ENERGIES FOR A SUSTAINABLE FUTURE

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ABSTRACT

Energy is one of the major problems the humanity will face in the coming century. While demographic and economic growths will require continuously increasing quantities of energy, it is today known that the natural reserve of oil, coal and gas that have been used since two centuries to provide the society's needs will have to be replaced by other sources. Beside the use of nuclear energy, that can provide a part of this energy, other sources have to be mobilised. Alternative ways to produce and consume energy already exist, but they have not been up to know massively developed, mainly because of their lack of economic competitiveness. This paper presents the state of the art of these technologies, and gives a insight on their future development.
Keywords: Energy, wind, solar, geothermic, biomass

1. Introduction

How far are our fossil fuel reserves limited ?

The World Energy Council (WEC) gives an estimation of the earth's fossil fuel reserves, as indicated in table 1. We can derive from these estimations the value of the "R/P" ratio, which gives the amount of remaining energy expressed in equivalent years of production of the year 2005. This ratio ranges from 36 years of oil (if we consider only the known reserve of conventional oil), up to more than 1000 years of coal (considering the estimated ultimate resource).

Tab. 1. *Fossil fuel reserves and resources (source WEC)*

Global fossil energy reserves, resources (Gtoe*)							
	Consumption 1850-2000	*Reserves*	*Resources*	*Resource Base*	*Production 2005*	*R/P (years)*	*Ultimate R/P (years)*
Oil							
Conventional	123	140	123	263	3.9	36	205
Unconventional	-	193	332	525			
Natural Gas							
Conventional	61	142	280	422	2.49	59	360
Unconventional	-	192	258	450			
Coal	148	600	2770	3370	2.88	205	1150
*Gtoe = gigatonnes (10^9) oil equivalent. Reserves + Resources = Resource Base. Sources: N. Nakenovic et al.: "Global Energy Perspectives", 1998. Cambridge Univ. Press for IIASA/WEC. BP Amoco "Statistical Review of World Energy", June 2000. Author's updates.							

In such a way that it can be concluded that there is no crucial risk of energy shortage, at least in the short term. Moreover, nuclear energy can be considered as a substitute to fossil fuels when the 4th generation fission reactors and fusion technology will be available.

But this optimistic vision must not hide some important realities :

- ✓ Even with large reserves, fossil fuels remain limited, specially if we consider that the energy world consumption continues to grow quickly (+2.5 % in 2005 according to the BP statistical review).
- ✓ Fossil fuels will remain strongly CO2 emission sources, even if capture and sequestration can reduce these emissions, but with a very high cost.
- ✓ The actual nuclear technology (3rd generation fission) consumes a resource (Uranium) that is itself a limited resource.
- ✓ The next generation nuclear technologies are today far from maturity, and will be much more expensive than the actual ones.

How abundant are renewable energies ?

Fortunately, fossil and nuclear energies are not the only one available at the earth's surface. Renewable energies have already been widely used by the humanity since its beginning, and they have today the potential to become an important alternative to the use of classical energies. One important thing to know is that they are really abundant. As an example, let us consider the energy available from the sun's radiation.

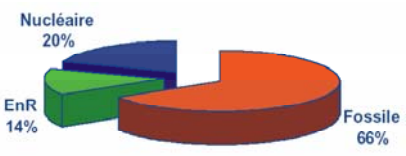
The sun is a huge mass of hydrogen and helium, emitting continuously an electromagnetic radiation deriving from the nuclear fusion reaction of its constitutive elements. This radiation reaches the terrestrial atmosphere with a density of about 1400 W/m^2, and our planet receives from the sun a constant heat flux of 1.8 10^{11} MW. In one year, the solar energy received is approximately 1.6 10^{15} MWh, i.e. 130 10^6 MTEP, or more than 10000 times the world's commercial energy consumption (10500 MTEP in 2005). At the ground level, this energy is reduced by the atmosphere's absorption, by earth's rotation, but in any case remains huge compared to our energy needs.

To give an order of magnitude, 5000 km^2 of photovoltaic panels, with an efficiency of only 10 %, would produce the same electric energy than the France's electricity consumption, (420 TWh). This surface is 1 % of the France's surface, or half of the surface occupied by buildings in this country.

