Supplementary Material: Figure S1 and S2

Energy Balance of Turbocharged Engines Operating in a WWTP with Thermal Hydrolysis. Co-Digestion Provides the Full Plant Energy Demand

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Figure S1. Thermodynamics diagram of the turbocharger as a function of specific entropy

The filtered air and biogas are mixed in the electronic carburetor. The resultant lean mixture is sent to the turbocharger compressor to increase pressure and density before entering the engine cylinders. The compressor of each of the two six-cylinder rows handles 1,469.5 kg/h (1,328.5 kg/h air and 141 kg/h biogas) at an initial temperature of 25 °C. The outlet compressor mixture is cooled by the intercooler at constant pressure being then injected into the inlet manifolds and afterwards into the combustion chamber. During the exhaust stage, gases are expanded in the turbine up to an outlet temperature of 483 °C with a maximum back pressure of 4.5 kPa above atmospheric pressure.

The compression ratio was calculated using a value of 65 ºC for the outlet intercooler air temperature. A minimum approach point of 10 ºC was applied for the main cooling circuit. The inlet temperature of biogas to the carburetor is 55 ºC. The biogas mass flow represents just 9.6% of the air mass flow, increasing the temperature of the air-biogas mixture by 2.6 ºC as it flows through the carburetor. Thus, a temperature of 25 ºC was assumed for the inlet mixture, disregarding the small heating effect caused by biogas flow.

Figure S1 represents the evolution of the different thermodynamic parameters as a function of the specific entropy (kJ/kg ºK).

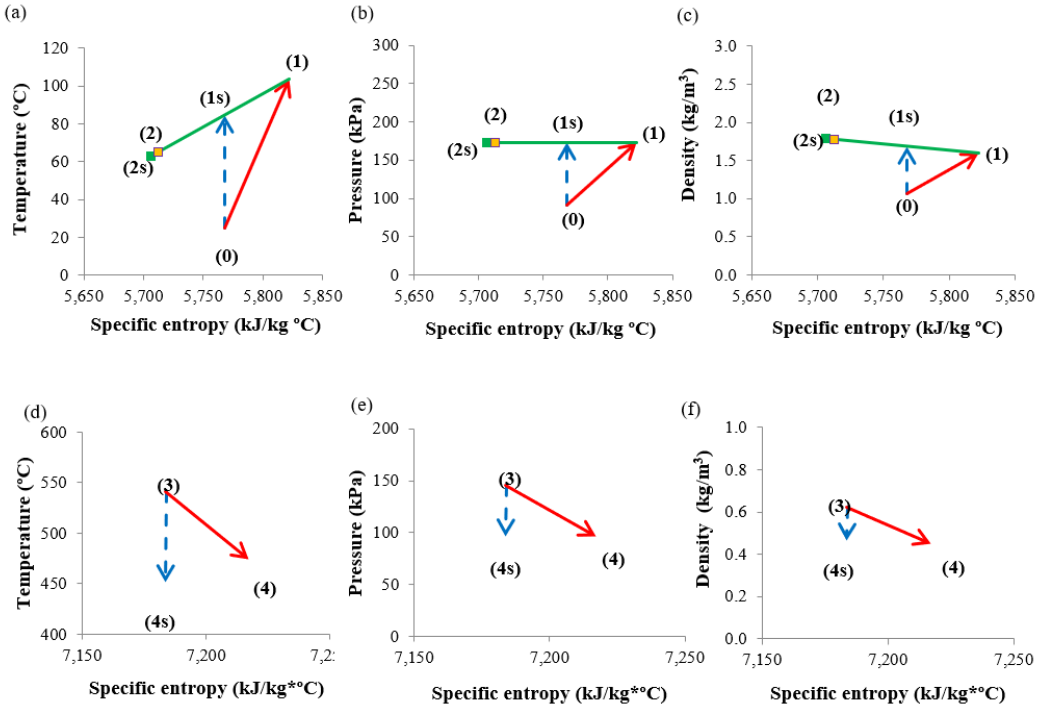

Figure S1. Thermodynamics diagram of the turbocharger as a function of specific entropy. (a), (b) and (c) Temperature, pressure and density of the compressor air circuit. (d), (e) and (f) Temperature, pressure and density of the turbine exhaust gas circuit. Point denoted as 0 corresponds to the mixture inlet conditions, 1s and 1 the isentropic and real compressed mixture, 2s and 2 the ideal and real outlet mixture of the intercooler and inlet to the cylinders. Point 3 shows the inlet of the exhaust gases into the turbine and 4s and 4 the isentropic and real outlet of the turbine. Compression (1–1s) and expansion (3–4s) were assumed as adiabatic, reversible and isentropic processes.

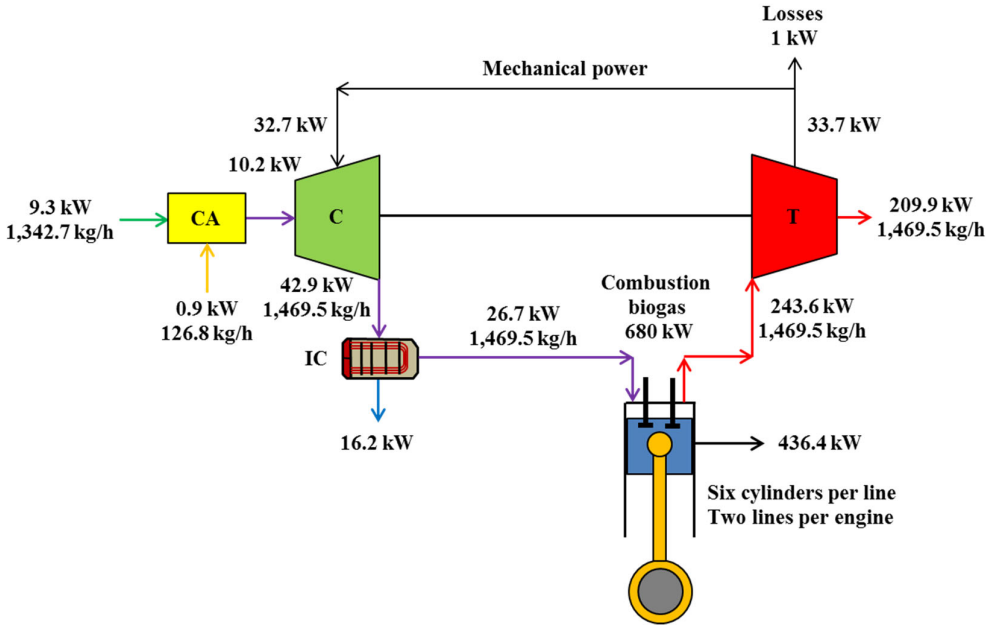

Figure S2. Mass and energy balance of one of the cylinder lines of the biogas engines. (C, compressor; T, turbine; IC, intercooler; CA, carburetor).