TECHNOLOGIES FOR EFFICIENT CONVERSION OF BIOMASS TO HEAT AND POWER

A BIOMASS BOILER MANUFACTURER'S PERSPECTIVE

BY LARS JUSTSEN, CSO

JUSTSEN®
Since 1959

World Bioenergy Association, June 2023
www.justsen.dk

AGENDA

- ABOUT US
  - KEY FACTS
  - MISSION STATEMENT
  - ENVIROMENT AND CORPORATE SOCIAL RESPONSIBILITY
  - MEMBERSHIPS AND INDUSTRY NETWORKS
- SOLUTIONS
  - DESIGN FUEL AND TECHNOLOGY APPLICATIONS
  - BOILER TYPES
  - BOILER SYSTEM COMPONENT - WATER-COOLED GRATES
  - RESEARCH AND DEVELOPMENT - MAIN INNOVATIONS
- AGRICULTURAL RESIDUES
  - KEY CHARACTERISTICS
  - CHALLENGES
  - SOLUTIONS
- SIMPLIFIED STEAM RANKINE CYCLE
- WATER / STEAM - MOLLIER DIAGRAM
- PERMISSIBLE INLET STEAM CONDITIONS (EXAMPLE)
- WATER INJECTION
- STEAM RANKINE CYCLE CALCULATION (EXAMPLE)
- CHP - SUPERHEATED BOILER DRAWING (EXAMPLE)
- CHP - LATVIA, RIGA ENERGIJA
- CHP - SLOVAKIA, TERMONOVA
- CONTACT DETAILS

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About us

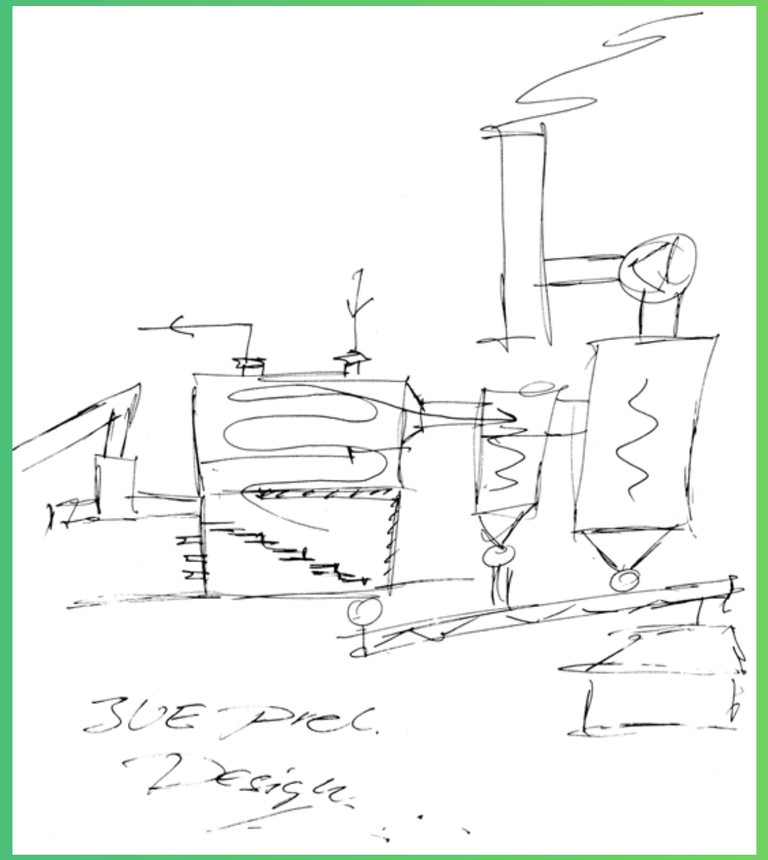
Key Facts

- Original equipment manufacturer (OEM) based in Denmark
- Designing and manufacturing advanced boiler systems for all types of biomass
- All heat transmission media (including superheated steam for CHP)
- Steam boiler output range 0.5 t/h to 50 t/h
- Hot water boiler output range 0.3 MW to 20 MW
- Key system element - Justsen water-cooled grates
- Over 60 years of experience (since 1959)
- Delivered around 3,000 boiler units
- Own electrical engineering division ‘’Justsen Elektro’’
- Three subsidiaries: Justsen Pacific Ltd. (Australia), Justsen Eesti OÜ (Estonia) and Euro Therm 2019 A/S (Denmark)

About us

Mission Statement

- Our **vision** is to be a highly specialized world leader in heating technology and maximum energy utilization from biomass.
- Our **mission** is to provide customized solutions of advanced biomass plants which last longer, require a minimum of maintenance, and offer a faster return on investment for our customers.
- Our core **values** are: environmental awareness, continuous development and innovation, loyalty and efficiency.



