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New frontiers in sustainable energy production and storage

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ABSTRACT

Evidently, one of the most effective ways to reduce CO_2 emissions consists in the deployment of renewable energies, with the advantage of securing and expanding the energy supplies of a given country. The main problem that arises is due to the intermittent temporary character of many renewable resources like solar and wind. For this reason, it has been recently concluded that in case of high integration of renewables into the distribution grid (more than about 30% of the electricity mix), the implementation of energy storage systems together with smart grids is necessary. Therefore, renewable energies for large scale power production in country would usually require the availability of a sufficiently large energy storage capacity. Unfortunately, current technologies can only provide energy storage to a very limited extent, and large R&D efforts will be needed to find adequate solutions. Due to these reasons, the European 2050 Energy Roadmap, should contemplate parallel development programmes for energy storage technologies (batteries, power-to-gas, hydrogen, etc.), and the upgrading of distribution networks, including smart grid technologies. With respect to renewable energies, we would like to point out that, in addition to their sustainability with respect to the environment, we will also consider in this Conference their economic sustainability, or price of the generated electricity, since we are immersed in a globally competitive economy. Another main topic of this Conference deals with advanced materials for key enabling technologies for a sustainable development, as contemplated in the Horizon 2020 Program. Among the multiple examples of materials that are essential for the improvement of energy generation and efficiency, we will centre our interest in topics including solar cells, fuel cells, energy storage and electric vehicles.

1. Energy utilization and climate change

During the last few decades the world has been involved in a transition from fossil fuels (carbon, oil, gas, etc.) towards renewable resources based on sustainable low-carbon technologies like solar, wind. The main reason for this transition is to avoid the large amounts of CO_2 being emitted to the atmosphere which amounted globally to 34.6 gigatonnes in 2012 [1] and 35.3 gigatonnes in 2013 [2]. If the emissions continue to grow at the same rate as in the last decades, the increase in temperature by the end of this century could be as much as 5 °C or 6 °C. In addition, as recently pointed out by the Intergovernmental Panel on Climate Change (IPCC) [3], in order to avoid a global warming greater than 2 °C by the year 2050, it would be necessary not to surpass the mark of 450 ppm in CO_2 atmospheric concentration; however, at present we have already reached the 400 ppm level (May 2013). The IPCC has also documented that in order not to reach a future global 2 °C increment, it would be required that the peak in annual emissions should occur not later than in the next 10–15 years.

In effect, according to the IEA Scenarios, from the representation in Fig. 1 of the annual CO_2 emissions future evolution, it can be observed that, if the present trends in emissions continue, in the year 2050 they would almost exceed the actual values by about 50%, corresponding to a temperature increase close to 6 °C (upper curve 6D in the figure) [4]. However, if emissions are drastically reduced (lower curve 2D) as proposed by the Blue Map Scenario, the temperature increase would only be 2 °C. Between both curves of Fig. 1, the partial contributions to the reduction of emissions by

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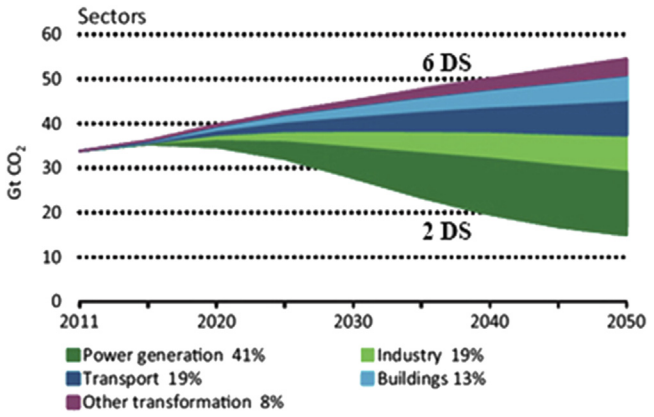

Fig. 1. Evolution (2011–2050) of CO_2 emissions for the current situation (upper curve 6D), and for the Blue Map Scenario (lower curve 2D). The vertical axis indicates the contributions of the different sectors to the CO_2 emissions abatement [4].

several technological sectors are indicated by several colored bands. Observe also in this figure that renewable energies can play a very important role (41%) in emissions abatement within the power sector. But also strong efforts to the decarbonization of the energy system are needed across many other sectors like transport (19%) and buildings (13%), which can contribute significantly [4]. As we have previously noted, even if we start now the strong limitations in emissions just mentioned, it will take still some years to turn down the slope of the lower curve (2D) of Fig. 1 and consequently, begin reduction of emissions.

