Preface

The preparation of a book has always been, and will continue to be, a complex and challenging task. This is my fifth book on energy matters. The first three books were dedicated to the use of different energy sources for the generation of electricity in the Latin America and the Caribbean region and on the use of nuclear energy at world level. One of these books was dedicated to the use of oil, natural gas, and coal for the generation of electricity, and the second to the use of different renewable and nuclear energy sources for the same purpose in the Latin America and the Caribbean region. This book is the second of two books dedicated to the use of conventional, renewable, and nuclear energy sources for the generation of electricity in the European region. In this particular book, the role of different renewable energy sources and nuclear energy in the regional generation of electricity is presented.

Providing a stable and secure supply of energy is a great challenge for governments seeking to achieve sustainable development goals, since most of the main energy sources providing economic growth and social development are present on the Earth only in specific locations, some of them under great political turmoil and instability, and in limited quantities.

Energy is, undoubtedly, an important element in the struggle of any country to alleviate poverty, promote economic growth, and foster social development. But as the world consumes more and more energy, stress is placed on current level of energy reserves and the environment at national, regional, and international levels. For this reason, the world should work together to safeguard the environment, but without slowing socioeconomic development, particularly in developing countries. Third World countries should look for adequate technological solutions in order to change present unsustainable patterns of consumption and production in developed countries and to seek the low-hanging fruit and the win–win solutions that provide the least costly ways of achieving sustainable development goals.

The book has nine chapters. Chapter 1 gives to the readers a general overview of the current situation and the future role that could be played by different energy sources in the generation of electricity in the European region. According to expert opinions, the use of energy at world level will continue to increase gradually until 2030. As a result of studies made by the French Association of Oil Professionals,

it is expected that for 2030, the world energy demand will be double and it is probable that it could be triple for 2050. Until 2030, the primary energy demand at world level is expected to increase annually at 1.7 %, which is somehow smaller than the world growth of 2.1 % registered during the past three decades. It is also expected that 90 % of the increase in the world energy demand in the coming decades will be satisfied with fossil fuels. If this forecast is true, then around 15,300 million tons of oil equivalent (112,500 million of barrels of oil) will be consumed at world level in 2030. Electricity production will account for 32 % of total global fossil fuel use.

In the specific case of the European region, fossil fuels, such as oil, natural gas, and coal are, by far, the largest sources of energy and are widely projected to dominate the European energy mix through to at least 2030. The European Commission's Energy Roadmap 2050 identifies natural gas as a critical fuel for the transformation of the energy system. The substitution of coal and oil with natural gas in the short to medium term could help to reduce emissions with existing technologies until at least 2030–2035. In Europe, the net growth in the past 11 years of natural gas power (118.2 GW), wind power (75.2 GW), and solar photovoltaic (solar PV) (26.4 GW) was at the expense of fuel oil (down 13.2 GW), coal (down 9.5 GW), and nuclear energy (down 7.6 GW). In the specific case of the European Union (EU) power sector, countries continue to replace aging fuel oil, coal, and nuclear power plants with modern technology, while at the same time increasing its total installed capacity to meet growing energy demand in the coming years. The use of renewable energy sources for the generation of electricity is expected to increase during the coming decades in all EU countries. In some of them, it is expected that the use of nuclear energy for the generation of electricity will also increase, while in others the use of this type of energy source is not included in their future energy mix or it will not be part of the energy balance in the future, such as is the case of Germany, Switzerland and Belgium, just to mention three countries as examples.

Chapter 2 provides to the readers with the latest information about the current and future role to be played by different renewable energy source for the generation of electricity in the European region. The book will highlight the increase in the deployment of renewable energy sources in the past decades and how this development has increased rapidly in recent years. Various types of government policies, the declining cost of many renewable energy technologies, changes in the prices of fossil fuels, an increase in energy demand, among other factors, have encouraged the continuing increase in the use of renewable energy sources for the generation of electricity in several countries from all regions, particularly in several EU countries. Despite global financial challenges, renewable energy capacity continued to grow rapidly compared to the cumulative installed capacity from the previous year.

In 2013, a total of 25.4 GW of new renewable power capacity was installed in the region. Over 72 % of all new installed capacity in the EU was renewable. It was, furthermore, the sixth year running that over 55 % of all new power capacity in the EU was renewable. The major increases were registered in wind power

by 44 %, followed by solar PV by 43 %, biomass by 6 %, and hydropower by 5 %. The EU energy mix in 2013 was the following: Natural gas had the major share with 22 % of the total, followed by coal with 19 %, hydropower with 16 %, nuclear energy with 14 %, wind power with 13 %, and solar PV with 9 %.

