Usage of GP750 Gasifier for Combined Heat and Power Production.

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Application of the GP750 Gasifier for Combined Heat and Power Production

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Biomass to Power and Heat

May 31 and June 01, 2017 in Zittau

GP750 gasifier for CHP and biochar production

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Efficiency of electricity generation by various processes

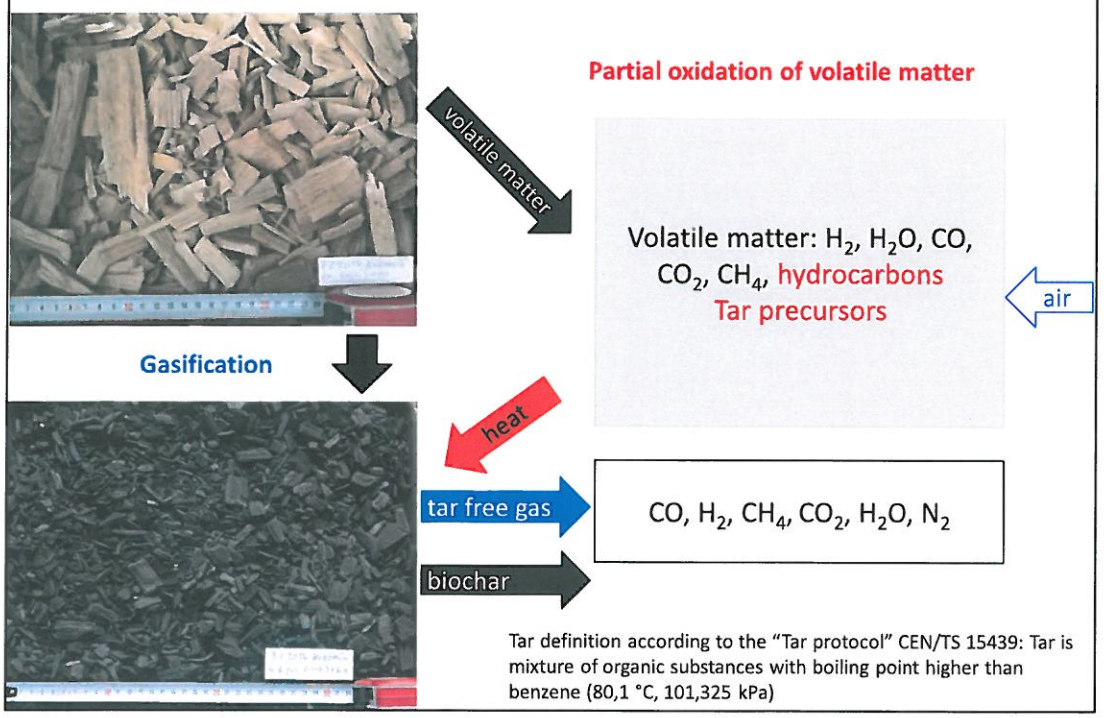
$$\eta_{tot} = \eta_{CE} * \eta_{CU}$$

η_{CE} - cold gas efficiency which takes into account only the chemical energy of a gas

Type of power generation	Cold gas efficiency η_{CE}, %	Gas to electricity efficiency, η_{cu}, %	Overall el. efficiency $\eta_{t^{-}}$, %	Inst. costs thousands EUR/kW_e
1. Thermal plant with steam turbine (11 MW_e) (Zelený kotel, 33 MW_t), Plzeň	-	-	27,6	3,0
2. Thermal power station (35 MW_e) (Biomass combustion, 105 MW_t), Hodonín	-	-	~ 33	-
3. Two-stage gasifier prototype GP200 (0,2 MW_e) TARPO spol. s r.o., 2011	80–90	~ 32	~ 28*	3,3
4. Two-stage gasifier GP 750 (0,75 MW_e) TARPO spol. s r.o., AIR TECHNIC s.r.o., 2014	80–90	~ 36	~ 32**	3,7
5. Gasifier coupled with SOFC	~ 95	~ 45-65	~ 40-60	Very high

* Modified diesel engine: 6S160 ČKD Hořovice
** Jenbacher AB, J316 GC (J320GC)

