Recent trends in pretreatment technogies for production of lignocellulosic biofuels

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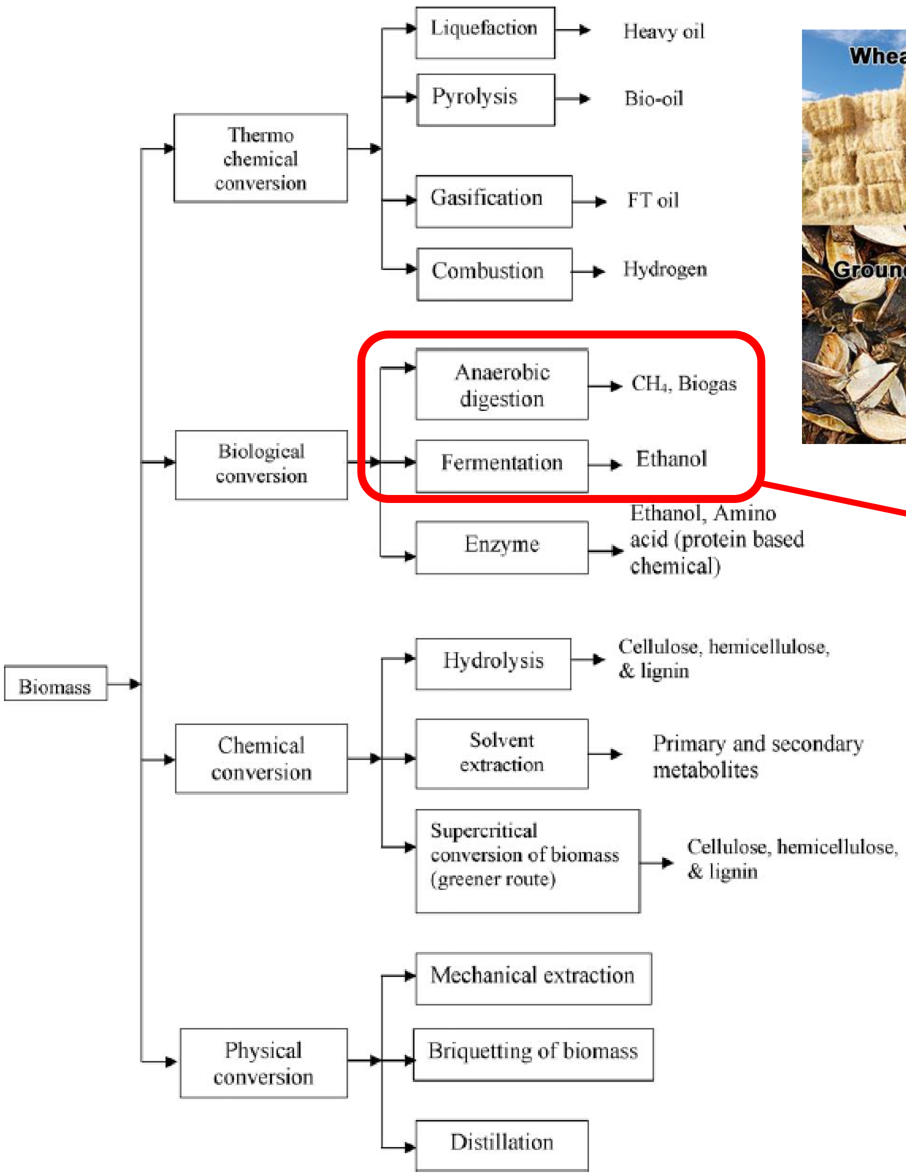
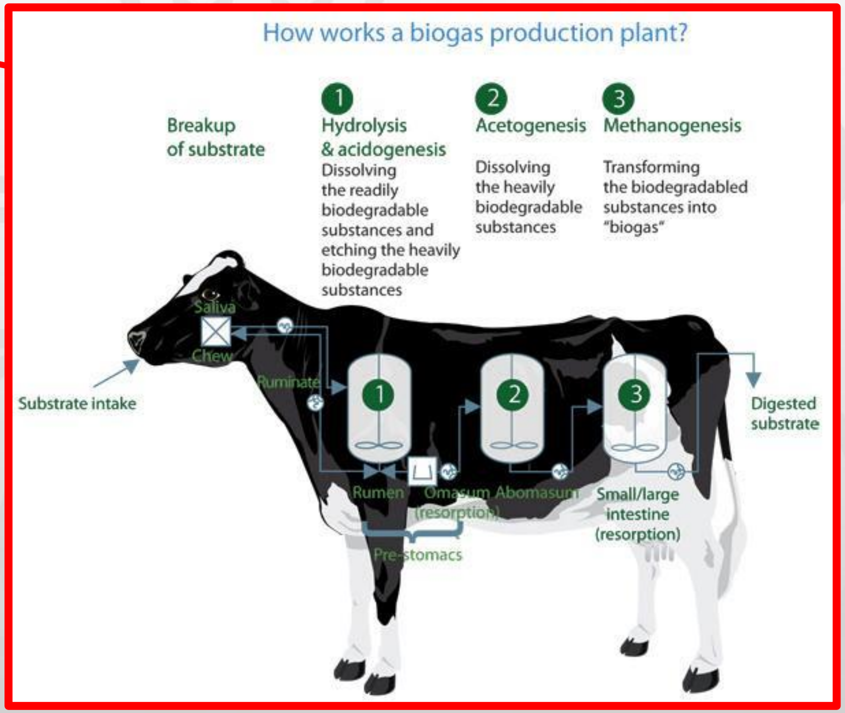
LIGNOCELLULOSIC WASTES

- **global biomass production 100·10^9 t$_{TS}$ in 2015,** majority used as food, feed, manufacturing industry, **european food waste production 1,9·10^9 t$_{TS}$ in 2015**
- **annual production straw based wastes was 5,4·10^9 t$_{TS}$ of in 2015** = freely available feedstock (*feed, mostly stored on fields, burned, or unutilized*)