The development of renewable energy sources, particularly energy from wind, hydro, solar, geothermal, hydrogen, and biomass is a central aim of the European Commission's Energy Policy. Undoubtedly, the exploitation of renewable energy sources will help the EU to meet many of its environmental and energy policy goals, including its obligation to reduce greenhouse gases under the Kyoto Protocol and the aim of securing its energy supply. Despite the reduction in electricity demand renewable energy source deployment has continued during the past years. This is a result of various national support schemes—in particular for solar PV and wind onshore—but also of constant technological improvement, decreasing prices (in the case of solar PV also due to a supply surplus), and greater supplier competition, which have all led to successful cost reductions. According to the EC, the EU is on track to meet its 2020 renewable target. But in 2012 some parties also voiced doubts because the current economic crisis could oblige some EU member states to downsize their renewable policies and thus jeopardize the implementation of their National Renewable Energy Action Plans (NREAPs) approved by the EC.

It has been estimated that the renewable energy sources' share in the electricity sector would be around 35 % in 2020, if the 20 % target for renewable energy sources is achieved. In the EU, renewable energy sources accounted for almost 70 % of the additions to electric capacity in 2012, mostly from solar PV and wind power. In 2011, renewable energy source met 20.6 % of the region's electricity consumption and 13.4 % of gross final energy consumption. Renewable energy sources made up just over half of total net additions to electric generating capacity from all sources in 2012. By the year's end, they comprised more than 26 % of global generating capacity and supplied an estimated 21.7 % of global electricity, with 16.5 % of electricity provided by hydropower.

Chapter 3 provides to the readers the latest information on the use of hydropower for the generation of electricity. Undoubtedly, hydropower is the major renewable generation technology in Europe today. It delivers storage capacity and stabilizing services for the power system, which are crucial for a high security of supply of electricity. Hydropower is a mature and cost-competitive renewable energy source and a key component of the energy mix in several EU countries, and it plays a key role in today's electricity mix in other regions of the world as well. As a multifunctional technology, it is indispensable to the electricity system, and will be even more important tomorrow, particularly, when other fossil fuels used today for the generation of electricity, particularly oil, will not be sufficient to satisfy the foreseeable energy demand during the coming decades.

When assessing the future of hydropower utilization in Europe, two basic influencing factors must be distinguished: (i) A change in exploitable river flow, mainly induced by climate change, and (ii) A change in the existing hydropower installed capacity in the individual countries. The book will highlight the following:

In Europe, hydropower is the main renewable electricity generation source (69 %), followed by wind (15 %), primary solid biomass (7 %), municipal waste (4 %), biogas (3 %), solar (1 %), and geothermal (1 %) power generation.

Chapter 4 provides to the readers the latest information on the use of solar energy for the generation of electricity. At the end of 2010, about 38 GW of grid-connected solar PV power was installed globally, producing about 40 TWh of electricity on a yearly basis. Europe has a cumulative installed capacity of more than 25 GW, making it the largest world market (65.8 % of the total). In 2011, the EU's solar electricity production was 44.8 TWh, with 51.4 GW installed capacity, an increase of up 98 % with respect to 2010. In 2011, in the EU new installations were 21.5 GW. The solar power share in 2011 was around 3.6 % in Italy, 3.1 % in Germany, and 2.6 % in Spain. It is expected that the total solar energy installation could reach at least 120 GW in 2020 reducing the use of fossil fuels and, in some cases nuclear energy, for the generation of electricity. The national strategies support the building of 84 GW solar capacity in 2020, which may underestimate the actual development taking place.

In 2012, available efficiencies in solar PV exceeded 20 %. The cost of producing solar PV electricity has fallen dramatically over the past decades, but it is still only competitive in niche (usually remote) standalone applications. Worldwide, solar PV sales reached 6 GW in 2010 with an important portion for decentralized power generation. In the EU-15, it is estimated that a significant market potential exists, perhaps as high as 2,000 MW, compared with 52 MW in 1995 and around 200 MW in 1999. During 2002, installed solar PV capacity in the EU grew some 37 % to 392 MW. The total installed capacity of solar PV systems in the EU at the end of 2009 was 7.2 GW, approximately 2.2 % of total electrical capacity. However, the solar PV market is still incipient. In the EU, only 0.4 % of total supplied electricity came from solar PV in 2009. Out of the 27.5 GWe of total new power capacity constructed in the EU in 2009, solar PV accounted for about 21 % (5.8 GWe, up from 5.1 GWe in 2008). In 2012, more than 69 GWe of solar PV was installed at the global level, producing 85 TWh of electricity in that year. This energy volume is sufficient to power annually the supply needs of over 20 million households. However, it is important to highlight that the amount of new solar power installed in Europe in that year fell sharply for the first time in more than a decade. New installations fell from 21.53 GW in 2011 to 17 GW in 2012. As a result of this decrease, Europe's share of new capacity, down from 74 % to 55 % (19 % reduction) in what the solar industry said was a turning point in the global solar PV market that will have profound implications in the coming years.