About us

Environment and Corporate Social Responsibility

We recognize that managing environmental impact is an integral part of our business activities. The **key principles** to guide our work activities:

- to comply with the relevant environmental legislation
- to identify and manage our significant environmental impacts
- to take action to prevent pollution, which may occur as a result of our operations
- to use renewable energy in our business activities and encourage our suppliers to do so too
- to monitor environmental performance and set new targets

We use renewable heat and power in the headquarters and production facility in Brabrand.

The company's website is made CO_2 neutral to neutralize the carbon emissions from both the website and the users of the website.

CO_2 neutral website ▸

About us

Memberships and Industry Networks

Justsen has joined several networks to actively participate and contribute to the bioenergy sector:

- Word Bioenergy Association
- Energy Supply DK
- State of Green Denmark
- AcuComm (Business Intelligence)

Solutions

Design Fuel and Technology Applications

Fuel Types:

- Wood based biomass
- Agricultural biomass (e.g., straw)
- Waste wood and treated wood (Grade A-D, RDF)
- Various – peat, spent coffee grounds and biomass mix with sludge/waste from coconut industry and African palm

Applications:

- District heating and heat & power
- Process industries (textile, food, furniture etc.)
- Woodworking industries and sawmills
- Agriculture and farming (greenhouses, poultry)
- Housing estates

Solutions

Boiler Types

HOT WATER
0.3 MW – 20 MW

STEAM (Saturated)
0.5 t/h – 50 t/h

CHP
Super-heated Steam

ORC
Organic Rankine Cycle

WID/ IED
Renew-ables

JUE-FVB
≤ 15 MW

JUE-GVB
≤ 20 MW

JUE-HHF
≤ 10 MW

JUE-VHS
≤ 8 MW

JUE-MMV
≤ 5 MW

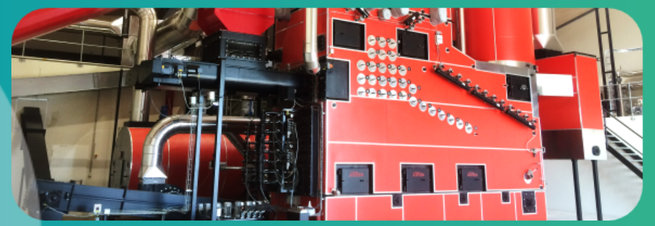
ARGUS

JUE-JWB-8.0
R&D

JUE-TDC-F
≤ 50 t/h

JUE-DHF
≤ 16 t/h

JUE-MMD
≤ 8 t/h



FLEX
≤ 5.4 MW

VERTICAL
≤ 5 MW

Solutions

Boiler System Component: Water-cooled Grates

- Low maintenance costs
- Minimizing radiation loss
- Self cleaning grate
- Controlled combustion and minimized emissions
- Quick reaction to changes in fuel load
- Handling large range of biofuels with varying calorific values
- Very long life expectancy
- Easy replacement of worn out grate bars

Solutions

Reseach and Development: Main Innovations

1970
The first wood chip boiler plant exported to Norway

2010
The first combined heat and power (CHP)

2012
ARGUS Flex Boiler line developed

2016
Bag Filters developed

2016
ARGUS Vertical Boiler line developed

2019/20
WtE (waste-to-energy) concept boilers developed

2020/21
JUE-JWB-8.0 high pressure hot water boiler

Agricultural Residues - Characteristics

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Justsen Energiteknik A/S

Lars Justsen, CSO

WBA Webinar: *Agricultural residues as key ingredient for a bioenergy future – Latest technological developments*