LIGNOCELLULOSIC WASTES



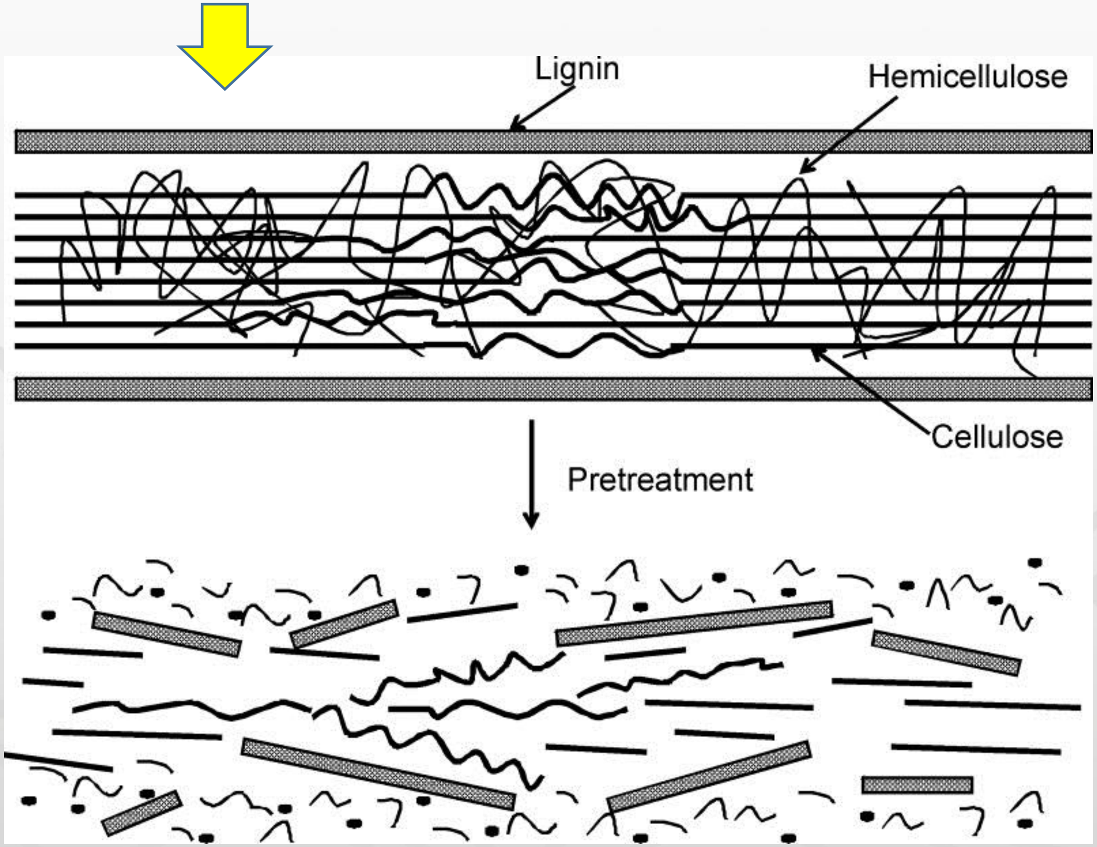


PRETREATMENT OF WASTES

- **native properties make lignocellulosic materials nondegradable or with a low transformation efficiency waste bioproduct**

biodegradability of native biomass does not exceed 20 %

concrete pillar



increase in biodegradability by 5-25 % & decrease in digestion time by 23-59%

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PRETREATMENT OF WASTES

- **physical, chemical, physico-chemical and biological methods**

biogas, biohydrogen, biooil, bioalcohols

BIOCHEMICAL TREATMENT

PHYSICAL METHODS

- mechanical disintegration
- drying

CHEMICAL METHODS

- acid treatment
- alkaline treatment
- solvolysis
- ozonolysis
- oxidation

PHYSICOCHEMICAL METHODS

- hydrothermal pretreatment
- steam expansion
- CO_2 or ammonia expansion
- irradiation

BIOLOGICAL METHODS

- fungi and moulds
- enzymatic hydrolysis

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SIZE REDUCTION

- First stage of preprocessing; achievement of final particle size

  1-10 mm + defibering

- **Energy requirement depends on**
  - **type of size reduction machine** *+ its set up*
  - **ratio inital/final particle size**
  - **biomass characteristics** *composition, moisture*

THE RIGHT CHOICE OF SUITABLE GRINDER/MILL DEPENDS ON MOISTURE OF BIOMASS

MOISTURE < 15 % WT.

- knife mill
- hammer mill
- disc mill

MOISTURE > 15 % WT.

- colloid mill
- extruder

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- roll mill
- ball mill
- vibratory ball mill

SIZE REDUCTION

Table 1. Energy requirements of specific machines.

Material	Initial/final size [mm]	Moisture content [wt %]	Equipment	Specific energy requirement [kWh t^{-1}]
Grass	200 / 100	10	Knife shredder	8.20
	100 / 2.5			4.10
Wheat straw	22.40 / 1.6	4–7	Knife mill	7.50
	22.40 / 2.5			6.40
	22.40 / 6.3			5.50
	22.40 / 1.6	4–7	Hammer mill	42.00
	22.40 / 2.5			29.00
	22.40 / 3.2			21.00
	200 / < 10	40	Retting mill	30.00
Straw, grass	–	–	Comminution unit	200
Rice straw	– / < 2	4–6	Ball mill	30 000
	– / < 2	4–6	Colloid mill	1500

energy least demanding (Knife mill)

1s:20l batch

60 min in n-loops

DISINTEGRATION OF WET MATERIALS IS HIGHLY ENERGY DEMANDED AND TIME CONSUMING OPERATION, MILLING IN LOOPS -> NO CONTINUAL MODE

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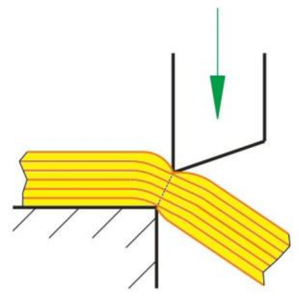
SIZE REDUCTION

- ***the new grinder was developed*** for disintegration of wet fibrous biomass
- biomass grinding –> interaction of shear F_S and compressive F_P forces

COMPRESSION
size reduction



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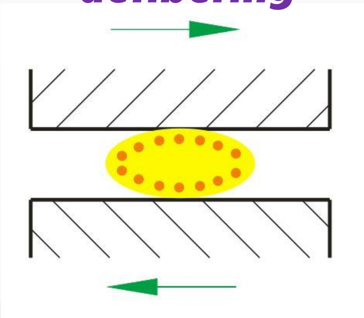
SHEAR
defibering



