat.
- pressure shock wave happens instantaneously as the process slurry flows just a few inches.
- PDX ERS extracts traditionally inaccessible starch through
  - extreme agitation
  - shearing impact of the condensation shock wave
  - requires less heat and time than conventional cooking
- more starch available for conversion to ethanol
- alpha amylase works more effectively
- reduces residual sugars and starch
- enables faster processing times.



1. STEAM IS INTRODUCED INTO AN ANNULAR CONDITIONING CHAMBER THAT IS WRAPPED AROUND THE CORE OF THE PDX® UNIT.

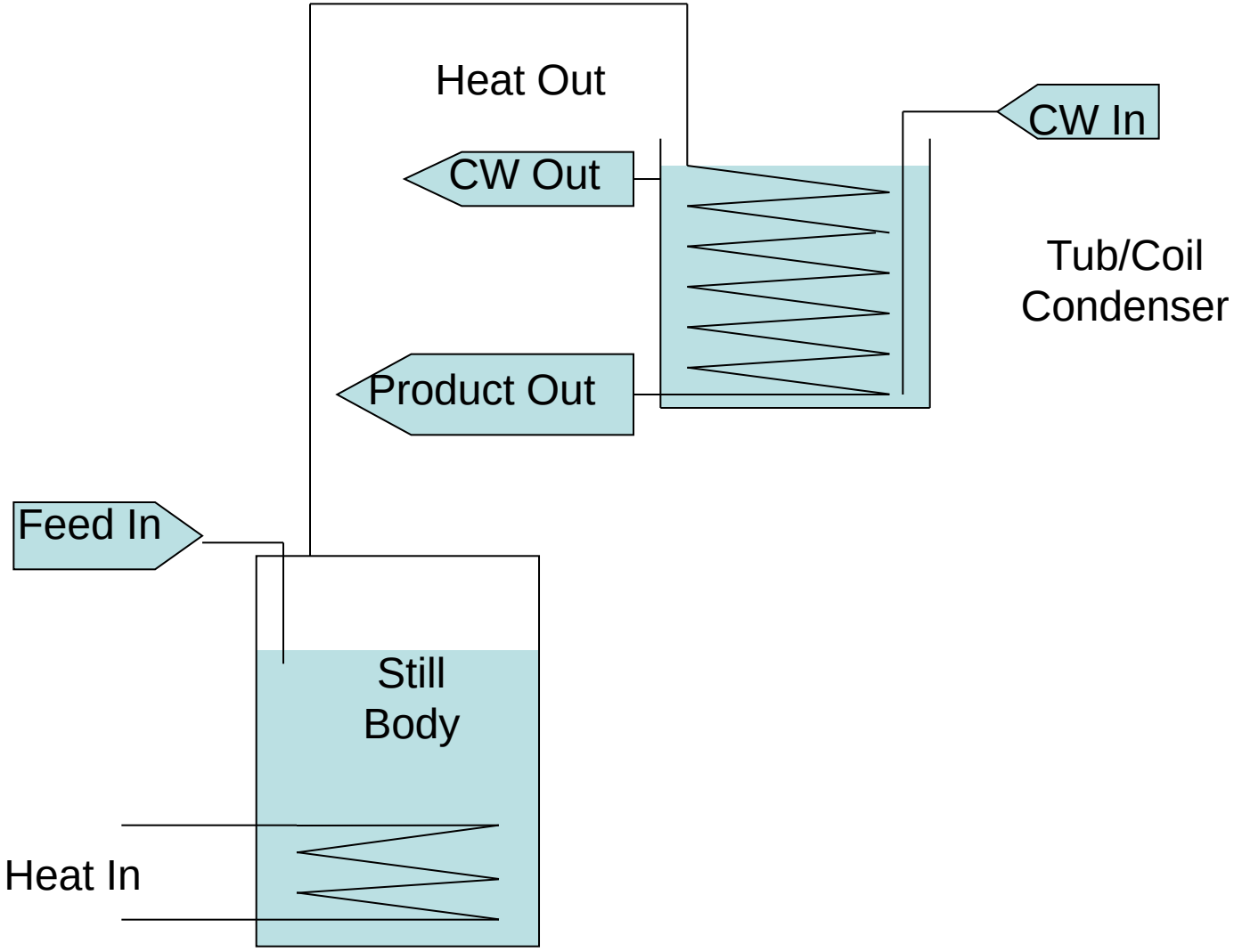
2. THE STEAM IS THEN INJECTED INTO THE PROCESS FLOW THEREBY CREATING MOMENTUM TRANSFER.

