Greece – China Call for Proposals for Joint RT&D Projects launched under the auspices of the Ministry of Science and Technology (MOST) of the People's Republic of China and the Ministry of Education, Research and Religious Affairs/ General Secretariat of Research and Technology (GSRT) of the Hellenic Republic.

Greek side: Funded under European Regional Development Fund (ERDF) and National Resources (GSRT), Chinese side: Funded under Ministry of Science and Technology of the People's Republic of China.

Project title:	**Integrated management and exploitation of multi-dispersed agricultural residues – application to energy production**
Acronym and project number, Start & Duration	**SYNAGRON** 81049 Start: 14/10/2019, Duration: 3 years
Partners from Greece:	1. University of Patras, Dept of Environmental Engineering (Coordinator) & Dept of Chemical Engineering 2. University of Western Macedonia, Chemical Engineering Dept 3. SIRMET S.A.
Partners from China:	1. Beijing University of Chemical Technology, BUCT 2. Beijing United Pioneer Environmental Engineering Co., Ltd 3. Nanjing Benran Environmental Technology Co., Ltd
Other Collaborating Organizations:	Khalifa University of Science and Technology, KUST, United Arab Emirates
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Deliverable D1.2:	**Report on Market Analysis**
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Beijing-Patras, 2021

EXECUTIVE SUMMARY

According to International Energy Agency (IEA), the global energy demand is set to drop by 5% in 2020, energy-related CO_2 emissions by 7%, and energy investment by 18% attributed to Covid-19 pandemic. Although, the estimated falls of 8% in oil demand and 7% in coal use stand in sharp contrast to a slight rise in the contribution of renewables, oil, gas and coal are still the main sources of primary energy. In the absence of a larger shift in policies, it is still too early to foresee a rapid decline in oil demand. However, a step-change in clean energy investment offers a way to boost economic recovery, create jobs and reduce emissions.

Alternative solutions, such as biochar, bio-oil, biogas and hydrogen, are one of the most significant renewable and sustainable energy sources. This report includes an economic analysis for the outcomes expected by the introduction of each final product of the processing plant into the energy market. Specifically, this study includes the market analysis for biochar, bio-oil, biogas and hydrogen in Europe and particularly in Greece, and in China from two different approaches (Greek and Chinese side).

According to the findings of this report, biochar, which can be can be made from any source material or feedstock with high carbon content, can be converted into a variety of products that include gases, solids, liquids and heat via thermochemical decomposition processes. Usually, is derived by wastes coming from agriculture, papermaking and other industries. Biochar prepared from these wastes through a series of methods, which can effectively reduce the discharge of solid wastes, improve the utilization efficiency of resources and protect the environment. In addition, it can be used as a soil amendment to enhance plant growth, pH and for the reduction of nitrous oxide emissions from soils. Furthermore, biochar can be used for carbon sequestration in order to remove greenhouse gases from the atmosphere.

In China, a country with a large population and agriculture, the total amount of biochar originated from crop waste is $6.16*10^8$t/year, from forestry waste is $1.04*10^8$t/year and

from livestock manure is $2.82*10^8$t/year, respectively. However, biochar products are sold in a wide range of prices ($0.08 to $13.48 per kilogram) own to its vast discrepancy in product's physical and chemical characteristics as well to the diversity of potential uses and associated markets that ranges across agriculture, forestry, mining, horticulture, nursery, and industrial adsorbent sectors.

Bio-oil, which is the liquid product from pyrolysis of biomass, is a renewable liquid fuel can be stored and transported and has numerous applications, provided that is upgraded, either with flash pyrolysis or hydrothermal liquefaction, due to its high viscosity, high water content and ash content, low calorific value, instability and high corrosiveness.

Bio-oil has been tested for many years but is still a new product at the commercial stage. For this reason, there is no developed market in Europe. The global leader in fast pyrolysis technology and commercialization is Canada. The values of crude bio-oil ranged from 0.09$/kg to 0.54$/kg until 2006 according to the National Renewable Laboratory of the U.S. Department of Energy. In China, the market price of the main bio-oils, which are bioethanol and biodiesel, is around 5472 $/t and 3792 $/t respectively, while the corresponding profit is around $467*10^8$ $/t for bioethanol and $100*10^8$ $/t for biodiesel, respectively.