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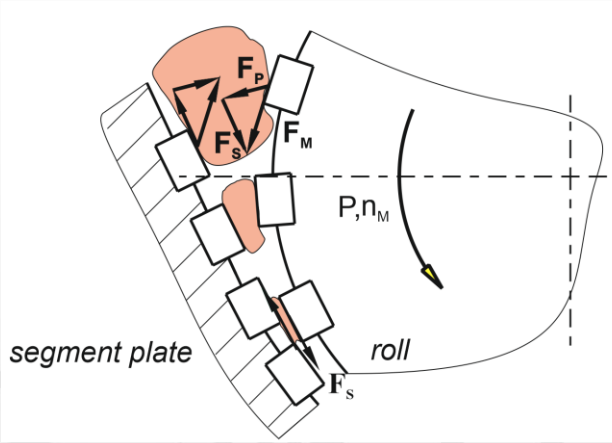

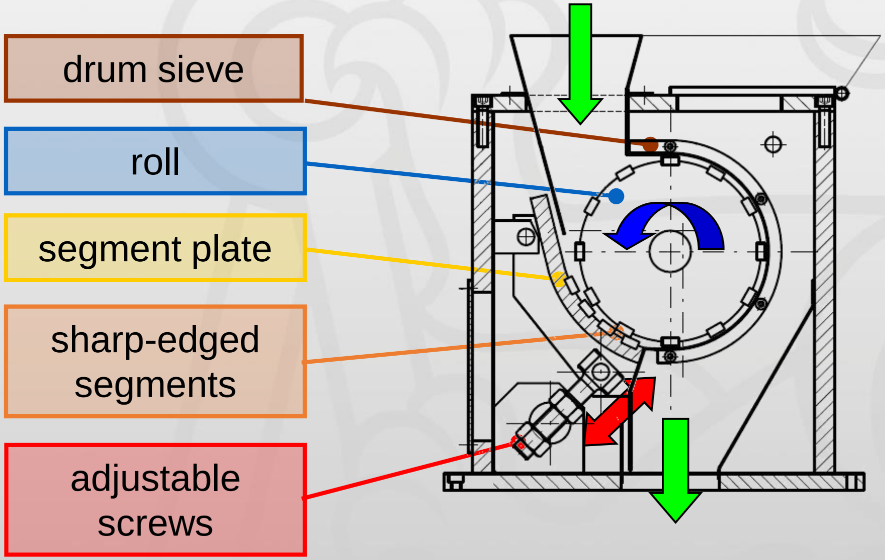

SIZE REDUCTION

- ***effectivity = particle size, energy demand biogas yield***

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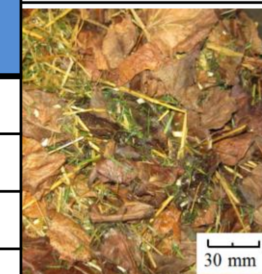
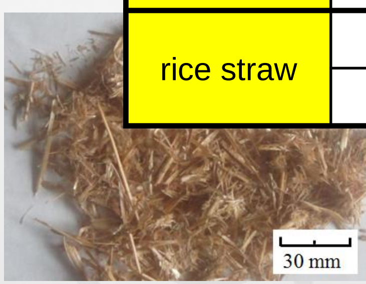
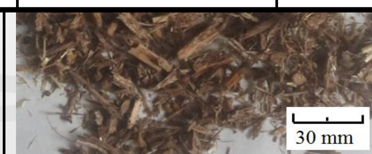
before				
after				

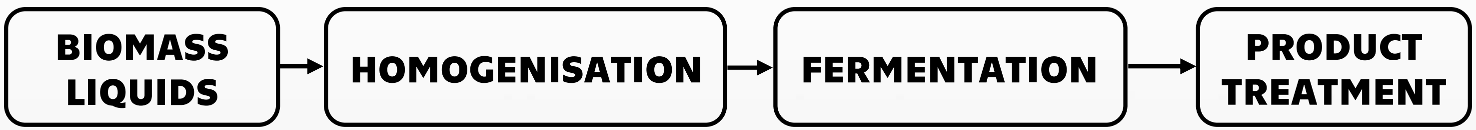
raw material	initial / final particle size (mm)	moisture (% hm.)	size reduction machines	energy demand ($kWh.t^{-1}$)
wheat straw	22,40 / 1,6	4-7	knife mill	07,50
	22,40 / 6,3			05,50
	22,40 / 1,6	4-7	hammer mill	42,00
	22,40 / 3,2			21,00
rice straw	N/A / < 2	4-6	ball mill	30000
	N/A / < 2	4-6	colloid mill	1500

raw material		wheat straw	grass	wood chips	BMSW
moisture (hm. %)		84,0 ± 0,6	82,1 ± 0,5	91,4± 2,6	73,0 ± 1,2
productivity ($kg_{TS}\ h^{-1}\ m^{-1}$)		190,5 ± 8,1	283,7 ± 15,8	60,6 ± 3,1	280,0 ± 14,0
energy demand ($kWh\ t^{-1}\ TS$)		19,6 ± 1,3	13,3 ± 0,7	142,2 ± 8,4	16,4 ± 1,4
biomethane yield $Y_{CH4PRTS}$ ($Nm^3 t^{-1}$ TS)	raw	193,0 ± 9,0	205,0 ± 3,0	-	-
	treated	260, ± 13,0	247,0 ± 4,0		
increase in CH_4 yield (% vol.)		35	21	-	-
decrsease in digestion time (%)		24	19	-	-