How difficult is it to use renewable energy

With a so huge potential, the question arises to know why renewable energies, which are "inifinite" in the time (the sun's lifetime is 5 billion years), equitably available at the earth's surface, and "free", have not been used in a more intensive way.

World energy consumption – Repartiotion by source



World renewable energy consumption – Repartiotion by source

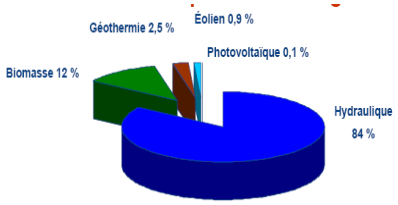


Fig. 1 –*Actual contribution of RES to the world's energy consumption*

As illustrated in fig. 1, Renewable Energy Sources (RES) amount for 14 % of the total energy consumption, but most of this contribution is due to hydraulic energy (large electric dams, 84 % of the RES contribution) and of biomass (wood boilers and firewood in developing countries, 12 % of the RES contribution). The remaining RES (wind, solar and geothermal) account for less than 1 %.

Two main reasons explain this situation :

- ✓ On a technical point of view, RES are intermittent and difficult to store. They are also distributed, which means that they produce small quantities of energy near the consumption sites, while the actual energy scheme is a centralised one, with a small number of large units producing important quantities of energy.
- ✓ On an economical point of view, Renewable Energy Systems are expensive in terms of investment. In such a way that the cost of the energy they produce is expensive compared to the actual market costs of fossil and nuclear energy, even if the energy source by itself (solar radiation, geothermal heat flux, …), has no cost.

We can then say that RES represent today an important energy resource, largely unemployed by lack of flexibility of use and of economic competitiveness. But since the energy landscape is moving very quickly, their potential market increases, and that is what is observed. In the 2 next sections, we give a quick overview of two of these renewable technologies, the wind and the photovoltaic energy.

2. Wind Energy

Technical maturity of the wind energy

Wind energy systems are systems which have been strogly modified and improved since 30 years. Improvements have been made on any of the components, which are the turbine itself, the mast, the mechanic converter, the electric generator, the electric converter, the control system, etc. The unitary size has increased and the investment cost has also strongly decreased.

In such a way that wind energy has today gained the rank in the energy competition of economically competitive systems. Private investors are today the main actors, and the wind industry has the capacity to lead by itself the research and development works that are needed to make the new turbines more competitive. This is illustrated in figure 3, wher we can see that, depending on the wind potential of a site, and the investment cost (between 800 and 1150 €/installed kW), the electricity is produced in onshore sites with a cost between 4 and 6 c€/kWh. Even if this cost is still higher than the cheapest conventional mean of electricity production (nuclear and coal), it remains competitive at the actual electricity market prices.