Principle of staged biomass gasification



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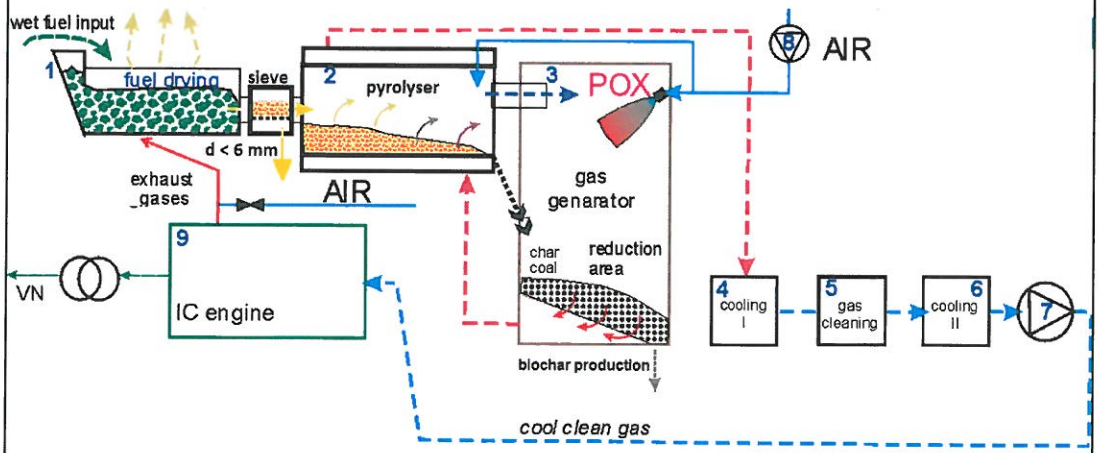
Installations of two-stage gasifiers

Locality	Engine type	Year of start-up Generator type	Installed power output	Current state
Kozomín	Jenbacher, 3xJ320	07/2014 5xGP750	2,1 MWe (3x710 kWe) 4,2 MW_t (gas)	Pilot operation of five GP750 units
Handlová	Guascor, FBLD560, FBLD480	06/2014 2xGP750	570 kW_e 430 kW_e	Operating from 4/2015
Dobříš	Guascor, FBLD560	1xGP750	630 kWe	Experimental unit
Kněževes	ČKD, 2x6S160	2011- 2013 GP200	2x100 kW_e	2014 Replaced by pyrolysis unit
Odry	Jenbacher, 2xJ316	Since 2012 2xGP500	2x400KW_e	Operating at lower output: 2x400 kW_e
Olešnice	ČKD, 2x6S160	2013 GP200 03/2015 GP200XL	2x100 kW_e	Transformed to twin-fire

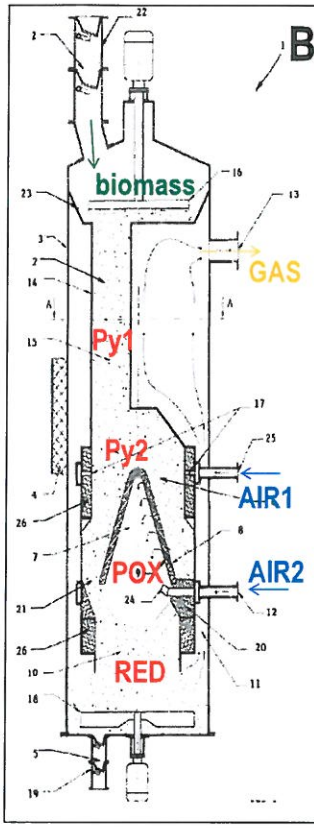
Principal scheme of the GP750 gasifier



Main parameters of GP750 unit used in Kozomín:

Nominal electric power	**710 kW**
Nominal wooden chips consumption (dry)	550 $kg \cdot h^{-1}$.
Chips dimension	6 to 50 mm
Biomass moisture (dryer input)	up to 60 wt. %
Overall efficiency (calculated from LHV)	**32 %**
Nominal fuel (dry) consumption	**0,7 $kg \cdot kWh^{-1}$**
Nominal electric output	**1,4 $kWh \cdot kg^{-1}$**