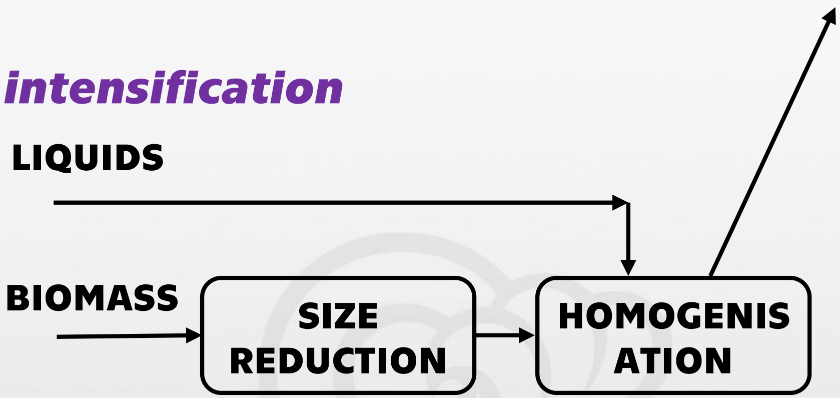
SIZE REDUCTION

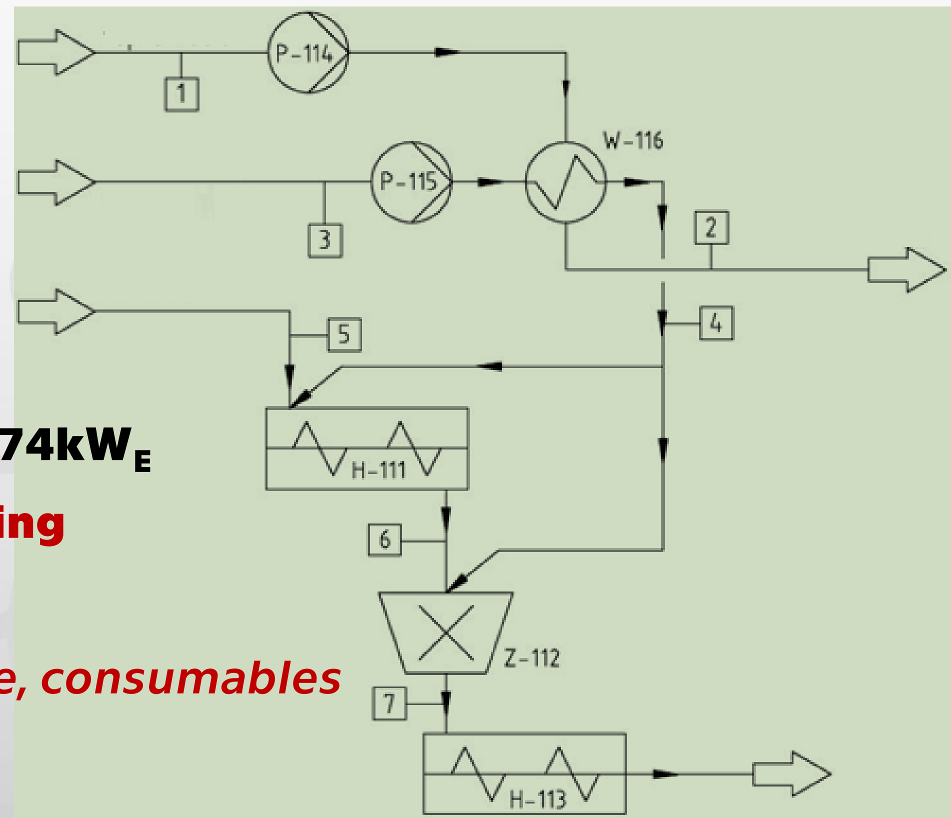
model BGS 500 kW_E

initial state



intensification



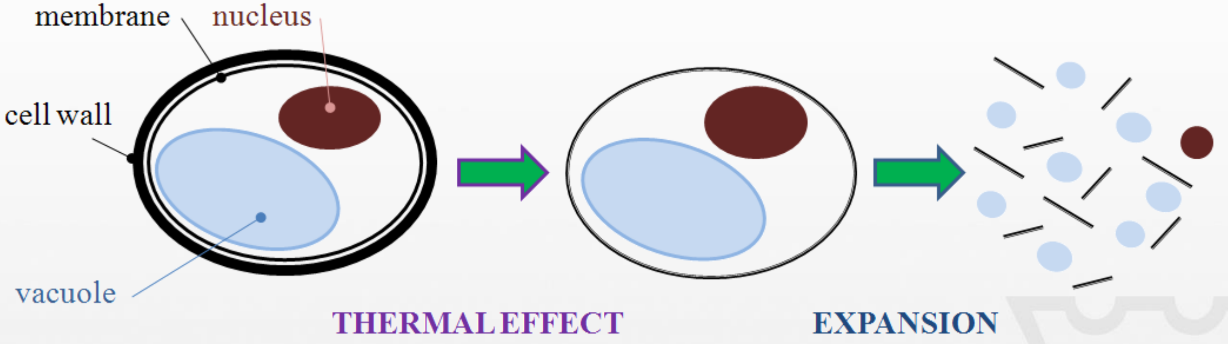


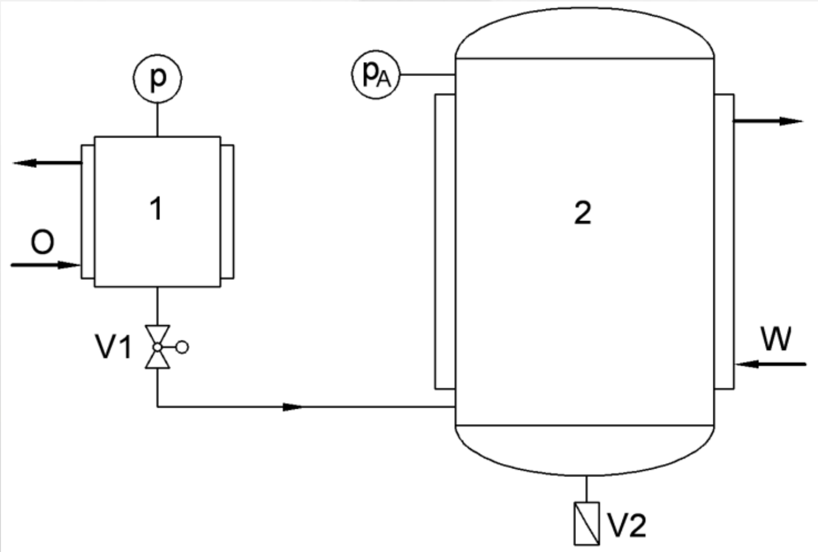
- **increase in power from 500 kW_E to 674kW_E**
- **4x decrease energy demand for mixing**
- **increase in revenue by 22 %**
- *OPEX increase – maintenance, servise, consumables*
- **simple payback 4 years**