On the other hand, after about a decade of low development, the concentrated solar thermal power sector (CSP) is now reviving, notably due to a favorable supporting framework in Spain and increasing investments in the USA. In Europe, a parabolic trough power plant with a power capacity of 50 MWe and 7.5 h of storage (Andasol 1) is in operation in Granada, Spain. Two more plants of 50 MWe each are scheduled to be built on the same site. Central receiving systems (solar tower) are the second main family of CSP technology. An 11 MWe saturated steam central receiver project, named PS 10, has been operating since March 2007

in Andalusia, Spain. This is the first commercial scale project operating in Europe. Solar Tres is another project under development in Spain based on a molten salt central receiver system. Parabolic Dish engines or turbines (e.g., using a Stirling or a small gas turbine) are promising modular systems of relatively small size (between 5 and 50 kWe), in the development phase, and are primarily designed for decentralized power supply. The solar only average load factor without thermal storage of a CSP plant is about 1,800 to 2,500 full-load hours per year. The level of dispatching from CSP technologies can be augmented and secured with thermal storage or with hybrid or combined cycle schemes with natural gas, an important attribute for connection with the conventional grid.

Total global CSP capacity in the European region increased more than 60 % to about 2,550 MW. Most of this capacity was added in Spain, home to more than three-fourths of the world's CSP capacity. No new capacity came on line in the USA, but about 1,300 MW was under construction. Falling solar PV and natural gas prices, the global economic downturn, and policy changes in Spain all created uncertainty for CSP manufacturers and developers.

Chapter 5 provides to the readers the latest information on the use of wind energy for the generation of electricity. Wind power is the single largest non-hydro renewable power generation source in the EU. Since 2000, wind power capacity has grown from 12,800 MW to 96,443 MW in 2012 and to 117,300 MW in 2013: 110.7 GW onshore and 6.6 GW offshore; this represents an increase of 9.1-fold in the last 14 years and 13 % of the total energy capacity installed in the EU. In 2013, a total of 1,159 MW of new wind power capacity (worth between € 13 billion and € 18 billion) was installed in the EU-28, a decrease of 8 % compared to 2012 installations.

During the period 1997–2013, wind power capacity has grown more than estimated: in 1997 wind power capacity was estimated to be 40 GW in 2010, but that figure was reached in 2005; in 2013 wind capacity reached 117.3 GW, around 192 % more than the capacity was planned for 2010. During the period 2000–2012, the wind power capacity increased to 271 %. In 2009, wind power installations accounted for 39 % of new power generating capacity installations in the EU. In 2012, the new wind power installations represented 26.5 % of all new power capacity installed, 12.5 % lower than in 2009, but 5.1 % higher than in 2011; 2012 is the year with the highest wind power plants installed in the EU during the period 2000–2012.

In 2011, wind power generation in the EU totaled 181.739 TWh, representing about 4 % of the total net electricity generation. Germany and Spain are the largest wind power producers, together accounting for 63 % of installed capacity. In Denmark, wind power accounted for almost 20 % of the net electricity generation, and in Spain and Portugal this figure was 10.6 % and 12.8 %, respectively. Despite the decrease in annual wind power installations in the EU, global installed wind power capacity increased by 24.1 %, and now stands at 197 GW. For most other sectors that have not become accustomed to growth rates of 30 % or more, this would represent a major achievement. The main markets driving growth continue to be Asia and Europe, which installed 21.5 GW and 9.9 GW, respectively, in 2010.

In 2011 the overall investment in wind power reached US$ 96 billion, according to Bloomberg New Energy Finance (BNEF). It is notable that 38 % of this total investment was accounted for by China and by large European offshore wind farms.

According to EWEA 2011, investment in EU wind farms in 2010 was € 12.7 billion. The onshore wind power sector attracted € 10.1 billion during 2010 (79.5 %), while the offshore wind power sector accounted for around € 2.6 billion (20.5 %).

European electricity generation is projected to increase at an average annual rate of 1.3 % in the decade 2010–2020, and 0.8 % in the decade up to 2030. If the reference scenario is reached, wind power production will increase up to 477 TWh in 2020 and 935 TWh in 2030. The EC's baseline scenario assumes an increase in electricity demand by 33 % between 2005 and 2030 (4,408 TWh). Assuming that EU electricity demand develops as projected by the EC, wind power's share of EU electricity consumption will reach 11.7 % in 2020 and 21.2 % in 2030.

