THE MANY FUTURES OF ENERGY

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→ | OVERVIEW

“Happiness is not an ideal of reason but of imagination.”

IMMANUEL KANT

ACCESS TO ENERGY IS considered a necessity for the survival and the development of individuals and societies.

The rich OECD countries are so addicted to energy availability in the daily life that even a temporary shortage of electricity or gas supply leads to a wave of panic and irrational behaviors, as recently seen during the Ukrainian crises. No energy today means no food tomorrow. Since the largest quota of the energy sources derive from oil, gas and coal, the control of those fuels is often considered a matter of national security.

In several developing countries, on the other hand, the chronic lack of energy services or their low affordability prevents any social and economic progress. Energy poverty can be dramatic even in regions with abundant resources, when they lack the infrastructures and the technology necessary for the distribution and use.

Access to energy is therefore a multi-dimensional issue involving social, financial and geo-political aspects beside the technical and geographical factors.

Nevertheless, the energy market has traditionally been a low-transparency business, based on a centralized control of the sources and the processes, with very little influence from the customers and low public attention. The less people know, the smoother it works.

Fortunately, the wheel is now moving. After the ineffective world summit in Copenhagen in December 2009, the energy debate has spread beyond the circle of the technical-scientific community and involves more actively the political level, the mass media and the civil society. The disequilibria of the present fuel-based system are more clearly perceived, especially the environmental damages created by carbon emissions and the perspective exhaustion of the fuels reserves.

The recent Energy Report from the International Energy Agency (IEA) suggests indeed that we are at the doorstep of a radical change in the way of producing and consuming energy and foresees different scenarios, each featuring specific advantages and supported by different groups of interest.

The following intends to offer an overview of the most promising opportunities for the future energy sector. For a better understanding of the discussion, the main energy-related concepts are summarized in the box.

THE «CLEAN» FUELS

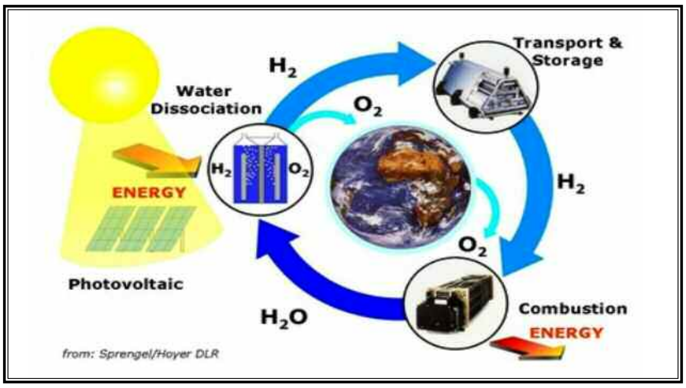
Since the known reserves of coal and natural gas appear sufficient to cover the world’s demand for another 150 years, utilities and big industries are investing in a technology called Carbon Capture and Storage (CCS), whose aim is to extract the carbon dioxide form the exhaustion gases and to store it underground as a liquid or solid waste.

Even if achieving a carbon-free combustion, those techniques present other environmental inconveniences, such as the absorption of a disproportioned amount of fresh water and energy (every third power station needs another one for the CCS only), resources that will be indeed more rare and valuable in the future.

In its 2008 Energy Report, for example, Greenpeace defines the CCS a “false hope”, since it will not be operative anyway before year 2030, it cannot eliminate the risk of gas leakages from the storage location and, most importantly, subtracts today crucial funds to the research on sustainable forms of energy.

RENEWABLE ENERGIES 'AT POWER 20'

Renewable energy sources include sunlight – collected either with photovoltaic or solar thermal techniques - wind power, hydropower, tides and waves, geothermal, biomasses (e.g. wood, plants, biofuels, micro-algae) and fermentation biogases. They represent altogether a niche segment, with an 8% production share in Europe and 2% worldwide, but showed a remarkable growth in the recent years. Europe differs from all other regions in its clear policy of subsidies and in the ambitious goal of achieving the quota of 20% by the year 2020 (the so called Directive "20-20-20").



The advantages of those sources are their quantitative abundance (usable wind power worldwide amounts at 200 times the global energy demand, solar irradiation 3,000 times), and their distributed availability which may guarantee independence from geo-political agreements (think of the benefit for the developing countries...) Moreover they are easily scalable to different sizes, from big power generation plants to micro domestic installations.

A strong limiting factor for renewable sources is the high cost of the installation in relation to the potential production: natural sources, dispersed and discontinuous, must be captured over a relatively large area and accumulated in some storage device (batteries, heat tanks, pressurized air).

