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Preface

A typical European consumes about 4 kW power. This includes the energy use related to all economic activities. This consumption is much above the biological needs of 100 W to maintain the body's metabolism. In a certain way, we all enjoy the exclusive work of 40 "slaves" caring for our life and well-being. The enhancement factor of 40 is not for free: The natural resources human beings have learned to exploit efficiently will come to an end over the next decades and the environmental damages caused by the CO_2-producing fossil fuels become obvious and are palpable. But mankind will continue to grow and the UN expects about 9 billion people on Earth in 2050. As a corollary, the present energy demand is expected to double. The primary problem is the growth of mankind; the secondary problem is the necessary supply of energy. Recent studies show a link between demographic development and energy availability: Demographic growth comes to a halt only if sufficient energy per capita is available. A *circulus vitiosus* closes.

The most critical future issue is therefore to supply mankind on Earth with clean and sufficient energy. Without it, it is difficult to see how a peaceful co-existence on Earth will be possible. It is a tremendous task for science and technology to provide the necessary energy sources for the future, which allows for a sustainable development. Most important is to save energy. A consequence of this goal could easily be that the demand of electricity will grow. As this is the most flexible form of energy, the safe and economic production of electricity deserve specific attention. But also transportation is of utmost importance facing a global world and the benefits of open markets.

There is no "silver bullet" which solves all these issues. Like in the past, several energy forms will be used in parallel, which, however, still have to be developed. As this takes time, also existing technologies as "bridging technologies" will play an important role for the next decades. Therefore, it is necessary to further improve materials, which allow increasing the efficiency of thermal power plants and maximally using the energy stored in the primary fuel. In this category belongs also the development of CCS technologies, the separation and sequestration of the inescapable CO_2 production of fossil fuels.

Three classes of supply systems provide long-term solutions: 1) Renewable energies (RE) in their different forms, 2) fission on the basis of fast neutrons and 3) fusion.

The scalable forms of RE are wind and solar systems; bio-mass, hydro-electricity and geothermal energy are limited or only of local importance. Wind and solar techniques reflect the unpredictability of nature and do not represent "guaranteed" energy. They have to be supplemented by back-up or storage systems. Fission reactors on the basis of fast neutrons have to be developed. They promise intrinsically safe operation, a higher system flexibility and internal incineration of byproducts with high radio-toxicity. Fusion would provide a clean and safe electricity source without fuel limitations. Its waste does not need storage over geological time scales.

None of these systems is developed in a satisfactory form. There is the need for photovoltaic material with higher efficiency to further reduce the system prices. Scalable storage systems for RE will most probably be on chemical basis involving hydrogen or, with higher energy density, hydrocarbons. The development of chemical storages may also lead to a fuel for future transportation. New fission power plants are developed in the frame of the Generation-IV concepts. The replacement of the light-water and pressurized-water reactors as they were commissioned in the '70s of the last century by modern types of Generation III might substantially improve the safety of fission energy production.

The development of economic storage systems, Generation IV and fusion reactors will take decades. Also the market penetration of these systems will take a long time. Many of the basic ideas involved are available for a long time. Alessandro Volta discovered the battery in the 18th century; the fuel cell was introduced by William Grove mid-19th century; the Sabatier reaction between CO_2 and hydrogen yielding methane is known since 1902; fusion is under development since the 1950s. It takes a long time to develop the components of modern energy supply systems and several generations have to work on it. It is a field of true interdisciplinary nature because physicists, chemists, material scientists and engineers have to work together.

The first Course of the Joint EPS-SIF International School on Energy was meant to provide a wide review of *New Strategies for Energy Generation, Conversion and Storage*, covering major fields with detailed lectures and topical seminars. The School, which made its debut in the summer of 2012, is the result of a collaboration initiative between the European (EPS) and the Italian (SIF) Physical Societies. The Courses are foreseen to take place on a biannual basis in the beautiful venue of Villa Monastero in Varenna, Lake Como, Italy.

It was the purpose of this summer School to bring together scientists of the different disciplines with relevance to energy technologies with young scientists who work in this field or plan to do so. The School gathered about 70 participants —lecturers, observers and students— of nearly 20 different nationalities. The lectures were delivered by 18 experts in various fields. Lively discussion sessions and student's talks were also oganized. (See: `http://www.sif.it/attivita/scuola_energia#presentations`)

Teaching and training the next generation of scientists is an important aspect in energy R&D. Not all, but many important areas of energy supply and distribution were covered —nuclear and non-nuclear techniques. The Proceedings of the School, published as *Lecture Notes*, conserve the teaching material presented and serve as a reference book for both specialists working in one of the energy fields but with interests in the status of other energy-related areas, and non-technical readers who want to get a general overview on the involved techniques and their prospects. The importance of energy as a field of "survival sciences" has to be made clear to the public and it has also to be made immune by objective information against the distorting economic and political lobbyism as it is unfortunately typical for this field.

In addition to the written versions of the School lectures, a few contributions selected as the *Best Student's Presentations* during the School are included. The *Summary and Highlights* are derived from the concluding remarks presented at the end of the School by one of the observer-participants, as wanted by one of us (L.C.) in order to get a real-time feedback of the actual message conveyed by such a School on energy.

We are specially grateful to all our distinguished colleagues who have accepted to write and timely provide their contributions for these *Lecture Notes*. Our thanks go as well to the Scientific Secretary of the first Course of the School, Matteo Burresi, and to the staff of the Italian Physical Society for their warm and efficient hospitality in Varenna.

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