3. THE PDX® GEOMETRY FORCES THE STEAM TO BECOME SUPERSONIC FORMING A CONTROLLABLE SHOCKWAVE.

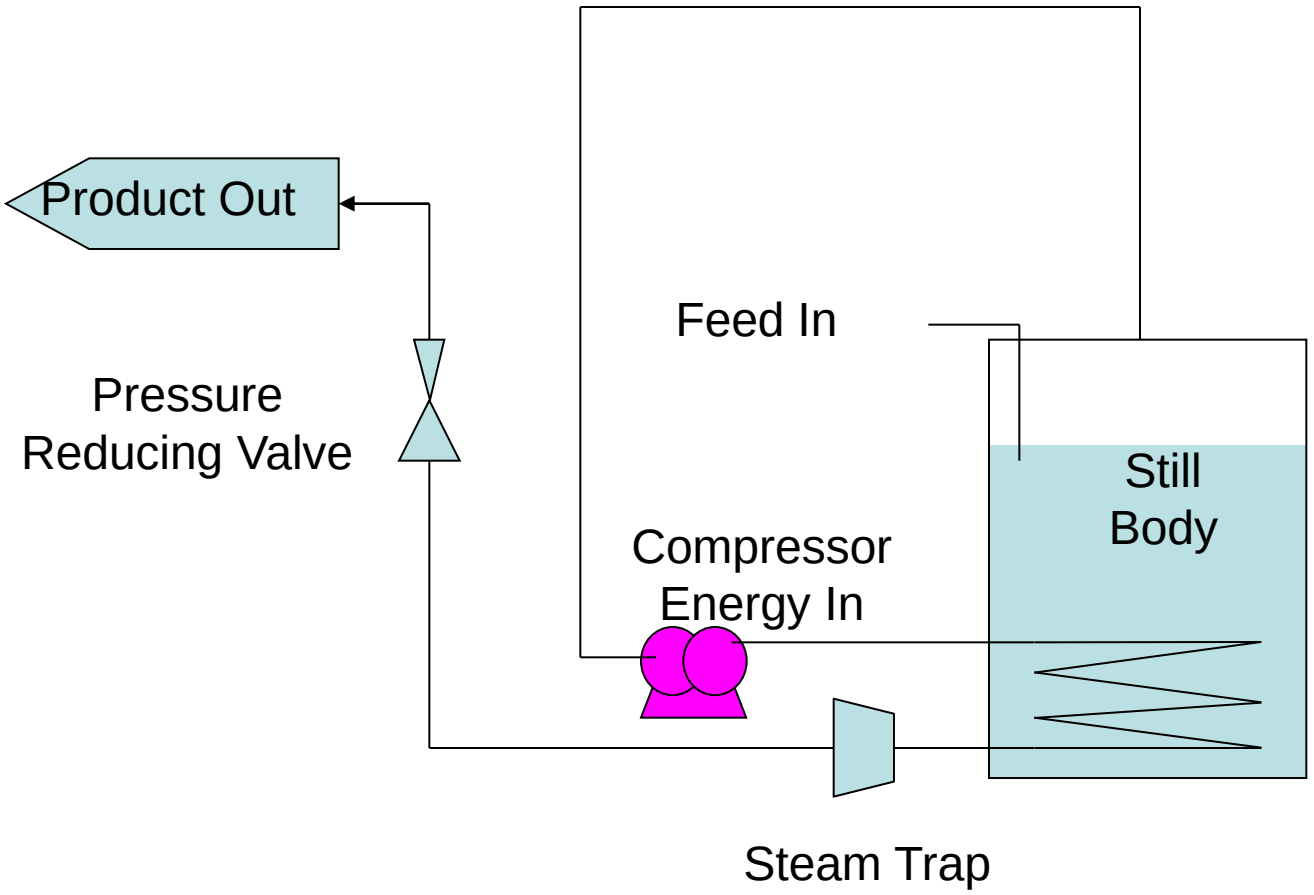
4. MIXING AND HEAT TRANSFER TAKES PLACE IN THE CONTROLLABLE LOW-PRESSURE, LOW-DENSITY SUPERSONIC REGION.

