The nature of the "liquid sunlight"

The nature of the "liquid sunlight"

Amelia Carolina Sparavigna[1]

1 – Department of Applied Science and Technology, Politecnico di Torino, Torino, Italy

ORCID 0000-0003-4502-8974

ABSTRACT Today, the term "liquid sunlight" refers to a green fuel obtained by means of a process inspired by the natural photosynthesis. The method to have this fuel is based on the combination of compatible inorganic and biological components to transform light, water, and carbon dioxide to methane. A similar term, "sunlight-to-liquid" or "sun-to-liquid", exists for a recently proposed synthesis of a gas, which is further processed to obtain kerosene. Here we will show that in the past the term "liquid sunlight" was used for the petroleum. Actually, the meaning of the term, today and in the past, is the same: conversion of the sunlight energy into a fuel.

What is the "liquid sunlight"? This is a term that we find in [1], referring to a green fuel obtained by a device designed in Berkeley, at the Joint Center for Artificial Photosynthesis. Inside the device, "arrays of nanowire electrodes and bacterial colonies are using the light to turn water and carbon dioxide into methane, the main component in natural gas". The process wants to imitate what the plants are doing during the photosynthesis. So the liquid sunlight is referring to the fuel that we can obtain starting from the fundamental process of splitting water into oxygen and hydrogen, in an artificial photosynthesis which is producing hydrocarbons [1].

The article [1] is proposing a discussion on the evolution of researches in this area since the 1970s. "The inspiration came in 1972, when Akira Fujishima at Kanagawa University and Kenichi Honda at the University of Tokyo showed that two electrodes - one titanium dioxide and the other platinum - would catalyze the splitting of water when illuminated with visible light" ([1] is referring to article [2]). This research inspired scientists to work on artificial photosynthesis. Among then, we find those of the National Renewable Energy Laboratory in Boulder, Colorado.

After many years and studies to find the best catalyser and electrodes, a new approach is given by the recruitment of bacteria "to help do the job". A team at the University of California, Berkeley, has made a solar fuel system with the use of "living catalysts" too [3]. The system is based on nanowire electrodes. The nanowires have carpeted surfaces to absorb more light and hold more catalyst. In the cell, one of the electrodes is seeded with bacteria. Also in Harvard, researches are working on the use of microbes [4].

After the report given in [1], many articles had been published on this subject and on the fuels produced by bacteria in general. However, the aim of this discussion is not the report of the literature, but the use of the term "liquid sunlight". The term is clear, it is the liquid fuel that we can obtain from sunlight [5], as explained by Peidong Yang, who is proposing the system developed at Berkeley [3] also for deep space missions [6], in order to have an effective manner to produce fuel and oxygen for the crew.

As previously told, the "liquid sunlight" is a fuel obtained by means of a strategy inspired by the natural photosynthesis. The researchers combined compatible inorganic and biological components, to transform "light, water, and carbon dioxide to the value-added product methane." In [3], it is described a solar-to-chemical conversion platform which is interfacing photoactive inorganic materials that produce hydrogen from water and sunlight with microorganisms that consume hydrogen to drive the transformation of carbon dioxide to methane with high efficiency.

In fact, the term "liquid sunlight" is impressive. It is evoking the possibility to have a sort of liquid phase of the light, that is, a liquid fuel which is the condensate of sunlight energy. We can find a term of this kind also in the "SUNlight-to-LIQUID", which is the title of a project of European Horizon 2020, for the development of an integrated solar-thermochemical synthesis of liquid hydrocarbon fuels [7]. We find this term rendered as Sun-to-Liquid, fuels from concentrated sunlight [8]. As told in [8], the project is devoted to produce renewable transportation fuels from water and carbon dioxide with concentrated sunlight. In [9], it is claimed that the project, which is funded by the EU and Switzerland, "has now successfully demonstrated the first synthesis of solar kerosene."

The sun-to-liquid fuels is produced in a solar thermochemical reactor. The solar reactor, developed by ETH Zurich, is obtaining a synthesis gas which is a mixture of hydrogen and carbon monoxide, from water and carbon dioxide via a thermochemical redox cycle. Then, this gas is processed to kerosene by an on-site gas-to-liquid system by HyGear. Therefore, the sun-to-liquid is the kerosene, a well-known combustible hydrocarbon liquid derived from petroleum. So the European project aims to obtain a product which is the same of that which is coming from the fossil fuel resources.

Kerosene is known for centuries. In the 10th century, the Persian scholar Muhammad Al-Razi (Muhammad ibn Zakarīya Rāzi) described in his Book of Secrets the distillation of petroleum, to have oil for lamps [10]. In the West, it was the Canadian physician and geologist Abraham Gesner who carried out in 1846 the first public demonstration of this illuminating liquid. Gesner later called it "kerosene", a word he invented and used as a marketing tool [11]. Kerosene was an inexpensive liquid and substituted the whale oil in lamps for lighting systems.

Soon petroleum became the liquid by means of which it was possible to obtain light and heat. It was returning the sunlight from which it had origin. So, in a book of 1898, Alexander Winchell defines it the "liquid sunlight" [12]. He also defined the natural gas as the "gaseous sunlight". The "solidified sunlight" was the coal and the coal-beds. Here the beginning of what he is telling on petroleum and natural gas in [12].