December 9, 2020

From WBA Webinar December 9, 2020

Examples of Agricultural Residues: Some Key Characteristics

Fuel Type:	Coniferous and broad-leaf wood (for comparative purposes)	Straw from wheat, rye, barley	Crude olive cake	Rice husk
Gross calorific value:	18.0 – 22.7 MJ/kg dry	16.6 – 20.1 MJ/kg dry	19.4 – 21.4 MJ/kg dry	14.7 – 16.6 MJ/kg dry
Water:	8 – 60% as received	8 – 25% as received	20-50% as received	5-25% as received
Ash:	0.1 – 1.0% dry	2 – 10% dry	approx. 10% dry	13 – 23% dry
Net calorific value:	5.73 – 20.7 MJ/kg as received	11.8 – 18.3 MJ/kg as received	8.48 – 16.6 MJ/kg as received	10.4 – 15.7 MJ/kg as received
Carbon (C):	47 – 54% dry	41 – 50% dry	approx. 50% dry	38 – 43% dry
Hydrogen (H):	5.6 – 7.0% dry	5.4 – 6.5% dry	approx. 6.9% dry	4.3 – 5.1% dry
Oxygen (O):	40 – 45% dry	36 – 45% dry	approx. 30% dry	35 – 47% dry
Sulphur (S):	0.01 – 0.05% dry	0.05 – 0.20% dry	approx. 0.20% dry	0.02 – 0.10% dry
Nitrogen (N):	0.1 – 0.5% dry	0.2 – 1.5% dry	approx. 1.5% dry	0.1 – 0.8% dry
Chlorine (Cl):	0.01 – 0.03% dry	0.1 – 1.2% dry	approx. 0.2% dry	0.03 – 0.3% dry
Potassium (K):	0.02 – 0.15% dry	0.2 – 2.6% dry	0.6 – 1.6% dry	0.28 – 0.43% dry
Ash shrinkage starting temperature (SST):	approx. 1,140 °C	approx. 860 °C	Low (limited data)	Low (limited data)
Physical properties:	Chips, strips, sawdust, etc.	Bales (Hesston, mini big, etc.)	Sticky	Low density, high silica content

Source: ISO 17225-1:2014(E) except for water content, ash melting behavior and physical properties.

Agricultural Residues - Challenges

Examples of Agricultural Residues: Challenges

Fuel Type:	Coniferous and broad-leaf wood (for comparative purposes)	Straw from wheat, rye, barley	Crude olive cake	Rice husk
Water:	Large range to cover for combustion chamber & low temperature corrosion			
Ash:				Large quantities to handle
Oxygen (O):			Low volatility ⇨ long burn out time on grate	
Sulphur (S):		SO_X emissions & corrosion issues		
Nitrogen (N):		NO_X and N_2O emissions		
Chlorine (Cl):		HCl and Dioxin emissions & corrosion issues		
Potassium (K):		Lowering of ash melting temperatures (K_2O) ⇨ fouling		
Ash shrinkage starting temperature (SST):		Slagging and clinkering on grate & fouling		
Physical properties:		De-baling into uniform fuel	Build-up in conveyors	Abrasive fly ash

Source: ISO 17225-1:2014(E) except for water content, ash melting behavior and physical properties.

