Grinder for the compact energy system

The circular saw blades are mounted on a shaft which is enclosed in a pipe with one end is open for the biomass intake and the other end is connected to the biomass dryer. The correlations developed by Mani et al. [1] were employed to estimate the energy requirement of reducing the biomass size to target size.

Air compressor and Pressure Swing Adsorption

The ASPEN Plus simulation software is used to size the air compressor as well as to estimate the energy required to compress air to the target pressure. The pressure swing adsorption (PSA) unit with a silver exchanged Zeolite was employed to produce nearly pure oxygen [2]. The SuperPro Designer simulation software was used to determine the size, weight, and energy requirements of PSA unit. The data necessary for PSA unit modeling was obtained from Santos et al. [2].

Heat exchangers for the compact energy systems

The compact heat exchangers with the high area density of around 1000 m^2/m^3 were employed for heating and cooling purposes of the compact energy system [3]. Few examples of compact heat exchangers are brazed plate fin, diffusion bonded plate fin, printed circuit, polymer, metal foam heat exchangers, and Chart-fio heat exchangers [3]. The heat transfer area of the compact energy system was determined using the ASPEN Plus.

Gasification and Steam Reforming Rectors

The catalytic plate reactor was selected for the gasification and steam reforming reactors as the feasibility of using coupled exothermic and endothermic reactions with the compact catalytic plate reactors have been demonstrated for various chemical reactions including catalytic methane steam reforming [3]. The necessary information for the simulation of conventional [4], catalytic [5], steam [6], supercritical [7], and microwave gasification [8] as well as steam reforming reactors [9] has attained from published literature. The RYIELD reactor model in ASPEN Plus was used to determine the energy balance for the catalytic plate reactor. The RSTOIC reactor mode was utilized for calculating energy balance for the steam reforming reactors. The volume of gasification and steam reforming reactors were calculated using residence time and mass flow rate. The thickness of a reactor based on the internal pressure, volume of reactor, and material (steel) density were used to determine the weight of gasification and steam reforming reactors.

Separation and Purification

The product gas resulting from steam reforming of syngas consists of CO_2, CO, H_2, H_2O, CH_4, NH_3, and may be H_2S. To use H_2 in fuel cell, it must be separated and purified from the multi-component product gas mixture. The integration of PSA unit with Pd-membrane technology can be used to purify hydrogen [10,11]. The PSA unit with structurally arranged monolithic activated carbon material can be used to remove a significant amount of CO_2, CO, and H_2O [10]. The optimal operating conditions of PSA column can be determined to remove CO_2, CO, and H_2O from syngas using adsorption isotherms [10]. The hydrogen is separated from a stream leaving the PSA unit column using Pd-membrane [11]. The PSA unit was modeled using the SuperPro Designer software and the modeling parameter values were obtained from Dunbar [11]. The Pd-membrane area was determined using empirical equations presented by Saltonstall [12]. The weight and volume of Pd-membrane process were calculated based on the hallow fiber membrane module design principles.

Powered-Engine Component

The specific power and power density were used to estimate the weight and volume of gas engine, fuel cell, and sterling engines, respectively (Table S3).

Table S1: Ultimate analysis (wt/wt% dry basis) of biomass used to make hydrogen/producer gas with different types of gasification technologies

Element	Conventional gasification	Steam gasification	Catalytic gasification
Ash	6	0.34	0.5
Carbon	47.28	44.75	51.26
Hydrogen	5.06	6.31	5.54
Oxygen	40.63	46.87	42.29
Nitrogen	0.8	1.68	0.18
Sulfur	0.22	0.05	0.23

Table S2: Selected gasification temperatures for modeling purpose

Type of gasification technology	Temperature (Celsius)	Residence time (s)
Conventional gasification	1100	2
Steam gasification	900	5
Catalytic gasification	750	4

Table S3: Conversion efficiency of hydrogen/hot producer to available energy, specific power, and power density of fuel cell, gas engine, and stirling engine

	Conversion efficiency	Specific power (kW/kg)	Power density (kW/L)
Fuel cell	55%	1.4	1.6
Gas engine	47.28	0.46	0.010
Stirling engine	5.06	0.054	0.010

Table S4: The data of operational time (h), target power (kW), and weight (kg) to generate Figure 4 in the manuscript

Operational time	Power	Weight
1	0.5	0.7
1	1	1.5
1	3	4.4
1	5	7.3
1	10	14.6
1	20	29.1
1	40	58.3
1	60	87.4
1	80	116.5
1	100	145.6
3	0.5	2
3	1	4
3	3	13
3	5	22
3	10	44
3	20	87
3	40	175
3	60	262
3	80	350
3	100	437
6	0.5	4
6	1	9
6	3	26
6	5	44
6	10	87
6	20	175
6	40	350
6	60	524
6	80	699
6	100	874
12	0.5	9
12	1	17
12	3	52
12	5	87
12	10	175
12	20	350
12	40	699
12	60	1049
12	80	1398

12	100	1748
24	0.5	17
24	1	35
24	3	105
24	5	175
24	10	350
24	20	699
24	40	1398
24	60	2097
24	80	2796
24	100	3496

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