Executive Summary

UNIFHY is a 43-month collaborative research project started on September 1st 2012, with a total budget of 3.3M€. The project aims at developing cost competitive, energy efficient, sustainable, thermochemical hydrogen production process from various biomass feedstocks.

The project is based on the utilization of plant components of proven performance and reliability and well established processes (UNIQUE coupled gasification and hot gas cleaning and conditioning system, via one 100 kWth indirectly heated reactor and one 1000 kWth enriched air reactor, Water-Gas Shift, WGS and Pressure Swing Adsorption, PSA).

The overall scope of UNIFHY is the integration of these components to obtain a continuous process for pure hydrogen production from biomass. Almond shells have been chosen to be used in the beginning of the experimentation owing to the lower price respect pellets and greater bulk density versus wood chips.

Regarding the hydrogen production, UNIFHY intended to increase the gas production quantity and at the same time improve its purity, for this reason three kinds of filter candles (non catalytic, catalytic, with catalytic foam) have been tested at different filtration velocities and gasification conditions. By the tests it has been proved that the hydrogen production has risen to about 60%-vol, vs 38% in the tests with no candle (about 50% increase), with a reduction of methane (from 10 to 2%-v), tar (from 10 to 1 g/Nm3), ammonia (from 3000 to 1500 ppm), and an increase in gas yields (from 1 to 2 Nm3/kgdaf) and water conversion (from 25% to 45%). Higher temperature, water content and ash/char accumulated increase the performance, as evidenced by experimental tests and CFD simulations. About 150 ceramic alumina foams (two porosities: 45 and 30 ppi) were impregnated with cerium oxide to increase their specific surface area (from 0.5 m2/g to 5-15 m2/g) and iron and copper catalysts where developed to test WGS performance. The 45 ppi foams showed higher differential pressure (about 150 vs 50 mbar for a standard reactor), thus the 30 ppi foams where chosen to prevent exceeding the differential pressure limits. The optimized wet impregnation of iron and copper precursor (> 10 and 5%-wt, respectively) permits to obtain promising CO conversion (until 43%) with a residence time of 1s. These systems present a good lifetime and are resistant to sintering. Bench scale tests and modelling of PSA showed that PSA performs well down to H2 concentrations of 34% at purity 5.0 with about 65% H2 yield (PSA at 6-7 bar, product H2 at pressure of 3-4 bar). A sulphur guard bed (ZnO reactor), a WGS, a PSA have been built and integrated in a Portable Purification System. Extensive gasification test campaigns have been carried out in order to evaluate the performance of the two gasifiers without and with candle filters. The startup time is about 5 and 24 hours for the 100 and 1000 kWth prototypes, respectively. Tests without candle filters at different gasification agents (steam/air/oxygen) and temperatures showed gas yield from 1.1 to 1.7 Nm3/kg of dry biomass, hydrogen content from 7 to 40%-v dry, tars, as particulate, in the range of 10-20 g/Nm3dry, sulphur and chlorine compounds in the range of 50-90 ppmv, ammonia up to 1600 ppmv. Test with candle filters showed the efficacy of the in-situ HT filtration system in removing particulate from the produced gas, reduced down to about 30 mg/Nm3dry thus with a removal efficiency > 99%-wt. The system was proven to be operable stably and in continuous in experimental run lasting more than 12 h. Hydrogen production at concentration of 99.99%-v was achieved. The economic and LCA analysis showed that UNIFHY can match the hydrogen target cost and emission of 3-10 €/Kg and 0.0134 kg CO2 per 1MJ H2 produced (0.3-3 t H2/day). See Final Report attached document which include photos, tables and diagrams.