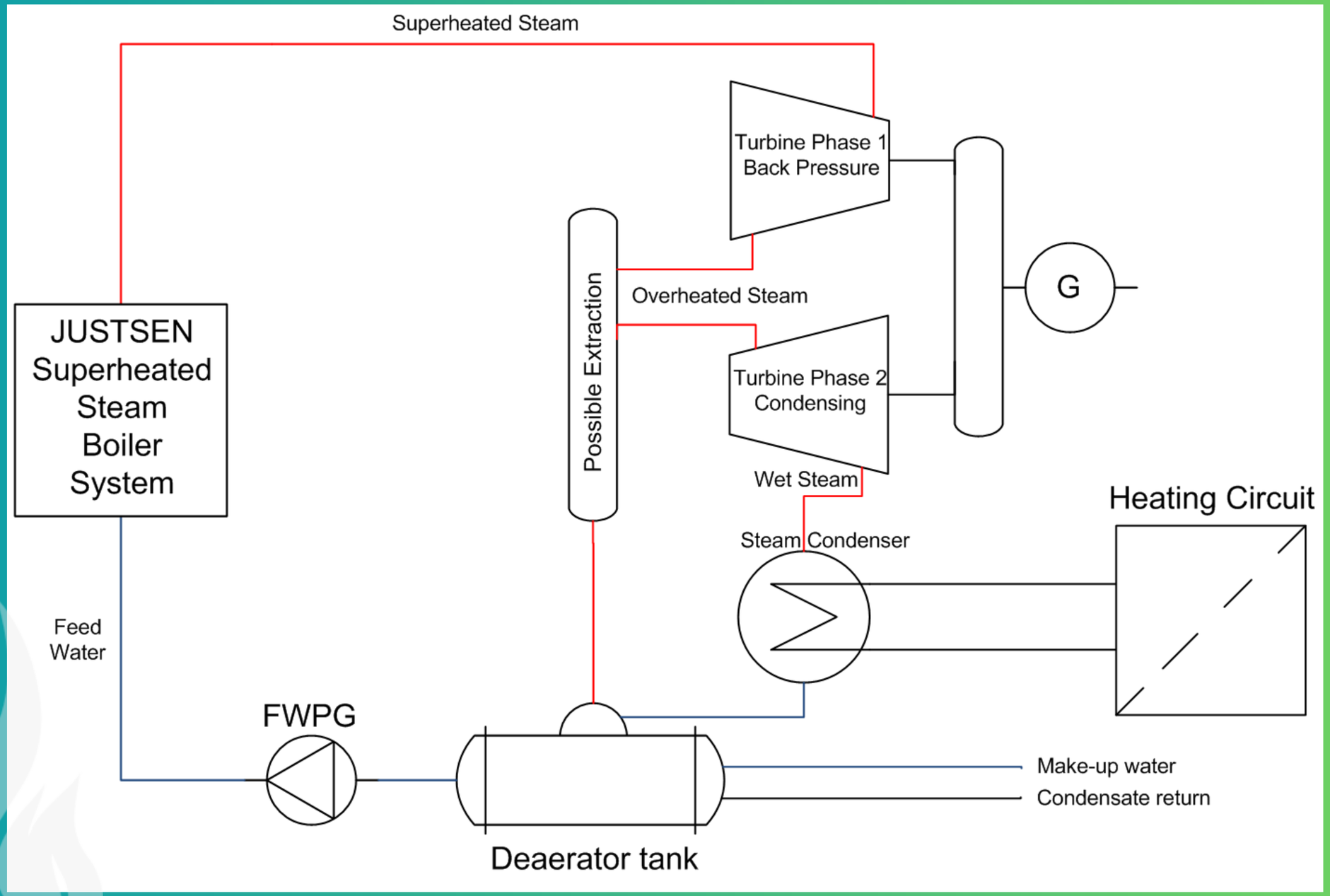
Agricultural Residues - Solutions

Examples of Agricultural Residues: Solutions

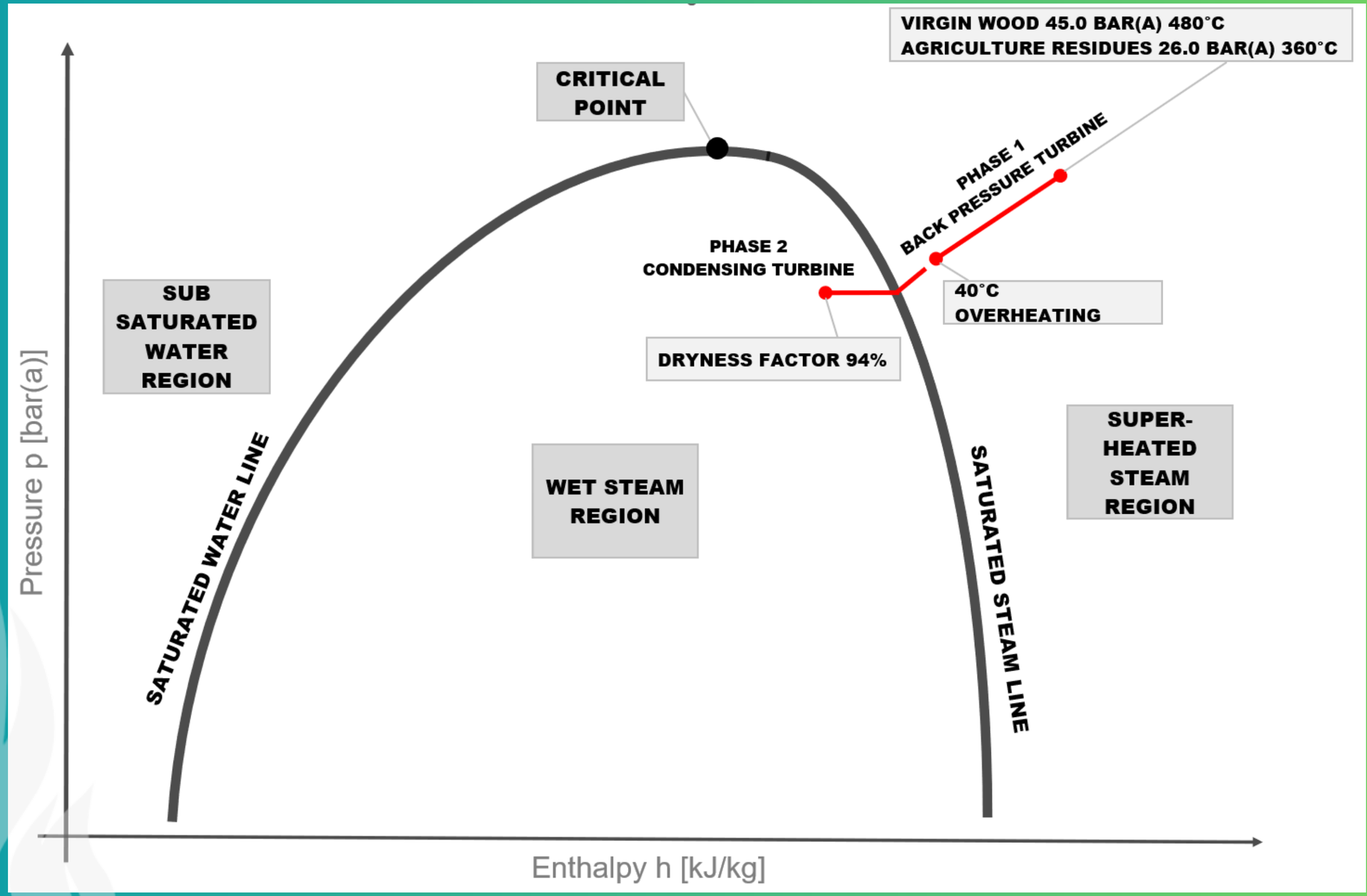
Fuel Type:	Coniferous and broad-leaf wood (for comparative purposes)	Straw from wheat, rye, barley	Crude olive cake	Rice husk
Water:	Varying flue gas recirculation (cooling) and combustion air pre-heating			
Ash:				Adequately sized ash handling in Hardox steel
Oxygen (O):			High length to width grate ratio	
Sulphur (S):		Emissions: lime injection Corrosion: adequately high water side temperatures and high grade steel		
Nitrogen (N):		Good boiler design, extreme staging of combustion air & Selective Non-Catalytic/Catalytic Reduction Systems		
Chlorine (Cl):		Good boiler design without “shelves” (Dioxin prevention)		
Potassium (K):		Large combustion chambers lowering flue gas temperatures before first boiler tube pass		
Ash shrinkage starting temperature (SST):		Water cooling of grate system and high pressure drop over grate		
Physical properties:		Good design	Good design	Easily replaceable wear and tear inserts