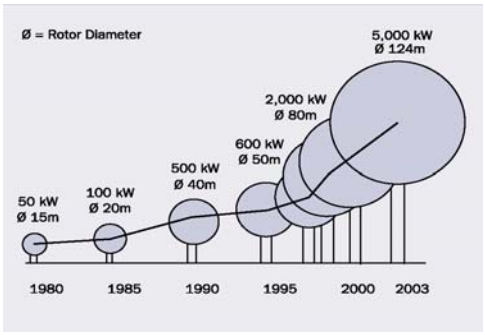


Fig. 2. *Evolution of the size ant he power of wind turbines (source EWEA)*

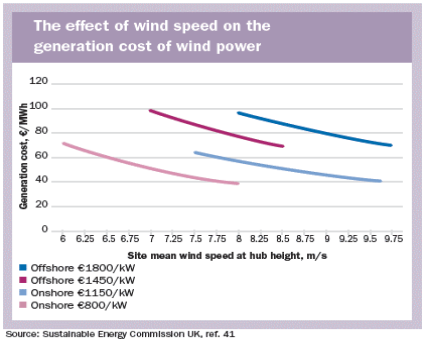


Fig. 3. *Cost of offshore and onshore wind energy*

The wind energy sector

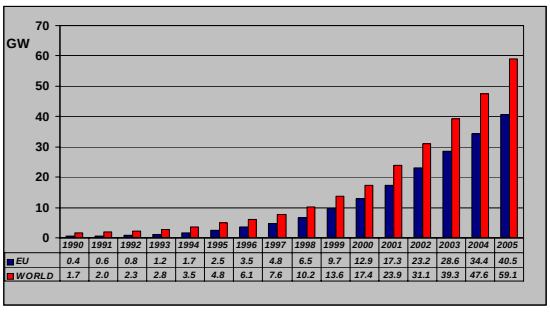


Fig. 4 - *Cumulative installed capacity (source EWEA)*

The figure 4 here over illustrates the exponential evolution of the wind energy market. The growth rates of the sector are impressive :

- 38.8 % in Europe over the period 1995-2000, and 25.7 % over 2000-2005
- 29.4 and 29.7 % respectively over the same periods at the world's level.

In some countries, wind energy begins to play more than a marginal role. Denmark expects in the coming years to reach more than 20 % of its electricity mad from wind energy

3. Photovoltaic Energy

Photovoltaïc energy is also a technology whose market is growing exponentially :

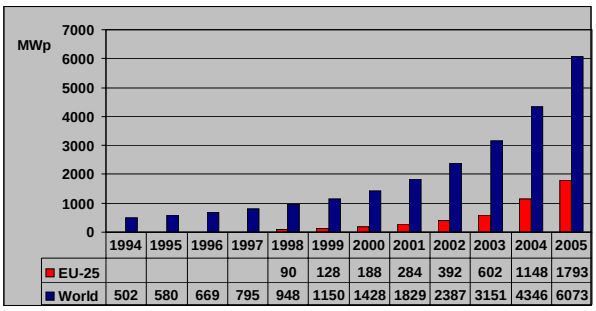


Fig. 5 - *Cumulative installed capacity (source EUREC, EPIA, Observ'er)*

However, its cost remain higher than other RES. The reason is that the manufacturing of PV cells is complex, it requires today the management of the Silicium technologies, which is expensive and leads to efficiencies that remain low (about 15 % today for crystalline cells).

On fig. 6, it can be seen that today, PV technologies can not be competitive at the actual energy market costs. However, many countries have decided ambitious politics in order to help the development of this sector. Japan is the oldest example, where the connexion of many MW of PV panels has been subsided by the Japanese government thank to the use of guaranteed feed-in tariffs. The Japanese PV industry has reached in some years the first rank, with 3 japanese firms in the top 5 of PV manufacturers. Similar programs have been undertaken in many European countries, and that is the reason why the market knows a so strong growth rate : this rate has reached 57 % over the 2000-2005 period !

Because of this strong evolution of the market, manufacturers expect to improve the manufacturing process as well as the cell's efficiency. PV energy could become competitive by 2030-2040.

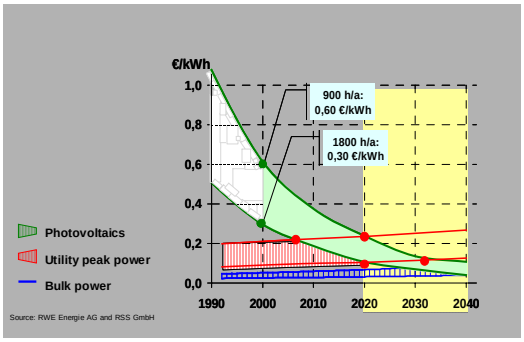


Fig. 6 *PV electricity costs, observation and previsions*

4. Conclusion

The human society has known since two centuries a very specific period of its history, dominated by a massive exploitation of fossil fuels. In a very short lapse of time (200 years compared to the 300 millions of year necessary for their elaboration), these fossil fuels have been depleted and the corresponding amount of CO_2 released in the atmosphere. This era will reach its end in the coming decades. New sources of energy have to be mobilised in order to allow the world's population to reach satisfactory conditions of live in a sustainable world. Renewable Energy Sources will be part of these resources. They have been not widely developed up to know only because fossil fuels were the cheapest solution to meet the humanity needs. Since the cost of RES systems will continuously decrease in the coming years, while the one of exhaustible resources will continue to grow, we have to expect to see RES play a more and more important role in the world's energy balance in a near future.