HYDROTHERMAL PRETREATMENT

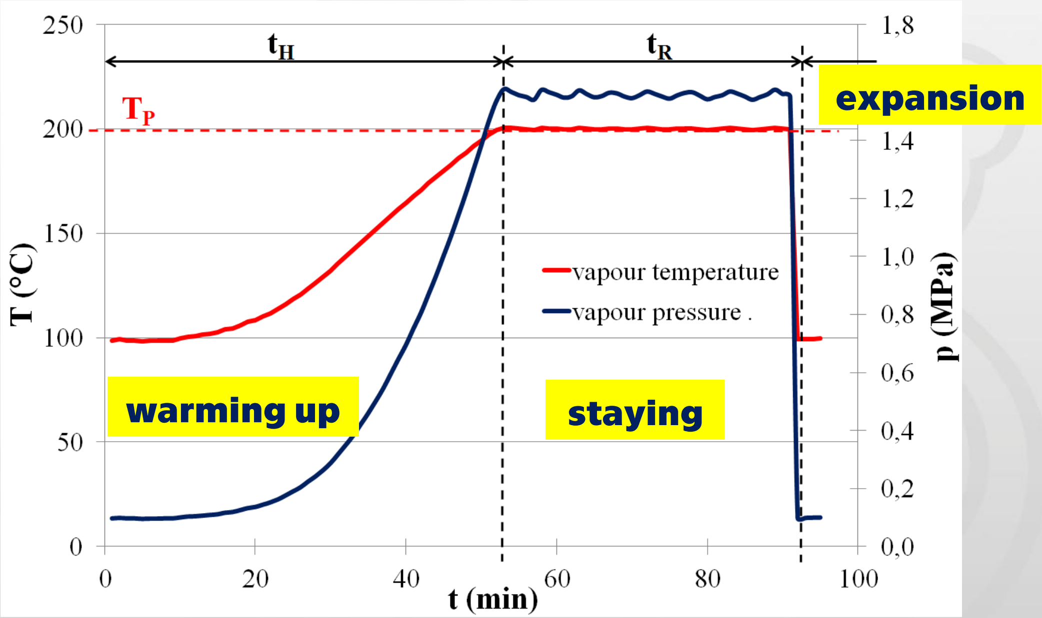
THERMAL-EXPANSIONARY PRETREATMENT

= Liquid Hot Water Pre-treatment & Steam Explosion





1 – hydrolyser; 2 – expansion vessel; V1 – ball valve; V2 – drain valve; O – heating; W – cooling



HYDROTHERMAL PRETREATMENT

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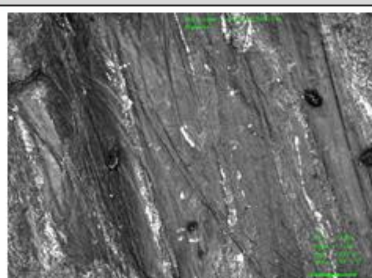
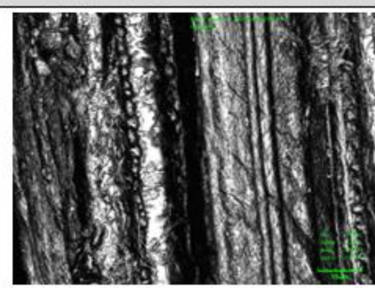
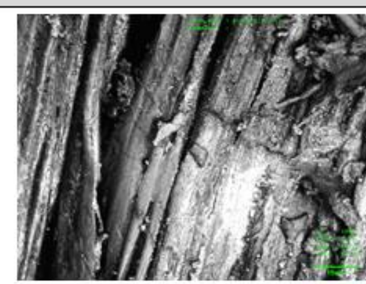
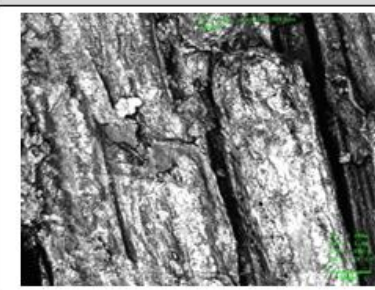
THERMAL-EXPANSIONARY PRETREATMENT

20 mm	untreated	170 °C / 20 min	185 °C / 40 min	200 °C / 60 min
TERMO				
TEP				

15μm	untreated	170 °C / 20 min	185 °C / 40 min	200 °C / 60 min
straw micro-structure				

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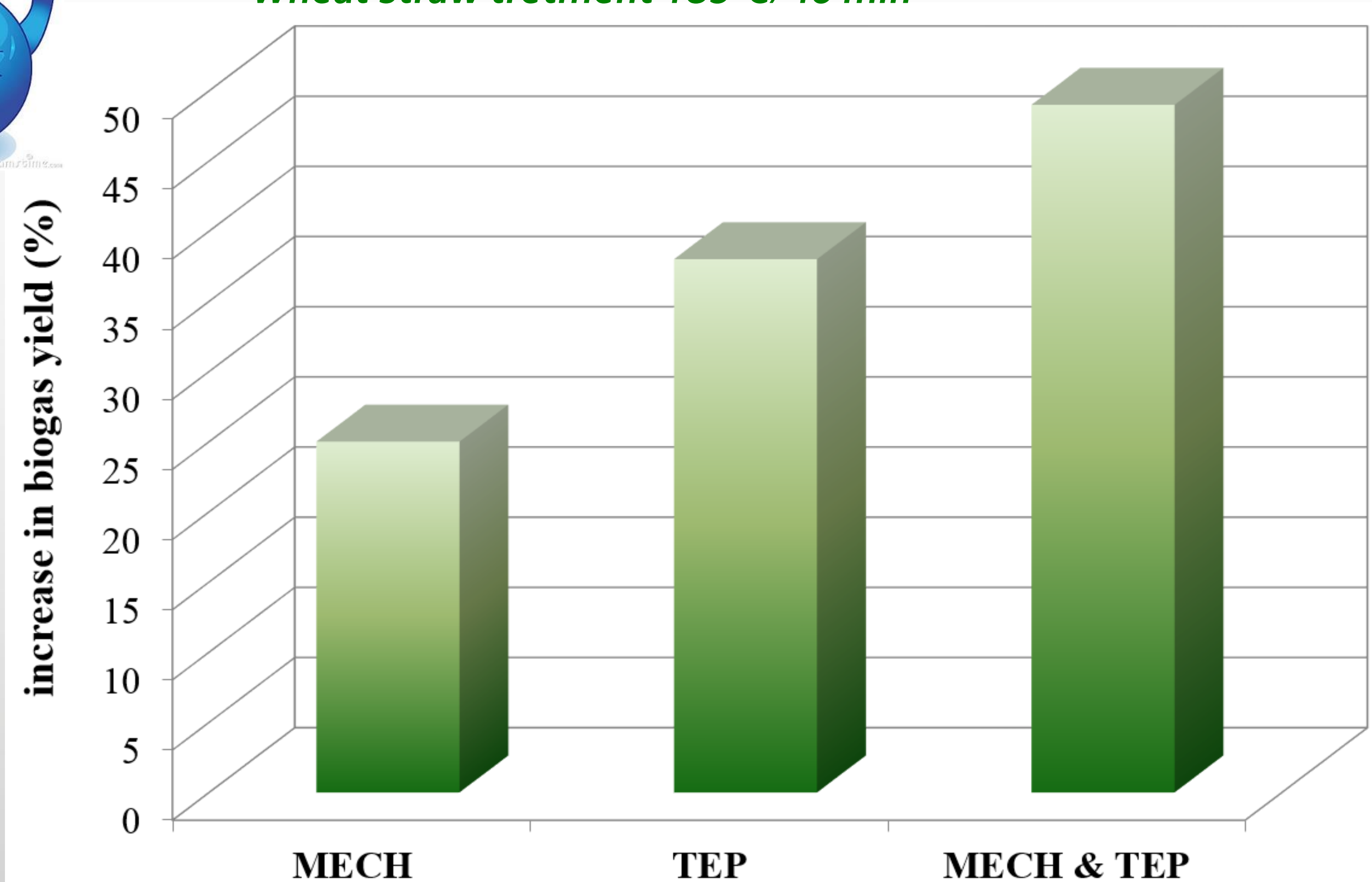
HYDROTHERMAL PRETREATMENT