"XXIV. Liquid Sunlight. Petroleum. The history of the search for native oil is romantic. Known for ages, it remained a mere curiosity till 1859. Even in America, where popular intelligence is supposed to utilize every possible advantage, petroleum rose only to the importance of a quack remedy for aches and other evils. But suddenly it assumed the sceptre of king. Men pursued it with the sound and fury of dogs on the track of their prey. They lost their power of reasoning on the subject. They could not be convinced that mineral oil is a geological product, fixed in its relations to the earth and to the strata as unchangeably and as intelligibly as iron or salt. They would not listen to the counsel of science. Every man was confident in his self-wisdom, and never inquired on what grounds he believed and acted as he did. There was oil - millions of barrels of it; and many investors were fortunate if not wise; and many, though wise, were not fortunate. It was a new situation." [12].

Alexander Winchell is mentioning a date, 1859. He is referring to the oil discovery at Oil Creek Pennsylvania and to th following oil rush.

In [12] the "gaseous sunlight is introduced in the following manner.

"Illuminating and Heating Gas is one of the products of the earth. ... its origin is undoubtedly similar to that of oil, and that oil is chiefly the product of the distillation of shales charged with vegetable matter - probably ancient sea-weeds. As sunlight is the active agent in vegetable growth, a stem or a leaf is simply a body of transformed sunlight. When imbedded in the rocks it is strictly and literally fossil sunlight. In petroleum, ancient sunlight is preserved in liquid form; in natural gas it is gaseous."

Soon after the Winchell's book was published, the petroleum became "that liquid sunlight which is revolutionizing the economic life of mankind", as told in a book of 1925 [13]. In [14], coal, oil, and gas are defined the "gifts from the sun." "When we burn coal, we are setting fire to the remains of an ancient forest, and setting free energy from the sun that was held inside the coal for thousands of years. Can you now tell why coal is called "black sunlight"? And why oil is called "liquid sunlight"?" [14].

The "black sunlight" is illustrated in [15]. As in the case of the "liquid sunlight", it is the sunlight solidified in coal. "The sun's emanations of light and heat became transformed into stem and frond and tissue. The coal is ancient sunlight that has been locked up like a treasure and buried in the earth for ages. … Here, in this flame [the flame from coal], the old sunlight is regenerated; this is the very sunlight which became latent in vegetable cells so long ago. It is locked-up sunlight set free after a long imprisonment." [12]

In [16], we find the other terms used for petroleum: "Black gold", "crude," and "Texas tea". Today, the term "black gold" is more familiar than the term "liquid sunlight". The reason is that we have not been using oil for a long time in the lamps for illumination and the use in heating systems is limited in western countries. Then, the "sunlight" is no more linked to oil.

So, in the past, the "liquid sunlight" was the petroleum, the liquid in which the energy of the sun was condensed and that was recovered for many uses. Today, it is the liquid fuel that we can obtain from sunlight in renewable or green processes. Again, it is the energy of the sun which is condensed in a material that we can use for fuel.

References.

[1] Bourzac, K. (2016). News Feature: Liquid sunlight. Proceedings of the National Academy of Sciences, 113(17), 4545-4548. DOI 10.1073/pnas.1604811113

[2] Fujishima A, Honda K (1972) Electrochemical photolysis of water at a semiconductor electrode. Nature 238(5358):37–38.

[3] Hybrid bioinorganic approach to solar-to-chemical conversion. Eva M. Nichols, Joseph J. Gallagher, Chong Liu, Yude Su, Joaquin Resasco, Yi Yu, Yujie Sun, Peidong Yang, Michelle C. Y. Chang, and Christopher J. Chang. PNAS September 15, 2015 112 (37) 11461-11466; first published August 24, 2015 https://doi.org/10.1073/pnas.1508075112

[4] Efficient solar-to-fuels production from a hybrid microbial–water-splitting catalyst system. Joseph P. Torella, Christopher J. Gagliardi, Janice S. Chen, D. Kwabena Bediako, Brendan Colón, Jeffery C. Way, Pamela A. Silver, and Daniel G. Nocera. PNAS February 24, 2015 112 (8) 2337-2342; first published February 9, 2015 https://doi.org/10.1073/pnas.1424872112

[5] Liquid Sunlight: Peidong Yang. https://www.youtube.com/watch?v=pgxI9GUrxjA

[6] Peidong Yang Group. http://nanowires.berkeley.edu

[7] SUNlight-to-LIQUID: Integrated solar-thermochemical synthesis of liquid hydrocarbon fuels. https://cordis.europa.eu/project/rcn/199438/factsheet/en

[8] https://www.sun-to-liquid.eu

[9] http://news.bio-based.eu/solar-fuel-breakthrough-sun-to-liquid-produces-solar-kerosene-from-sunlight-water-and-carbon-dioxide/

[10] Zayn Bilkadi (1995). The Oil Weapons, Saudi Aramco World, January/February 1995. Available at https://archive.aramcoworld.com/issue/199501/the.oil.weapons.htm

[11] James D. McNiven (2018). The Yankee Road: Tracing the Journey of the New England Tribe that Created Modern America, Vol. 2: Domination. Wheatmark, Inc., 7 mar 2018.

[12] Winchell, Alexander (1898). Walks and talks in the geological field. F. Starr Editor. Publisher Meadville et al., at https://archive.org/details/walkstalksingeol1898winc/page/n7

[13] The World's Work. A History of Our Time, Volume 49. Doubleday, Page & Co., 1925.

[14] John Martin Scott (1973). Heat and fire. Parents' Magazine Press.

[15] Anthracite Coal Mining: "Black Sunlight" circa (1920) Bray Studios. Available at https://www.youtube.com/watch?v=KEnlGAekPes

[16] Grolier Educational Staff (1992). New Book of Knowledge 1992. Grolier, Limited.