Source: ISO 17225-1:2014(E) except for water content, ash melting behavior and physical properties.

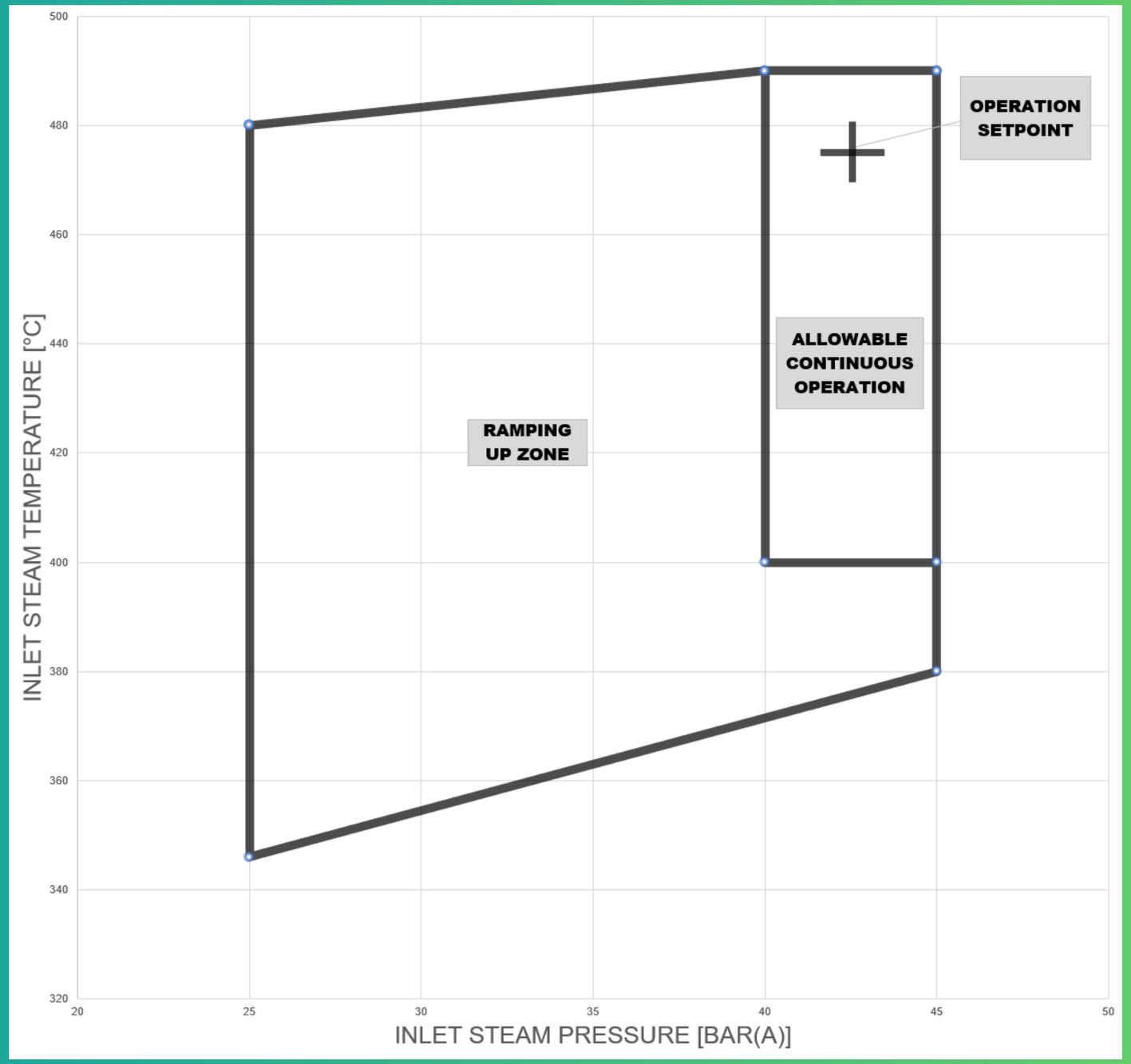
Simplified Steam Rankine Cycle



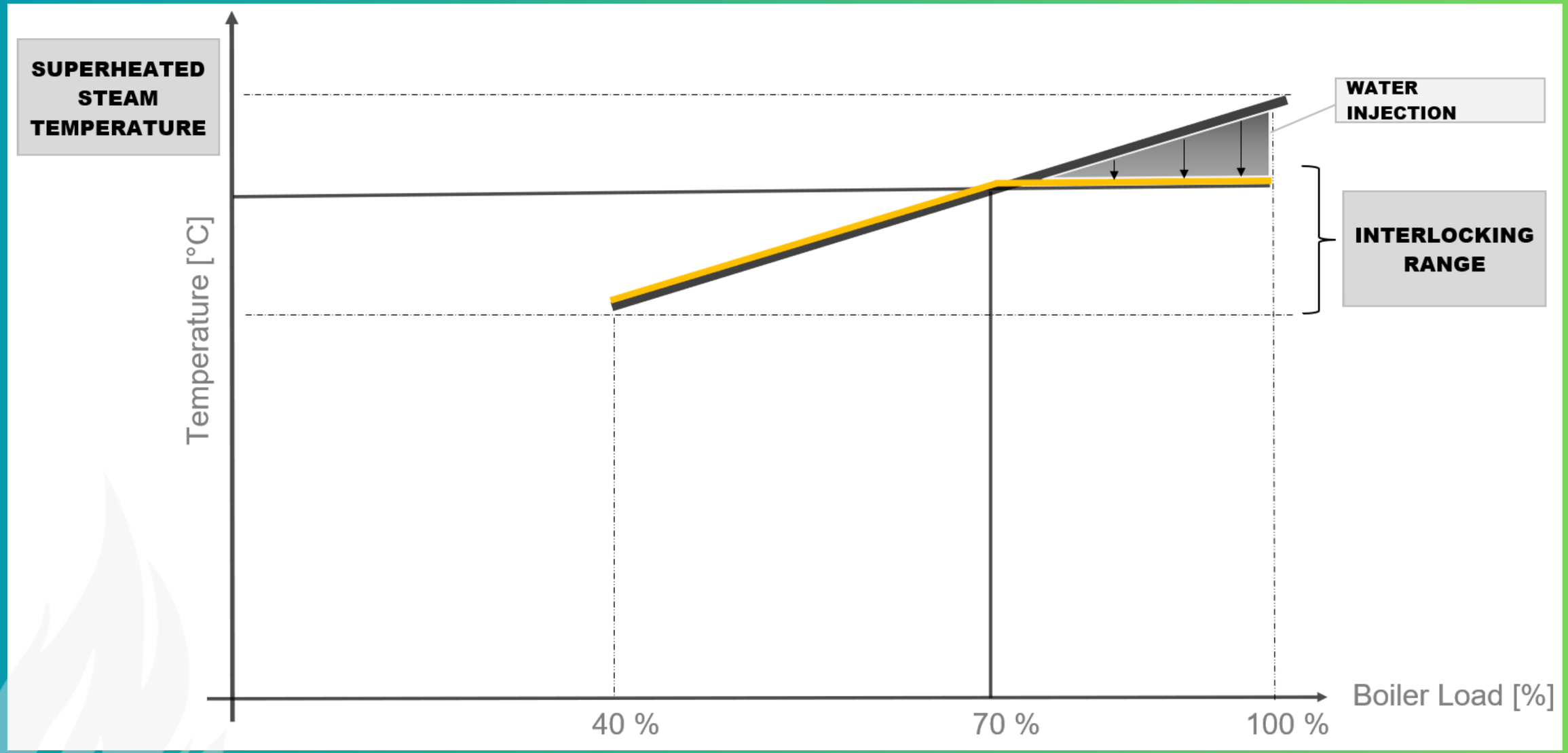
Water / Steam - Mollier Diagram



Permissible inlet steam conditions (example)