THERMAL-EXPANSIONARY PRETREATMENT

Wheat straw tretment 185°C/40 min



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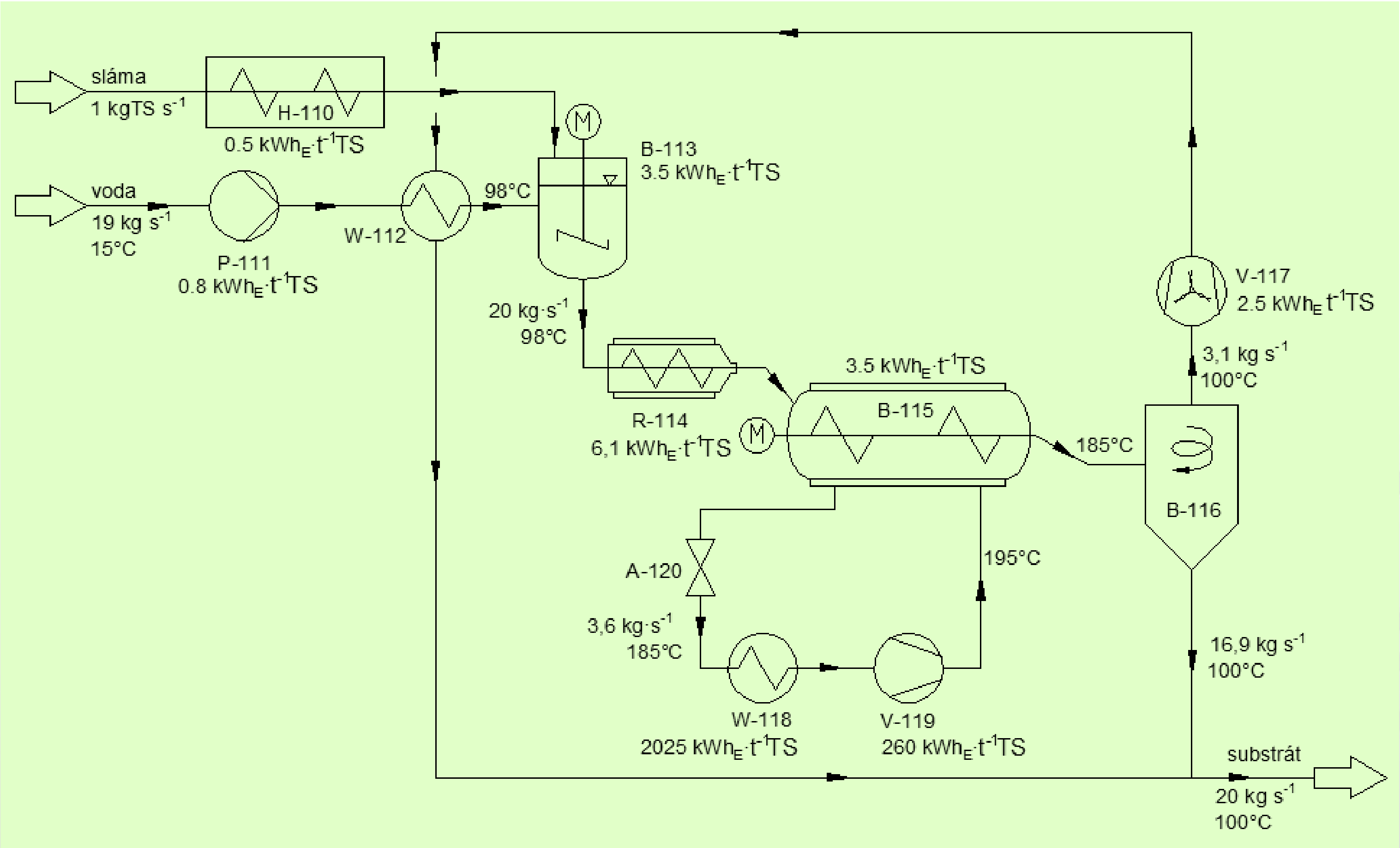
HYDROTHERMAL PRETREATMENT

-> batch 5 % wt. of biomass, 185°C, 40 min



- ➢ **energy not self sufficient proces -> need of external heat source**
- ➢ **energy balance can be improved by heat regeneration in complex technology**