The market potential however is really huge, and sufficient to attract research centers, manufacturers and energy suppliers into a "technological run" which is expected to achieve a decisive cost reduction of the renewable technologies, and their subsequent large-scale adoption. In particular, the segment of off-shore wind generators is living a golden season, with rate of growth of 15-20 % per year, and unit cost decreasing at 0.04-0.08 cent/kWh, thus competitive with the traditional fuel generators.

Also the civil and residential segment presents various innovations, such as the "solar tile" or the vertical-axis wind turbines, which tend to simplify their installation and the structural integration within the buildings.

The Energy Social Forum held in Stuttgart in January 2009 presented examples of energy sharing among small communities or multi-family groups. It was noted that a direct participation in the production cycle stimulates a more critical approach in the use and consumption of energy.

THE HYDROGEN ECONOMY

A different possible scenario is based on the use of hydrogen (H_2), a totally clean fuel releasing only water steam and easily convertible into heat, electricity, or motion of vehicles.

Several research projects and information groups are now active on that technology. The European Commission launched in 2006 the project "HyFleet" by sponsoring a fleet of 47 public buses, now circulating in ten EU cities with excellent results. BMW has manufactured a pre-series of 100 units of its 'Hydrogen-7', with satisfactory performances and driving range.

The Hydrogen technology, however, requires the development of complementary systems, such as storage devices or distribution networks, which still show poor efficiency and limited diffusion. The advent of the Hydrogen Economy – so baptized by Jeremy Rifkin in his best-seller dated 2002 – is therefore possible but highly uncertain.

NUCLEAR EXPENSES

The CO_2 alarm is pushing big investors and several governments like US, China, France and Italy towards a return to the nuclear power, a technology appreciated for the high energy productivity at low cost (0.02-0.04 Eur/kWh) and the virtual zero-footprint on the atmosphere.

Against new nuclear programs, however, both environmentalists and scientists like Nobel laureate Carlo Rubbia keep warning about two unsolved problems: the unsafe storage of the radioactive wastes (refer to the aborted "Yucca Mountain project" in USA, the biggest attempt ever to create a long-term storage facility) and the uncertain evolution of the costs, which are expected to ramp up in the next decades.

The nuclear energy represents a rigid model, highly centralized and requiring decade-term plans of inflexible operation. In a context of open market, growing flexibility, and diffusing alternative technologies, the nuclear choices appear strategically shortsighted.

WHAT A SMART GRID

The traditional power network is designed on a unidirectional model of energy distribution (from

PROPRIETIES OF ENERGY

ENERGY = the physical quantity associated to the dynamic processes and responsible for any activity or movement.

FORMS OF ENERGY = Gravitational (potential of an elevated mass), kinetic (mass in movement), Electrical, Magnetic, Chemical, Electromagnetic (light or radiation), Thermal, Nuclear.

SOURCES OF ENERGY = sunlight, wind speed, tides and waves, water jumps, biomasses, fossil fuels, nuclear fuels

CHANGE OF ENERGY FORM = transformation or conversion.

Example of a vehicle: chemical energy (fuel) -> kinetic energy (motion) -> heat (brakes).

Energy can be stored and transported, but the various forms are not equivalent in this respect. Optimal for storage are potential energy (e.g. pumping stations), chemical (in fossil fuel or batteries) and nuclear. On the contrary, electrical energy is very flexible to use and to be transmitted over long distances, but cannot be stored.

THE MAGNITUDES OF ENERGY

The international unit to measure energy is the Joule (J), a very tiny amount for the practical applications. One joule is the work of lifting by one meter a potato of 100 grams.

3,6 million joules equate 1 kilowatt-hour (kWh), the unit used by electricity suppliers.

8 million joules (2,000 calories) is the average daily energy intake for a working man.

The range of billion joules (gigajoules [GJ]) expresses the energy consumption per person in one year; Fig. 1 represents the differences between the average consumption in India (6 GJ), Europe (95 GJ) and USA (200 GJ).

In Industry, energy is often measured in equivalent tons of oil [toe], corresponding to 42 GJ circa. The world population in 2007 consumed 12,000 Mtoes (million toes), 80 percent coming from the combustion of oil, gas and coal (Fig. II).

DISTINCTION BETWEEN ENERGY AND POWER

While energy is a cumulated quantity, power is *the rate* at which energy is exchanged or consumed. If energy is thought as the water content in a recipient, power is the water flow through the tap, thus energy per unit of time, and is measured in watt (W) (joule per second).

The distinction between Power and Energy is important for intermittent energy sources, e.g. for wind generators. The installed power, expressed in kilowatt (kW) or megawatt (MW), indicates the peak generating capacity under full wind speed, and is related to the initial investment. The produced energy, instead, is the cumulated amount of kilowatt-hours produced in a day or in a year, and depends also on the wind behavior in the specific location.

Typical sizes for wind turbines are 200-500 kW up to 3 MW for very large units.

