PRECEPT 2: FEEDSTOCK CHARACTERIZATION

 # 1

Table 1 reports the dry-basis ultimate (elemental) analyses of ten unconventional fuels (seven types of biomass and three types of waste), and their lower heating value (LHV), moisture content and density. For each feedstock evaluate:

1. The dry ash free (“d.a.f.”) atomic composition (weight basis)
2. The higher heating value (assuming that the complete oxidation product of Chlorine is HCl), dry basis
3. The LHV and the HHV of the as received feedstock
4. the energy density (expressed as MJ/m^3)
5. the mass flow rate of as received biomass required by a plant having 100 MW of thermal input (LHV basis)
6. the corresponding mass flow rate of moisture in the feedstock
7. the mass flow rate of stoichiometric air required by the combustion process
8. the product gas composition
9. the daily production of ash

 # 2

Consider a biomass-fired plant made of

- a covered storage area
- a wood chipper
- a biomass boiler
- an Organic Rankine Cycle generating electricity and heat (CHP).

On the basis of the following data:

- the feedstock, green oak (at the harvest conditions, as characterized in Table 1), is received as timbers (with an average diameter of 50 cm, average length of 2.5 m) in the covered storage area and arranged into log piles whose height is 5 meters and void fraction is 15%.
- the average air condition of the storage area is 15 °C, 70% relative humidity
- the storage area is managed according to the “first in, first out” logic
- during the storage period wood timbers are naturally dried to a moisture content (wet basis) equal to 35%
- after storage, wood timbers are chipped into 5 mm particles by means of an electrically driven chipper absorbing 170 kJ/kg of wood
- wood particles are transported from the chipper to the boiler by a belt conveyor absorbing 45 kJ/kg of wood
- the boiler is designed for a stack temperature of 130 °C and a thermal loss equal to 0.8% of the fuel LHV thermal input
- about 3% of the inlet carbon is not oxidized (unconverted carbon in ash)
- the excess air of the boiler is 40%
- flue gases specific heat capacity at constant pressure (c_p) = 1.11 kJ/kg-K, air c_p = 1.02 kJ/kg-K, ash c_p = 7.5 kJ/kg-K
- the ash boiler outlet temperature = 450 °C
- the ORC (cycle) electric efficiency = 25%

Evaluate the mass flow rate of as received wood required by the plant to generate 1 MW of net electric power, and assess the area for the storage.

Repeat the same evaluation assuming that as received wood is directly chipped and burned (no covered storage area). Compare the efficiency values of the two cases, i.e., use of dried vs. wet wood, and motivate why they differ.

ADDITIONAL DATA

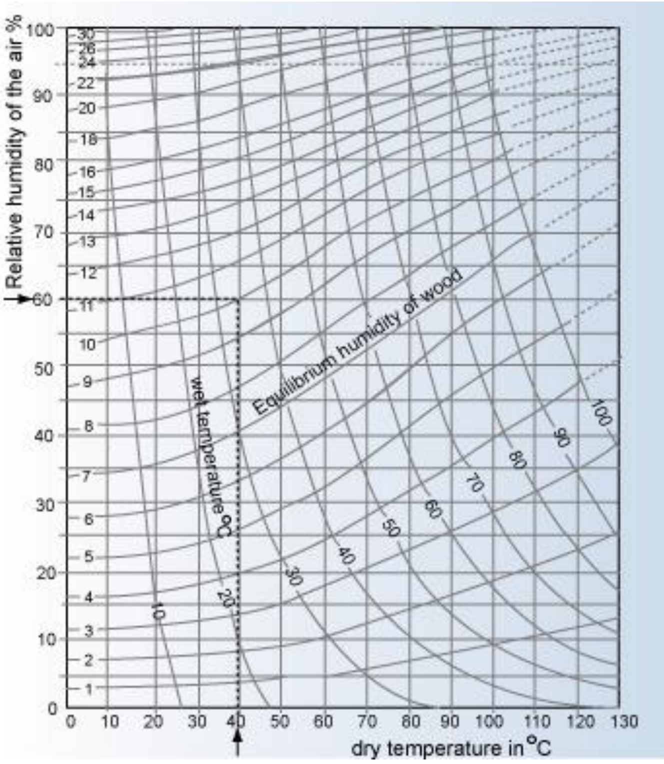

Figure 1. Equilibrium Moisture Content (dry basis) of oak as function of air relative humidity and temperature.

		demolition wood	oak (harvest conditions)	seasoned oak (after storage)	wood pellets	switch grass	straw	pig manure	MSW	plastic waste	SRF	coal Illinois #6
%, weight dry basis	C	49.10	48.80	48.80	47.10	47.80	47.50	35.00	30.80	81.10	40.90	64.60
	H	5.83	6.09	6.09	6.73	5.76	5.90	4.38	0.96	13.33	6.45	4.20
	O	44.10	45.00	45.00	45.81	35.10	40.80	21.30	21.50	0.00	34.00	13.70
	N	0.14	0.00	0.00	0.15	1.17	0.70	2.79	1.09	0.11	1.51	1.30
	S	0.00	0.00	0.00	0.01	0.10	0.15	0.00	0.78	0.01	0.43	2.90
	Cl	0.00	0.00	0.00	0.00	0.00	0.40	1.19	0.71	0.20	0.65	0.12
	ash	0.83	0.11	0.11	0.20	10.07	4.55	35.34	44.16	5.25	16.07	13.18
LHV, kJ/kg, dry basis		17813.00	17769.00	17769.00	18607.00	16767.00	17763.00	12829.00	11990.00	39182.00	18463.00	25200.00
Moisture content, %		10.00	50.00	15.00	8.50	15.00	8.00	66.00	35.00	14.00	20.00	2.00
Density (as received), kg/m^3		700.00	850.00	750.00	700.00	190.00	95.00	910.00	350.00	910.00	400.00	875.00

Table 1: Ultimate (elemental) analyses, LHV dry basis, moisture content (wet basis, i.e., moisture mass / total feedstock mass) and density of biomass and waste residues commonly used in energy systems.