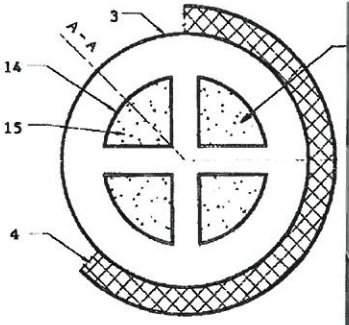
Basic description of GP750 gasifier



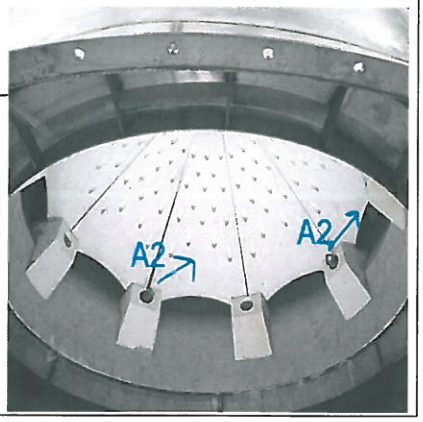
Gasifier	Dimensions of POX chamber		Volume	Flow*	Residence time*
	D,m	H,m	m^3	m^3/h	s
GP750	2,5	2,3	~4,0	~1300	~10

* Standard temperature and pressure

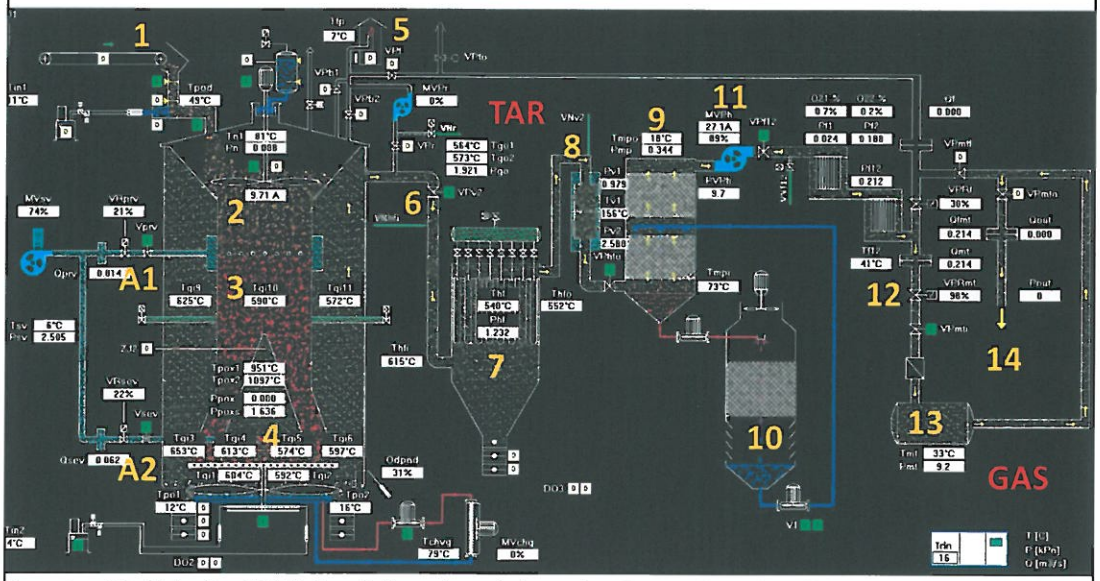
Pyrolysis zone



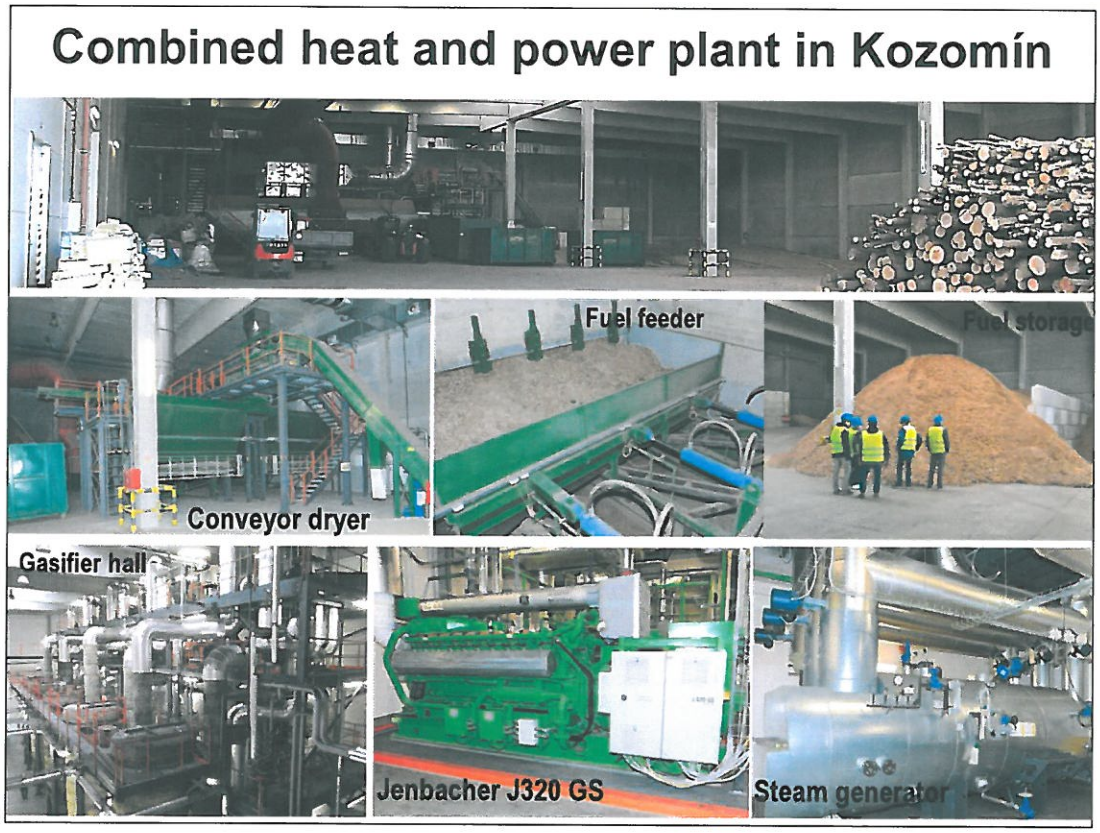
POX chamber



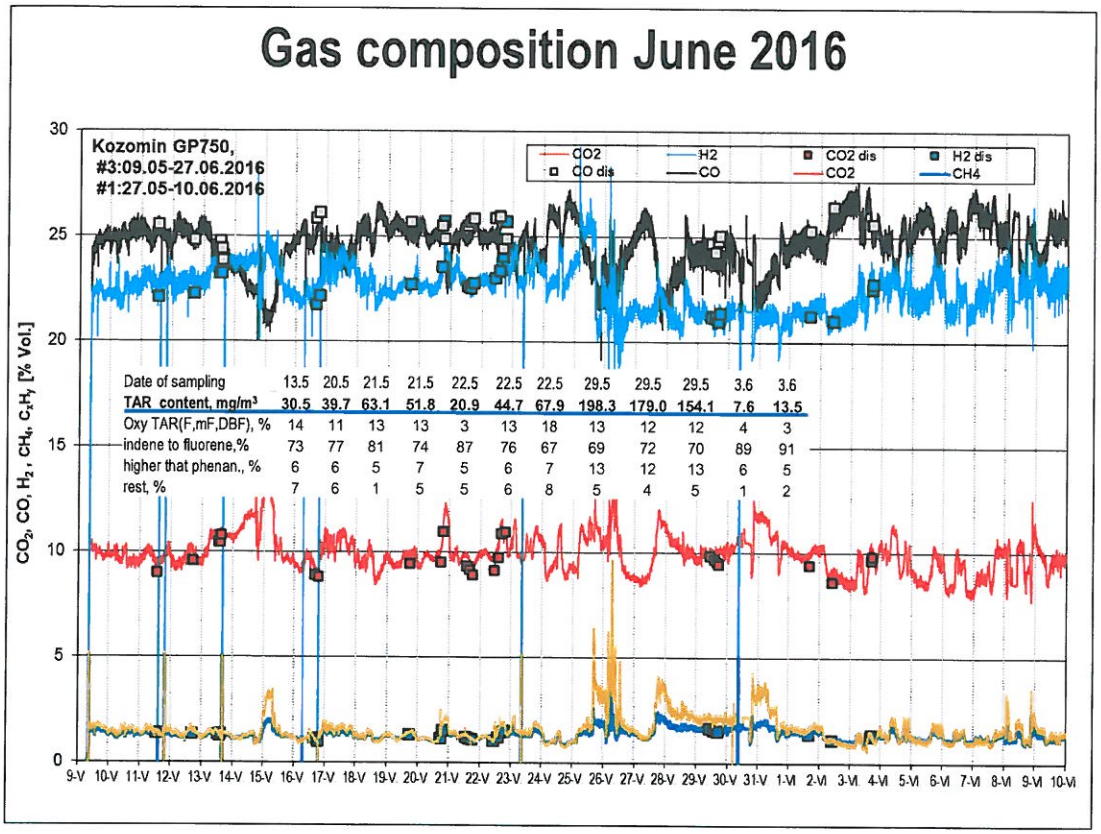
Technological flow sheet of gasification unit