Biogas is produced during anaerobic digestion of organic substrates. Examples of these substrates are sewage sludge, animal manure, organic fractions of household and industry waste, and energy crops. It is gas fuel with similar characteristics to natural gas.

The European countries such as Germany, Austria, Denmark and Sweden are among the technical leaders, with the largest number of modern biogas plants. The cost of biogas production varies significantly, and it depends on parameters such as the substrate used and the possibilities to distribute the resulting digestate in the

surrounding agricultural area. Based on the respective international prices 1 kg of biogas costs approximately 0.07€.

In Greece there is still lack of knowledge and information not only of farmers but also of industries and the general public about the potential of energy recovery of waste, their end use and their advantages. Generally, in Greece, anaerobic digestion is used as a waste management method and is not accompanied by biogas and energy production. Lastly, biogas can be used to generate heat through direct combustion, to generate electricity from fuel cells or microturbines and cogeneration of heat and electricity.

Chinas' biogas industry has a history of nearly 100 years. According to the statistics of China Rural Energy Industry Association, there are 1298 enterprises in Chinese biogas industry, with 12000 employees and an annual total output value of 1.846 billion CNY (around 240 billion euros). Biogas energy in China is divided into compressed and purified biogas for vehicles, liquefied and purified biogas for vehicles, canned liquefied and purified biogas, direct use of biogas, pipeline purification of biogas, biogas power, biogas liquid and biogas residue chemical products, etc.

The electricity price of biogas is 0.61 CNY/kWh (0.07€/kWh), in accordance with the new energy grid price standard of Henan Provincial Development and Reform Commission, However, there are many difficulties in the development of biogas industry, including the slowdown of household biogas development year by year, the rapid decline of utilization rate; the large-scale development of biogas project; the small and medium-sized biogas project still has not been paid attention; the development of biogas still faces some difficulties, and the pilot effect is not obvious.

Hydrogen is an abundant element, and it can be found in many substances in nature such as fresh water and biomass. Unfortunately, it is difficult to find hydrogen in nature as a separate element. Instead it is chemically linked to oxygen in water and to carbon in hydrocarbons. Hydrogen is an energy carrier and not a primary source. However, hydrogen energy is a clean (does not emit CO_2 and during its use, almost zero air

pollutants are released), efficient, safe and sustainable secondary energy, which can be obtained through primary energy, secondary energy and industrial fields. The primary source that produces hydrogen will be either renewable or nuclear energy.

The main hydrogen production technologies include coal gasification, reforming of natural gas with steam, biomass gasification, electrolysis using renewable energy sources and nuclear processes. It is well known that research activity in Europe is largely maintained and directed by Framework Programs. In Greece, the first significant move in the H_2 sector was the establishment in 2003 of the Hellenic Hydrogen Company. This company is a scientific non-profit organization with the aim of assisting in the efforts for the application of hydrogen technologies in Greece.

The current estimated cost of fossil fuel hydrogen is around 1.5€/kg for the EU. This is highly dependent on gas prices without taking into consideration the cost of CO_2. The estimated cost of fossil fuel hydrogen with capture and storage of carbon is around 2€/kg, while the cost of renewable hydrogen is 2.5-5.5€/kg. However, the cost of renewable hydrogen decreases rapidly.

Currently, the application market in China is mainly fuel cell bus and logistics vehicle. 2021 is the first year of the fourteenth five-year plan. In accordance with the plans issued by various provinces and cities, it is conservatively estimated that there will be about 1000 hydrogenation stations to be built in China by 2025.

China is rich in coal resources, so it mainly uses coal to produce hydrogen technology, accounting for more than 60% of the national hydrogen production technology. In terms of hydrogen production technology China already has large-scale hydrogen production from coal, natural gas and methanol. Among the main hydrogen production methods, the cost of hydrogen production from coal is the lowest, about 8-10 CNY/kgH_2 (1.04-1.30€/kgH_2), the cost of hydrogen production from natural gas is about 12 CNY/kgH_2 (1.56€/kgH_2) and the cost of hydrogen production from renewable energy is about 20 CNY/kgH_2 (2.60€/kgH2). From 2012 to 2020, the overall market price of hydrogen in

the country has risen from 29.34 CNY/kgH_2 (3.80€/kgH_2) to 35 CNY/kgH_2 (4.55€/kgH_2).

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