In comparison, the power of nuclear or fuel stations ranges from 600 to 2500 MW, equivalent to a park of hundreds large wind turbines.

EFFICENCY

In any conversion a quota of the incoming energy is not converted into the desired form, due to dispersion into heat, noise or other un-useful effects. The ratio between the desired output and the input is the efficiency, very important when comparing different solutions or different technologies (e.g. tungsten lamps vs LED lighting).

The higher the efficiency, the lower is the energy consumed to achieve the same result.

For practical and economical reasons, the efficiency tends to increase with the size of an apparatus. A 1000 kW generator is normally more efficient than 10 generators of 100 kW. This factor is key when choosing the optimal scale of a power installation or network.

the power station to final users) and cannot sustain more than 25-30% of renewable sources without risks for its operative stability. To overcome such limitations new power grids equipped with intelligent and inter-communicating devices are being developed. The "smart grids" will allow real time transits of energy among users and a high number of distributed generators, similarly to how Internet works out the exchanges of information among single computers.

The smart grid technology represents a focus of the US Energy program promoted by the Obama's administration, and is being implemented as first step through the installation of intelligent energy controllers and meters in several US cities.

Also the European Commission has included the smart grids in its strategic research agenda, promoting a dedicated funding within the current Framework Program 7 running until year 2013.

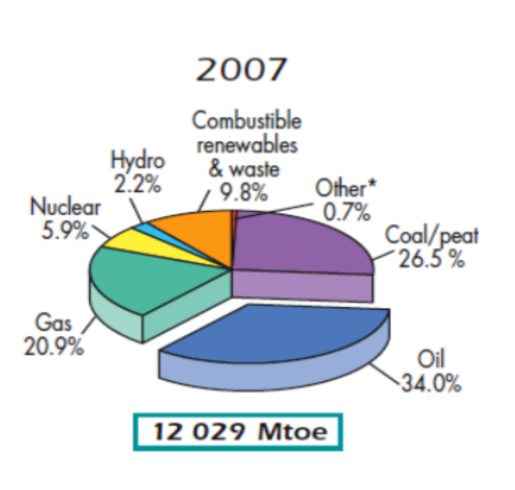


FIGURE I

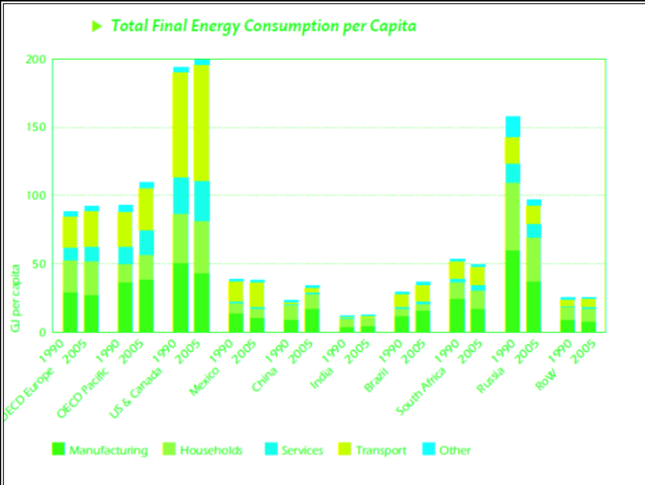


FIGURE II

FUTURISTIC ENERGIES

Beside the technologies described above, other futuristic lines of research have now been launched, normally sponsored by public funding, in the hope of achieving a prototype and perhaps practical applications in a few decades.

An important project concerns the nuclear *fusion,* the reaction between hydrogen isotopes occurring inside the stars, which can provide a virtually unlimited amount of energy with minimal environmental impact. Through one of the biggest technological cooperation of our era, the governments of US, Europe, Japan, Russia, China, Korea and India have started in 2006 the project ITER, with the scope of realizing a prototype of large fusion reactor, now under construction in the site of Cadarache (South France). Skeptical voices object that the intrinsic difficulty of dealing with a core material at a temperature of some-million degrees makes the whole project extremely uncertain and practically unrealizable before 30-40 years.

Another interesting direction relates to the greenest dreams of the mankind: replicating the natural photo-synthesis processes of plants and leaves, to capture sunlight energy and atmospheric carbon at the same time. The Massachusetts Institute of Technology (MIT) with its program 'MIT Energy Initiatives' is now at the forefront of that line of research, expecting operative results within the current decade.

Last but not least, the project SERT of the NASA is exploring the futuristic technology of the "space solar". It consists of a park of solar panels installed on satellites, able to transmit power to a receiving station on Earth through a microwave or a laser beam. The critical factor is the long distance between transmitter and receiver, but the possibility to exploit permanent irradiation, independent from meteorological circumstances, represents the attractive advantage.

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