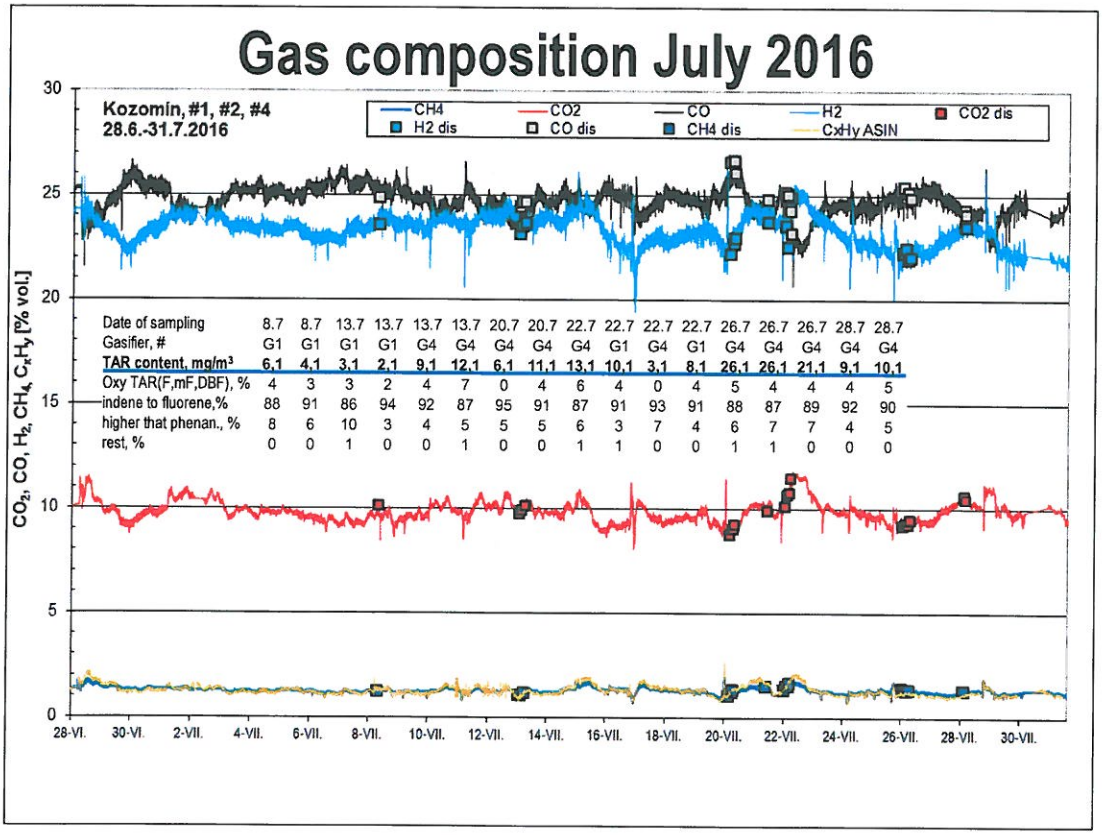


1 - entry of fuel into the GP750, 2 - allothermal pyrolysis section, 3 - autothermal pyrolysis section, 4 - POX section, 5 - combustion flare, 6 - gas output, 7 - bag filter, 8 - heat exchangers (gas/water), 9 - contact water cooling, 10 - cooling tower, 11 - gas blower, 12 - gas flow measurement , 13 - mix tank, 14 - pipe to IC motor.
A1-primary air inlet, A2- secondary air supply
GAS - point for gas quality sampling (on-line, off-line), TAR - point for gas sampling according to Tar Protocol