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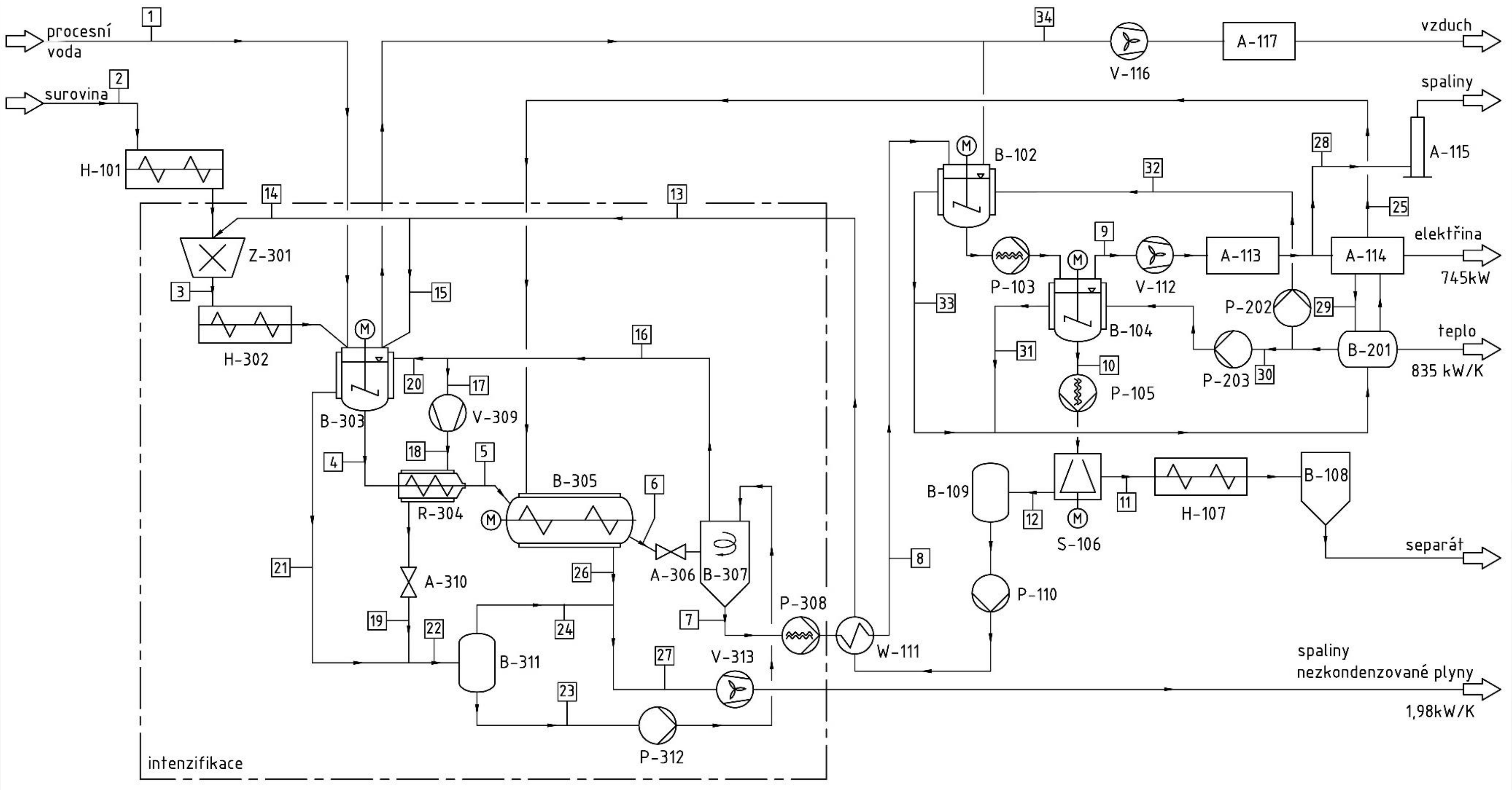
INTENSIFIED BIOGAS PLANT



A CASE TECHNO-ECONOMIC STUDY

INTENSIFIED BIOGAS PLANT

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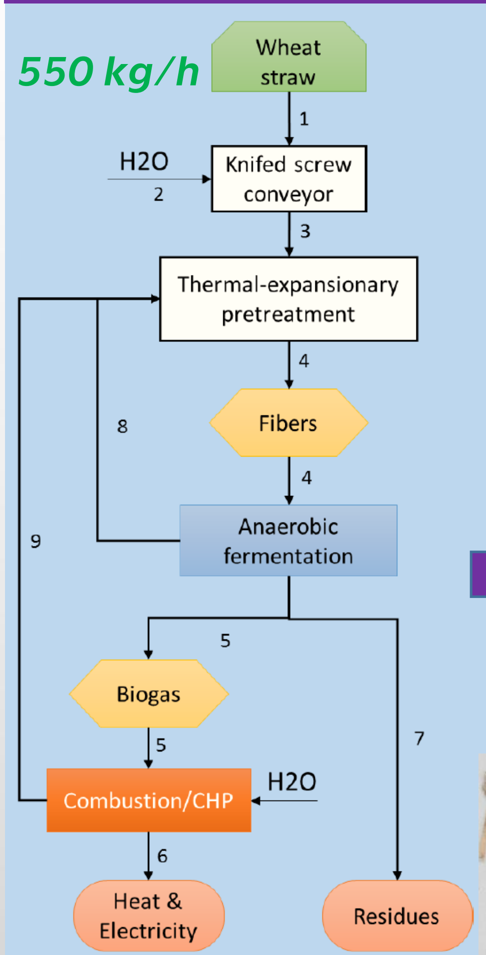
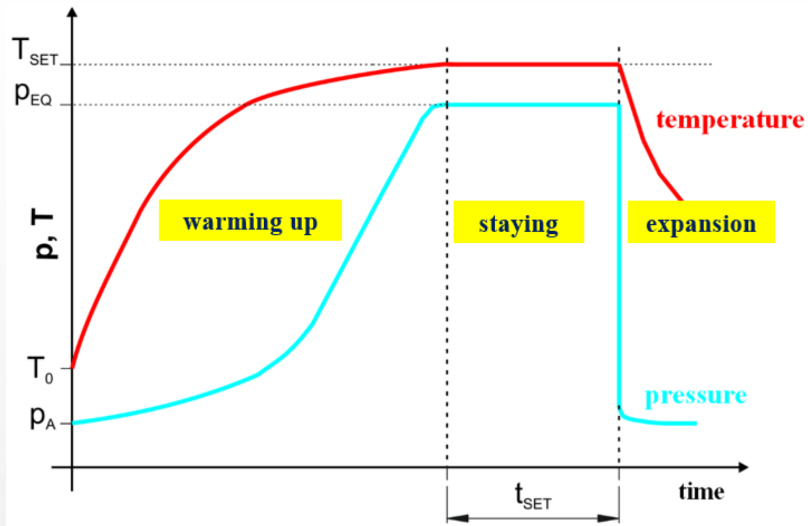
1ST CONCEPTION





