Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 126 (201709) 541–548

Energy Procedia

www.elsevier.com/locate/procedia

72nd Conference of the Italian Thermal Machines Engineering Association, ATI2017, 6-8 September 2017, Lecce, Italy

Boron as a storage medium for solar energy

Enrico Gianfranco Campari[a*], Michele Bianchi[b], Luca Tomesani[b]

a Department of Physics and Astronomy, University of Bologna, viale Berti Pichat 6/2 Bologna 40127, Italy. enrico.campari@unibo.it
b Department of Industrial Engineering, University of Bologna, viale Risorgimento, 2 Bologna 40136, Italy.

Abstract

The use of Boron as an energy storage medium in the framework of solar energy systems development is suggested, highlighting its potential advantages. The issue which is considered here is mainly that of reducing the energy waste connected with power transfer from areas of high solar energy productivity to highly industrialized areas, such as those of Europe, where the energy is needed. Both the production and transfer of Hydrogen or the build up of power lines give rise to an energy loss which can be up to 50% of the produced energy. A cycle is described in which Boron is used as a means to store and transport solar energy from a production site to the location where the energy stored in Boron will be used. This cycle would solve the long range transport and long term storage problem, which are two critical issues of a prospective solar energy economy. We describe how the use of Boron could indeed be a solution to the problem which is both energetically favorable and environmentally safe.

Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association

Keywords: Boron, Boron oxide, solar energy, hydrolysis, combustion, reduction.

1. Introduction

The power from the Sun, as electromagnetic radiation, on each unit surface of the Earth perpendicular to the Sun direction, is, outside the atmosphere, about 1,36 kW/m^2, with a peak power centered in the middle of the so-called visible region (wavelength 500 nm) [1]. This is the ultimate energy source for the Earth, since wind power, waves power and even energy stored in Carbon and oil, all comes from the Sun. Energy source independent from the Sun are geothermal energy and nuclear energy. Unfortunately, nuclear energy from fissile elements presents severe risks and cannot be considered a long lasting energy source [2]. Maybe worst, the process to obtain energy from Hydrogen nuclear fusion is not, at the present time, a practical and efficient technology. It can be quite effectively defined as perpetually 30 years away, because of breakthroughs announced with monotonous regularity and

*Corresponding author. Tel. +39 051 2095148 email: enrico.campari@unibo.it

1876-6102
Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association
10.1016/j.egypro.2017.08.276

regularly dismissed. Geothermal power is cost effective, sustainable and environmentally friendly and recent technological advances have expanded the range of viable resources. But, despite Earth's geothermal resources be in principle adequate to supply humanity's energy needs, only a very small fraction may be profitably exploited. Geothermal energy must therefore be considered an help and not the solution of the mankind energy supply problem [3,4].

The widespread knowledge about these facts, together with the recognition that fossil fuels will not last forever [5] and that a Carbon-free economy would be a much better choice for the environment, has spurred in the last decades the development of solar energy [6]. Moving from a fossil fuels to a solar energy economy would get rid of most of the problems connected with pollutant emission of harmful substances and greenhouse gases [7]. Not to mention the problems connected with political conflicts caused by their volatile prices.

One of the most interesting options to obtain energy from the Sun is to build large plants where light from the Sun is collected and used to directly obtain electric energy or fuels like Hydrogen. As regard the better choice of solar energy production sites, the potential importance of desert areas is widely recognized. There are, for instance, very good reasons for the localization of solar power plant at places like the south coasts of the Mediterranean sea (see figure 1). Large unused areas with less cost and no competition with other uses like agriculture or nature maintenance; sun shining nearly every day of the year. The latter is particularly important for the success of processes using Concentrated Solar Power, which is more dependent on purity of atmosphere and the amount of sunny days than on the amount of solar radiation reaching the ground (which is higher at low latitudes). South Mediterranean regions present very low cloudiness in summer and also low in winter.

The main problem to be addressed for a large scale solar energy production in desert areas is how to store and transport the energy from production to the utilization areas. None of the current solutions can be considered fully satisfactory. As regard electric energy, the drawback is the relevant cost of a power line plus the energy loss over long distances. The overall losses between the power plant and consumers is estimated to be above 6% [8]. Unfortunately, this is computed for an average distance between plant and consumers in the range of 100-200 km. The longer the distance, the greater the losses. Furthermore, an energy storage system must still be used if any excess produced energy has not to be lost.

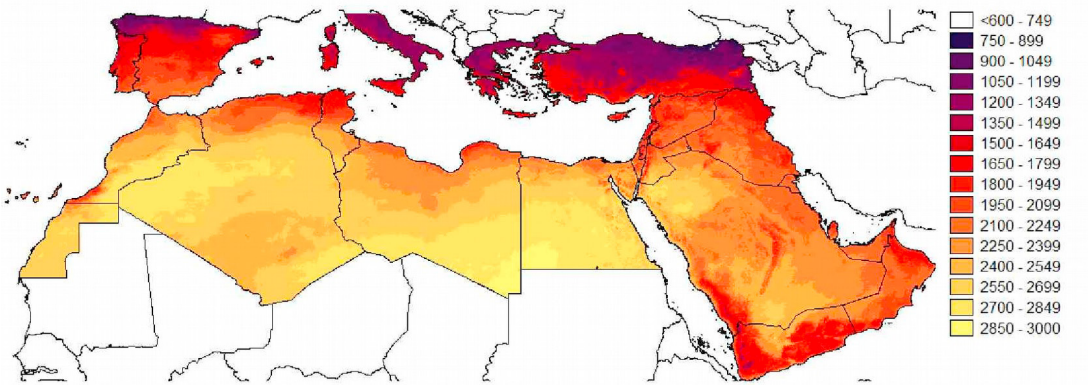

Figure 1. *Annual direct normal irradiance in the Mediterranean region in the year 2002 in (kWh/m^{2}yr).*

An international foundation, the Desertec Foundation [9], has been established, with the mission to promote the large-scale production of solar and wind power in the desert regions of the world. Among other projects, a solar plant (160 MW electric power) has been financed and built by this foundation in Ouarzazate, Morocco, to produce electric energy which was in origin to be transferred to Europe by High Voltage Direct Current (HVDC) transmission. Despite its apparent simplicity and economic convenience, this project is facing many problems, mainly due to the high costs of realizing HVDC transmission lines (those already existing, like the submarine power line below Gibraltar strait cannot stand the extra power produced by the new solar plants). As a consequence, the Foundation is now more concerned with the needs of countries of North Africa and the forecasts are that imports to Europe will not take place on a large scale until after 2030.

The alternative method currently envisaged is that to store and transport energy into Hydrogen [10]. Three