Combined heat and power plant in Kozomín
Conveyor dryer
Fuel feeder
Fuel storage
Gasifier hall
Jenbacher J320 GS
Steam generator


GP750 #5
HF
#5
#4
#3
#2
#1
Hall with gasifiers


Gas composition June 2016
Kozomin GP750,
#3:09.05-27.06.2016
#1:27.05-10.06.2016
CO2
CO dis
H2
CO
CO2 dis
CO2
H2 dis
CH4
Date of sampling 13.5 20.5 21.5 21.5 22.5 22.5 22.5 29.5 29.5 29.5 3.6 3.6
TAR content, mg/m³ 30.5 39.7 63.1 51.8 20.9 44.7 67.9 198.3 179.0 154.1 7.6 13.5
Oxy TAR(F,mF,DBF), % 14 11 13 13 3 13 18 13 12 12 4 3
indene to fluorene,% 73 77 81 74 87 76 67 69 72 70 89 91
higher that phenan., % 6 6 5 7 5 6 7 13 12 13 6 5
rest, % 7 6 1 5 5 6 8 5 4 5 1 2
CO2, CO, H2, CH4, CxHy [% Vol.]
9-V 10-V 11-V 12-V 13-V 14-V 15-V 16-V 17-V 18-V 19-V 20-V 21-V 22-V 23-V 24-V 25-V 26-V 27-V 28-V 29-V 30-V 31-V 1-VI 2-VI 3-VI 4-VI 5-VI 6-VI 7-VI 8-VI 9-VI 10-VI


Gas composition July 2016
Kozomin, #1, #2, #4
28.6.-31.7.2016
CH4
H2 dis
CO2
CO dis
CO
CH4 dis
H2
CxHy ASIN
CO2 dis
Date of sampling 8.7 8.7 13.7 13.7 13.7 13.7 20.7 20.7 22.7 22.7 22.7 22.7 26.7 26.7 26.7 28.7 28.7
Gasifier, # G1 G1 G1 G1 G4 G4 G4 G4 G4 G1 G4 G1 G4 G4 G4 G4 G4
TAR content, mg/m³ 6,1 4,1 3,1 2,1 9,1 12,1 6,1 11,1 13,1 10,1 3,1 8,1 26,1 26,1 21,1 9,1 10,1
Oxy TAR(F,mF,DBF), % 4 3 3 2 4 7 0 4 6 4 0 4 5 4 4 4 5
indene to fluorene,% 88 91 86 94 92 87 95 91 87 91 93 91 88 87 89 92 90
higher that phenan., % 8 6 10 3 4 5 5 5 6 3 7 4 6 7 7 4 5
rest, % 0 0 1 0 0 1 0 0 1 1 0 0 1 1 0 0 0
CO2, CO, H2, CH4, CxHy [% vol.]
28-VI. 30-VI. 2-VII. 4-VII. 6-VII. 8-VII. 10-VII. 12-VII. 14-VII. 16-VII. 18-VII. 20-VII. 22-VII. 24-VII. 26-VII. 28-VII. 30-VII.

Fuel properties and their effects on generator operation

Proximate and ultimate analysis of selected fuels

fuel properties	Handlová, 2014	Kozomín, 2015	Kozomín*), 2016	Kozomín, 2016
moisture, W^a	5.00	14.00	2.61	2.89
ash, A^d	1.08	2.78	1.03	0.98
volatile matter, V^d	79.75	78.80	78.84	78.21
fixed carbon, F_c^d	19.17	18.42	20.14	20.81
Q_i^a	16.94	14.72	16.71	17.23
Q_i^{daf}	18.16	18.02	17.40	17.99
ultimate analysis, ^{d}				
C	49.58	50.28	48.62	48.40
H	6.30	6.15	5.88	6.08
N	0.50	0.27	0.23	0.19
O	42.52	40.48	44.24	44.34
S	0.02	0.04	0.01	0.01