5. THE PDX® UNIT ALLOWS CONTROL OF THE SUPERSONIC ZONE, AND HENCE CONTROL OF THE SYSTEM'S UNIQUE CAPABILITIES.

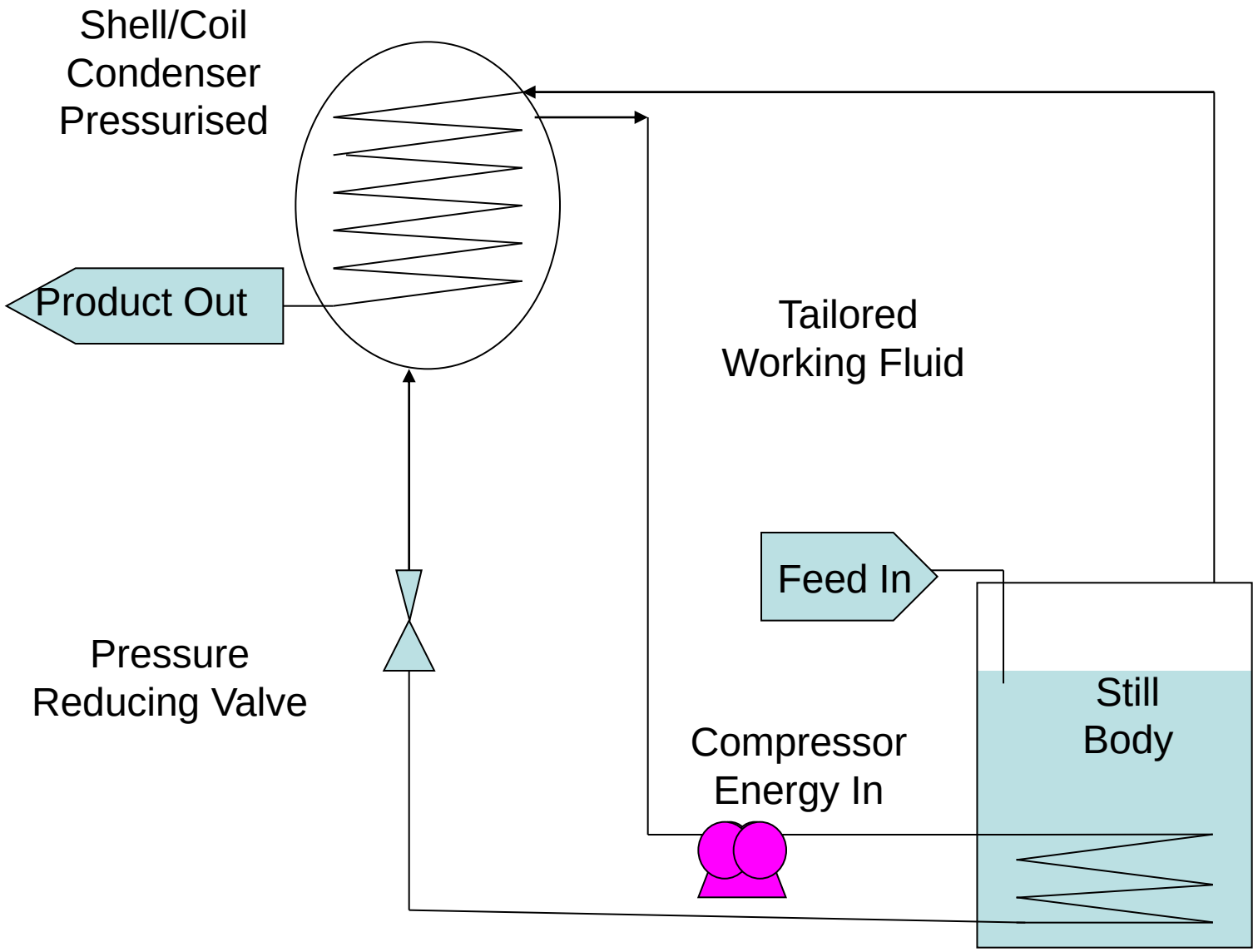
Traditional Still



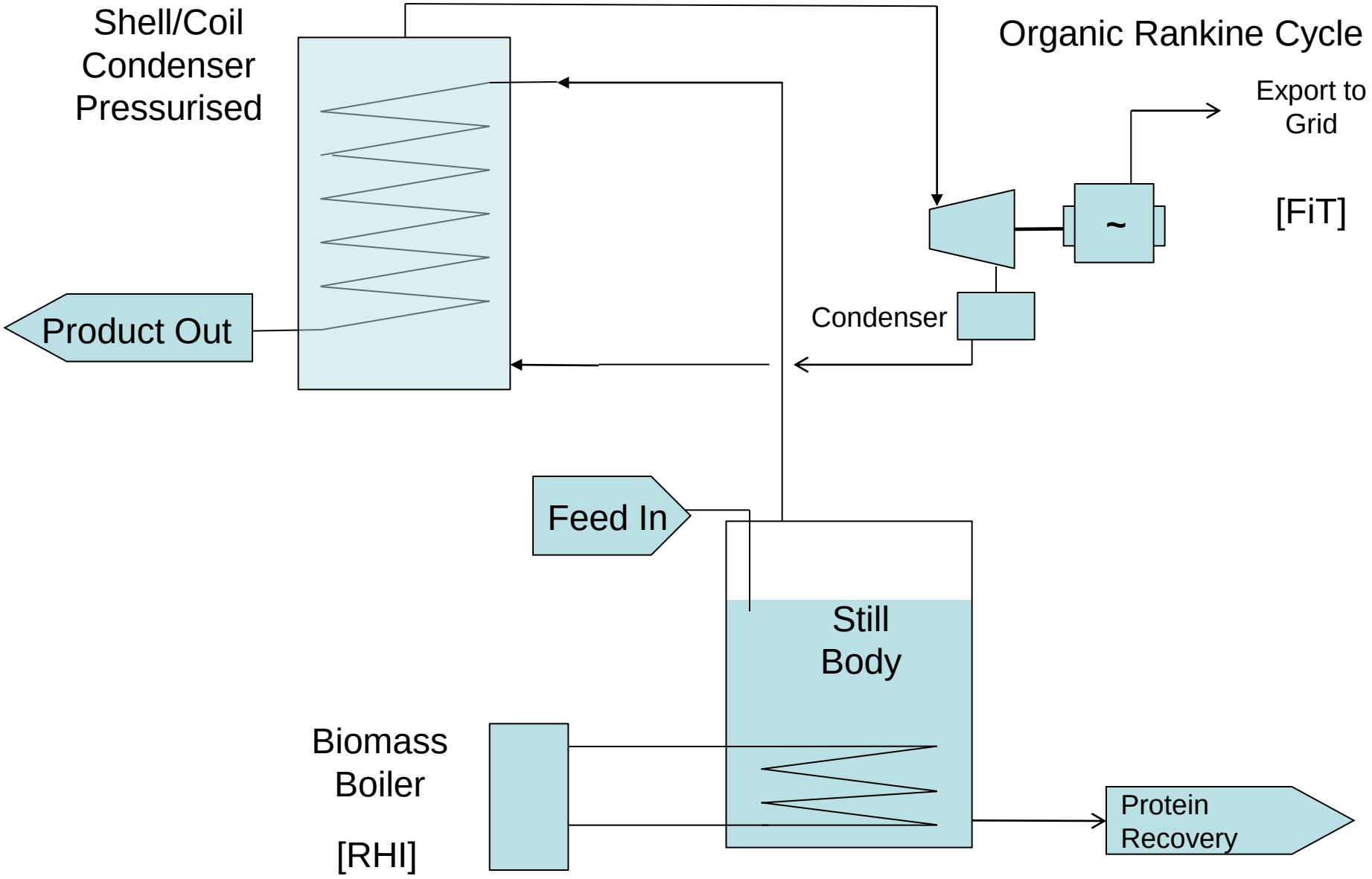
Vapour Recompression Still



Heat Pump Still



Subsidy Still



Energy Efficiency

- Whisky production is largely the moving about of water with the occasional organic contaminant
- Highly energy intensive.
- Low grade heat output from condensers.
- Batch process – intermittency problems
- Phase change heat store.

Resource Efficiency

- Malt whisky sector has specific limitations
  - Geography (must be in Scotland):
    - Remote from cheap & reliable energy resources
    - Availability of high quality water (summer)
    - Transport
    - Siting
  - Agriculture
    - Availability of high quality grain
    - Availability of high quality wooden casks
  - Economics
    - Wait >8 years before positive cash flow

A Cry for Help

- Need intensification concepts that fit in with constraints
- Community is receptive but sceptical
  - History of bright ideas that crashed and burned
- Must be robust
- Must be compatible with copper
- Incremental innovation

Acknowledgements

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  - 2007 – Sean Meade; Prabha Dhavala
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- IBDC
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- SFC