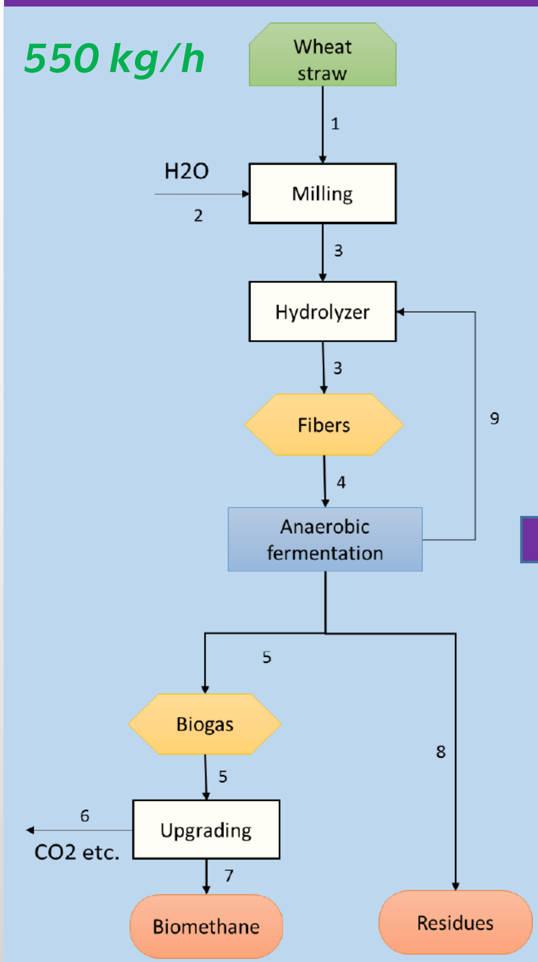
THERMAL EXPANSIONARY PRETREATMENT

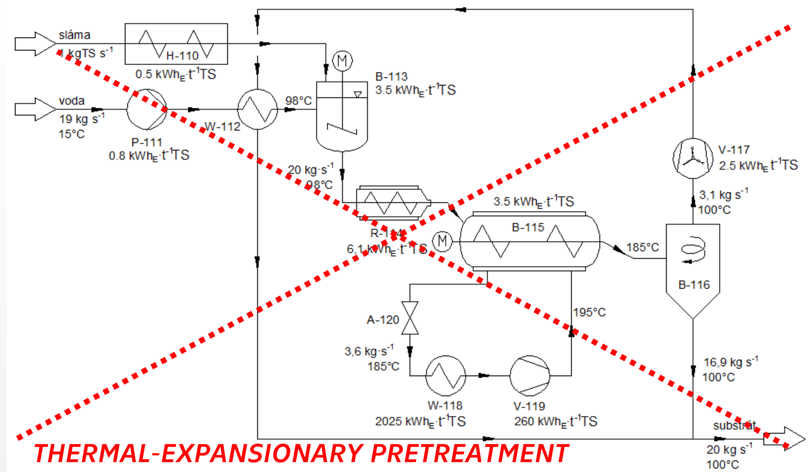
INCREASE IN BIOMETHANE UP TO 50 %

ISBL Capital Cost [$MM year^{-1}]	3.816
OSBL Capital Cost [$MM year^{-1}]	1.562
Engineering Cost [$MM year^{-1}]	1.068
Contingency [$MM year^{-1}]	0.534
Total Fixed Capital Cost [$MM year^{-1}]	**6.945**
Variable Cost of Production [$MM year^{-1}]	0.10
Fixed Cost of Production [$MM year^{-1}]	0.70
Cash Cost of Production [$MM year^{-1}]	**0.80**
Gross Profit [$MM year^{-1}]	0.20
Total Annual Capital Charge [$MM year^{-1}]	1.44
Total Cost of Production [$MM year^{-1}]	2.24
Pay-back period [year]	**30**

INTENSIFIED BIOGAS PLANT

2ND CONCEPTION





MECHANICAL SIZE REDUCTION INCREASES BIOMETHANE YIELD UP TO 40 %

ISBL Capital Cost [\$MM year^{-1}]	2.59
OSBL Capital Cost [\$MM year^{-1}]	1.04
Engineering Cost [\$MM year^{-1}]	0.72
Contingency [\$MM year^{-1}]	0.36
Total Fixed Capital Cost [\$MM year^{-1}]	**4.71**
Variable Cost of Production [\$MM year^{-1}]	0.16
Fixed Cost of Production [\$MM year^{-1}]	0.53
Cash Cost of Production [\$MM year^{-1}]	**0.69**
Gross Profit [\$MM year^{-1}]	0.18
Total Annual Capital Charge [\$MM year^{-1}]	0.98
Total Cost of Production [\$MM year^{-1}]	1.66
Pay-back period [year]	**25**

DEMAND TO PRETREATMENT

DEMAND TO TECHNOLOGY

- HIGH CONVERSION EFFICIENCY
- EASY PROCESS, *NO OR SIMPLE PRETREATMENT*
- NO DEGRADATION OF PRODUCTS
- MINIMUM WASTE GENERATION
- MINIMUM ENERGY DEMAND
- HEAT RECOVERY SYSTEM
- MINIMUM USAGE OF CHEMICALS

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DEMAND TO PRETREATMENT

DEMAND TO MACHINES AND APPARATUSSES

- EASY CONTROL, SERVICE AND MAINTENANCE
- CORROSION RESISTANCE
- MINIMUM OF EXPENSIVE MATERIALS AND SPECIAL PARTS
- COMPROMISE – WORKING VOLUME TO PRICE OF EQUIPMENT
- LOW FINANCIAL DEMAND IN INVESTMENT AND OPERATION

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PROCESS ENGINEERING

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