*)chips stored for long period in the open air

Mass and energy balance during long time operation

	July	August	September	October	November	December
Wet fuel consumption [tons]	1733	1427	1395	1530	1376	1390
Average water content [wt. %]	40,0	38,2	38,5	40,5	41,3	42,7
Dry fuel consumption [tons]	1039	882	858	911	808	796
LHV of wet fuel [MJ·kg^{-1}]	9,7	10,1	10,0	9,7	9,5	9,3
Biochar production [tons]	38,1	45,2	26,4	25,7	29,4	26,2
Biochar yield (compared to dry fuel) [wt. %]	3,7	5,1	3,1	2,8	3,6	3,3
Electric production [MWh]	1427	1309	1244	1327	1063	1083
Dry fuel consumption [kg·kWh^{-1}]	0,728	0,673	0,690	0,687	0,760	0,735
Overall efficiency [%]	**30,6**	**32,9**	**32,1**	**32,4**	**29,3**	**30,3**
Overall efficiency (w/o biochar) [%]	**32,4**	**35,7**	**33,7**	**33,8**	**31,0**	**32,0**

Quality of biochar produced by GP750

	Wooden chips			Biochar		
Related to dry sample	Hardwood	Softwood	Mix	Hardwood	Softwood	Mix
Combustible [wt.]	99,0	99,6	99,2	82,8	83,5	68,0
Ash content [wt.]	1,03	0,379	0,795	17,2	16,5	32,0
Volatile matter [wt.]	82,9	83,5	83,4	4,48	2,95	4,90
Fixed carbon [wt.]	16,1	16,1	15,8	78,3	80,6	63,1
Higher heating value [MJ·kg^{-1}]	19,0	19,2	19,3	27,9	27,3	21,0
Lower heating value [MJ·kg^{-1}]	17,7	17,9	18,0	27,8	27,2	20,9
Specific surface area (S_{BET}) [m^2·g^{-1}]	-	-	-	600	659	401
Specific mesopore area [m^2·g^{-1}]	-	-	-	238	261	-
Volume of micropores [ml·g^{-1}]	-	-	-	188	205	JB8

- Produced biochar does not contain any organic pollutants due to long residence time (several hours) in the high temperature zone (t > 600 °C)
- Textural properties of produced biochar are not dependent on a particle distribution JB5
- Average specific surface area S_{BET} = 600 m^2·g^{-1}
- High volume of micropores assure good water retention abilities
- **All samples of produced biochar fulfil the requireme JB6 of European biochar certificate**

Typical gas composition from downdraft and staged gasifiers

	Downdraft Imbert	GP300	Viking DTU 75 kW_{th}	GP200	GP500	GP750
Biomass moisture, wt.	<10	<10	35-45	<10	<10	<10
CO	25,5	24,6	19,6 JB9	26,7	25,0	25,3
H_2	17,2	16,4	30,5	23,0	22,3	22,7
CH_4	***3,0***	***2,2***	***1,2***	***1,1***	***2,0***	***1,3***
CO_2	9,6	9,6	15,4	8,0	9,5	9,7
N_2	***43,5***	***46,1***	***33,2***	***40,6***	***41,1***	***40,9***
Other	1,2	1,1	0,1	0,6	0,2	0,1
Tar content, mg/m^3	**1000-2000**	**1300-2000**	**<5**	**0,5-2,0**	**5,0-40**	**20-200**
LHV (15 °C) MJ/m^3	6,3	5,7	5,6	5,9	5,9	5,8

Conclusion

- **GP750 gasifier is capable to simultaneously produce gas and biochar**
- Most suitable fuel for realisable operation are wooden chips with size 6–50 mm.
- Gas quality produced by GP750 is suitable for different types of IC engines.
- GP750 produces low tar gas (typically below 50 $mg \cdot m^{-3}$), HHV = 6,5 $MJ \cdot m^{-3}$ (Power production (>32 % Netto).
- Gas treatment consists of: hot candle ceramic filters for particles removal and water scrubber for cooling < 40 °C
- **High biochar quality (500-900 m^2/g)**
- Gas quality and biochar production depends on:
  - fuel properties (size distribution, moisture content, ash content)
  - operating parameters (ratio of primary and secondary air, frequency of grating, temperature in POX chamber).

Thank you for attention

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