Water Injection



Steam Rankine Cycle Calculations (example)

Txxxx XX - Preliminary Steam Rankine Cycle Calculations

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Lars Justsen

04.10.2022

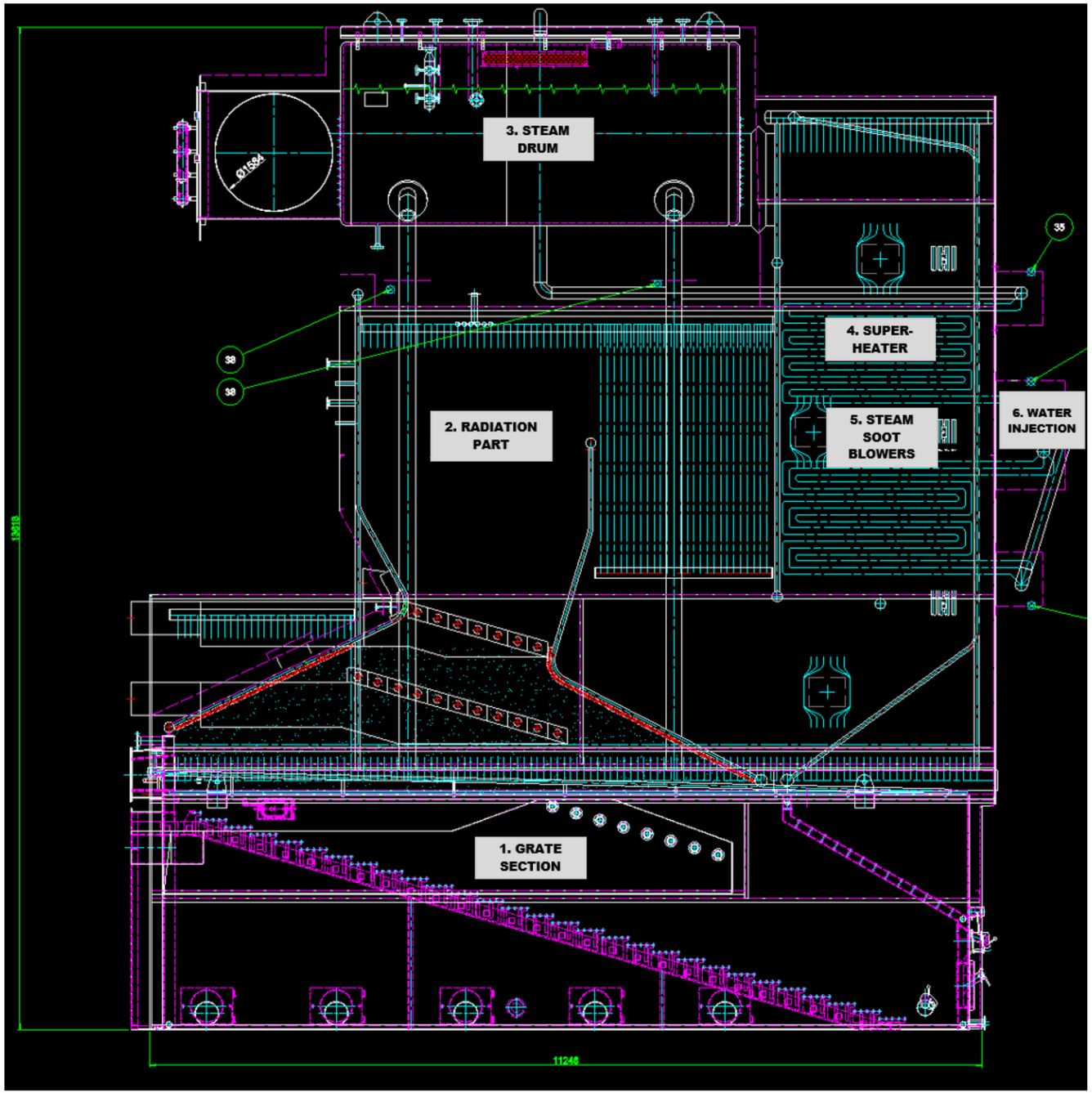
	Turbine stage 1 (back pressure)					Turbine stage 2 (condensing)					Delta over stage 1+2		
	INLET TURBINE		OUTLET TURBINE		Delta over turbine	INLET TURBINE		OUTLET TURBINE		Delta over turbine			
Boiler output	20000	kg/h	20000	kg/h		19000	kg/h	19000	kg/h				
Specific enthalpy, steam	3332,04	kJ/kg	2818,10	kJ/kg		2818,71	kJ/kg	2548,33	kJ/kg				
equal to	0,925564	kWh/kg	0,782803	kWh/kg		0,782973	kWh/kg	0,707867	kWh/kg				
Steam capacity, total	18.511	kW	15.656	kW	**2.855 kW**	14.876	kW	13.449	kW	**1.427 kW**	**11,4%**	**4.282 kW**	**26,7%**
Feed water temperature	105,0	°C				105	°C						
Specific enthalpy, water	442,560	kJ/kg				440,215	kJ/kg						
equal to	0,122933	kWh/kg				0,122282	kWh/kg						
Water capacity, feed water	2.459	kW				2.323	kW						
Boiler capacity	**16.053**	**kW**				**12.553**	**kW**						
								Dryness: 94,0%					
Working pressure	39,0	bar(a)	4,0	bar(a)		3,9	bar(a)	1,210	bar(a)				
Saturation temperature	248,9	°C	143,6	°C		142,7	°C	105,0	°C				
Superheated temperature	450,0	°C	180,0	°C		180,0	°C	105,0	°C				
Degrees superheating	201,1	°C	36,4	°C		37,3	°C	0,0	°C				