The reduction of carbon emissions at the global scale can only be achieved if all major players in the world assume their responsibility for mitigating CO_2 emissions. At present, international negotiations towards a global treaty on the reduction of CO_2 emissions are taking place which should culminate in a new World Climate Change Agreement in Paris (December 2015) to be applied from 2020 onwards [5]. The Agreement will contain a set of commitments which will be applicable to all countries and implemented as national laws. In addition, the Agreement should contemplate the recent recommendations from the 5th Assessment Report of the IPCC [3]. Among all major countries in the world, the role that will played by the United States and China will be crucial. At present the top contaminating country in the world is China with emissions in 2013 almost doubling those of the United States which comes second. However, if one looks at CO_2 emissions per capita in 2013, the United States (21 tonnes/cap), Australia (18 tonnes/cap), Canada (17 tonnes/cap) are more than double those of China (7.4 tonnes/cap) [2]. However, on the positive side we would like to remark that the emissions per unit of gross domestic product, or carbon intensity, are diminishing at a fairly high rate in most places. As a consequence, in the case of China for instance, during the last years the rate of growth of emissions has been continuously decreasing and it is planned that in the near future this tendency will continue at a higher pace [2].

2. Past and present status of renewable resources for power generation

First, we would like to point out the tremendous growth of the main renewable resources for power generation during the last decade as shown in Fig. 2. Thus, in 2013 alone, 35 GW of wind power [6] and 40 GW of solar photovoltaics (PV) [7] were installed throughout the world, reaching the cumulative installed power the values of 319 GW and 140 GW, respectively, at the end of this year. To put these numbers into context, let us observe that in the case of PV, for instance, in order to reach the values predicted by the IEA Scenarios for the decade 2030–2040, the corresponding cumulative power increase will have to reach more than several thousand GWs, and therefore enter the terawatt scale (1 TW = 1000 GW) [4].

To better appreciate the past growth of PV, we have plotted in the left part of Fig. 3 the values of the PV cumulative installed power Q(t) since the mid-1970s, when the technique was already well established, up to the end of 2012 [8]. Evidently, the plot has to be represented in a log scale since the values of Q(t) have increased during this period by more than four orders of magnitude until it has recently (2013) reached a global value of about 140 GW [7]. One interesting observation from Fig. 3 is that, after a further future increase of one additional order of magnitude, Q(t) will enter the terawatt (TW) scale, as predicted by the IEA Blue Map Scenario for 2050 [9,10]. It should also be remarked that for a technique to play a significant role in the electricity mix, at the global scale, the corresponding power capacity should be of the order of a few TW. Finally, we would like to observe with the help of Fig. 3 that to reach a value of this magnitude, the annual growth rate of Q(t) from now to 2050 would only need to be on the average of about 7%, in contrast with previous growths of about 30–40% in the past. Note also that the proposed curve plotted in Fig. 3 after 2012 approaches

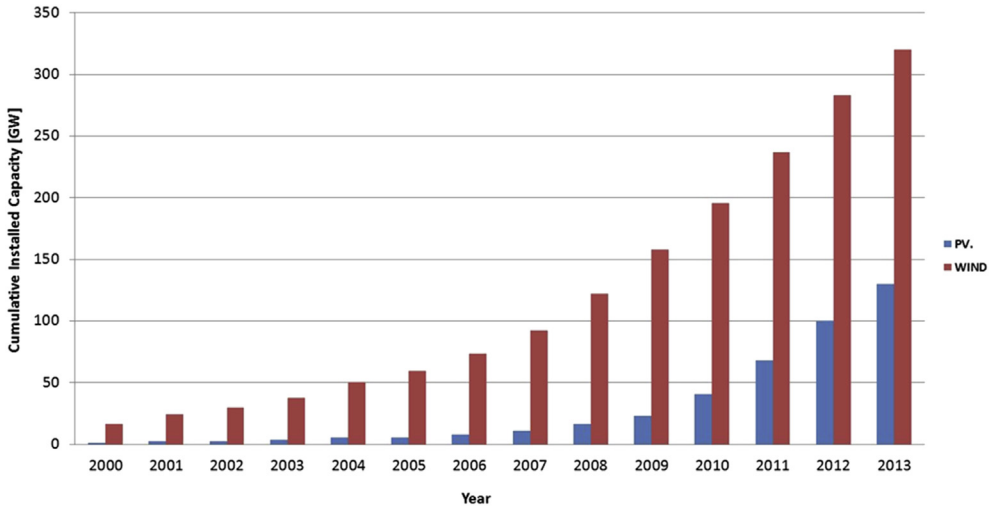

Fig. 2. Evolution (2000–2013) of the global cumulative installed capacity for wind power and solar PV [6,7].