Estimated refrigeration turbine 1+2	150 kW^e	0,9%
Estimated refrigeration generator	80 kW^e	0,5%
Estimated power to terminals	4.052 kW^e	25,2%
Hot water (condenser cooling)	11.770 kW^{th}	73,3%
Forward flow temperature	90 °C	
Return flow temperature	70 °C	

Combined Heat and Power (CHP) Biomass Boiler (example)

MAIN BOILER COMPONENTS

1. WATER-COOLED GRATE SYSTEM
2. RADIATION PART
3. STEAM DRUM
4. SUPERHEATER
5. STEAM SOOT BLOWERS
6. WATER INJECTION



Combined Heat and Power (CHP) Biomass Boiler (Riga -Latvia)

JUSTSEN® Since 1959

24.0 MW Boiler Output // 4.0 MWe Output

Combined Heat and Power (CHP) Plant -Slovakia

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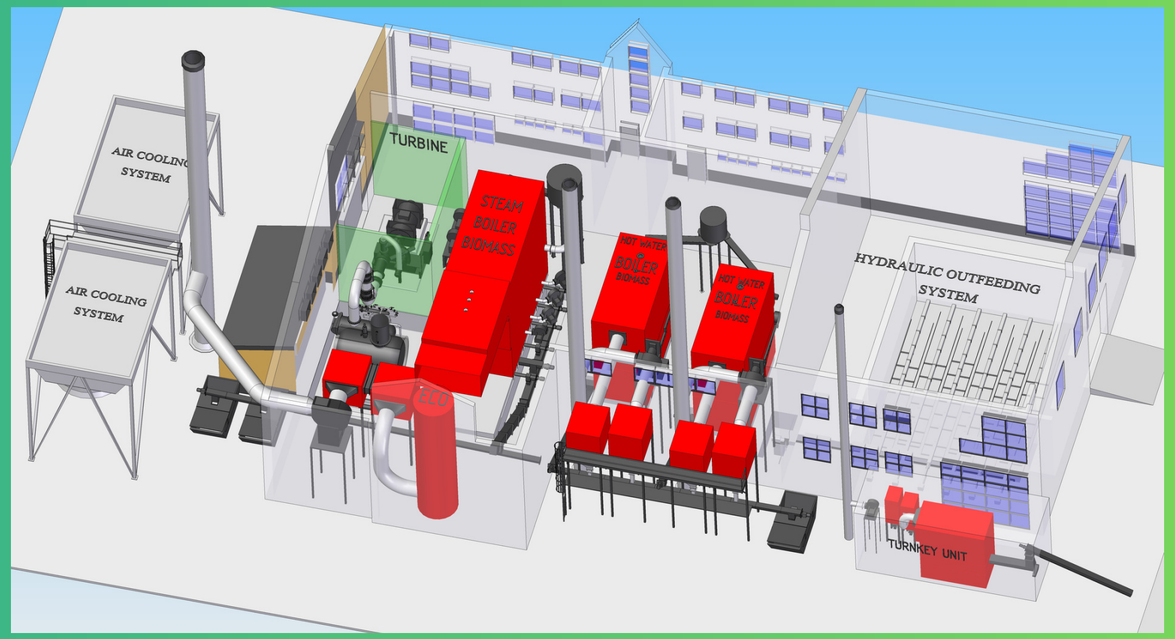

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Thank You

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