Chapter 6 provides to the readers the latest information on the use of geothermal energy for the generation of electricity. Europe is the world leader in geothermal direct use. Geothermal is used in 32 European countries, mainly for space heating, bathing, and balneotherapy, than for heating greenhouses, aquaculture, and industrial use. However, except for Iceland, geothermal energy is not a main player among renewable energy source in Europe, although many regions have prospective resources which can be applied on a wide scale, especially for heating.

Geothermal electric generating capacity grew by an estimated 300 MW during 2012, bringing the global total to 11.7 GW and generating at least 72 TWh. The total production is projected to increase to 10.4 TWh in 2020. China remains the presumptive leader in direct geothermal energy use (21 TWh in 2010), followed by the United States (18.8 TWh in 2012)[1], Sweden (13.8 TWh in 2010), Turkey (10.2 TWh in 2010), Iceland (7.2 TWh in 2012), and Japan (7.1 TWh in 2010). Iceland, Sweden, Norway, New Zealand, and Denmark lead for average annual geothermal energy use per person. About 90 % of Iceland's total heating demand is derived from geothermal resources.

Although there is limited data available on recent growth in direct use of geothermal energy, output is known to have grown by an average of 10 % annually from 2005 through 2010; much of that growth was attributed to ground-source heat pumps, which experienced an average annual growth of 20 %. Assuming that these growth rates have persisted in the last two years, the global geothermal heat capacity reached an estimated 66 GWth in 2012. GHP represents the largest and historically fastest-growing segment of geothermal direct use. In 2012, it reached an estimated 50 GWth of capacity; this amounts to about three-quarters of estimated total geothermal heat capacity, and more than half of heat output. Of the

[1] The largest geothermal development in the world is The Geysers located north of San Francisco in California, USA.

remaining direct heat use (nearly half), the largest share goes to bathing and swimming applications, with smaller amounts for heating (primarily district heating), industrial purposes, aquaculture pond heating, agricultural drying, snow melting, and other uses.

Heat pumps can generate heating or cooling and can be used in conjunction with combined heat and power (CHP) plants. Global installed heat pump capacity doubled between 2005 and 2010, and it appears that this growth has continued in subsequent years. In the EU, GHP capacity rose by about 10 % between 2010 and 2011, to a total of 14 GWth, led by Sweden (4.3 GWth), Germany (3 GWth), France (1.8 GWth), and Finland (1.4 GWth).

In 2008, the total installed capacity of geothermal power plants in the EU was near 700 MW. In 2011, geothermal power capacity installed in Europe reached 1,690 MW. Over 50 % of the installed capacity is located in Italy, while there are also some applications in Iceland and Turkey. Greece had a 2 MW geothermal power plant capacity until 1999, but since then the installed capacity in Greece has been removed. In Europe, the total power production from geothermal power plants was 14.832 billion kWh in 2012.

Chapter 7 provides to the readers the latest information on the use of biomass energy for the generation of electricity. Biomass is a special source of renewable energy in a number of ways. First, it can directly provide all three types of energy carriers: electricity, heat, and fuel (liquids, solids, and gas). Second, it is easily storable and dispatchable; when there is not enough sun or wind, biomass-fired generators can be ramped up as need be. Third, the major drawback: biomass requires strict management to be sustainable. No matter how many solar panels we install, we will not use up the sun any faster, nor will we measurably reduce the amount of wind on Earth if we keep installing wind turbines. But with biomass, we have to avoid resource depletion, prevent monocultures from reducing biodiversity, and ensure that the energy needs of rich countries are not met at the expense of food needs in poor countries.

In 2005, EU-27 electricity production from biomass was 102 TWh. Biomass sourced electricity production is forecasted to increase to 232 TWh in 2020; this represents an increase of more than double the level reached in 2005. Largest additions in biomass-sourced electricity are expected in Germany, UK, France, the Netherlands, and Italy. In Europe, biopower capacity increased by almost 2 % in 2012 to 31.4 GW, and generated around 136 TWh. Of this total, 35.9 TWh was produced by biogas in CHP plants, and 18.2 TWh was generated by the renewable municipal solid waste. Germany, Europe's leading biopower producer, increased its generation by 11 % to 41 TWh, with half of this coming from biogas power plants. Total biopower capacity rose from 0.3 GW (mostly biogas CHP plants) to more than 7.6 GW, although new construction slowed in 2012 relative to previous years. Germany's CHP plants generated 20.5 TWh of electricity in 2012 (up from 17.5 TWh in 2011, an increase of 17.1 % with respect to that year), amounting to around half of Europe's electricity generated with biogas.

Biomass-fired power plant's output increased from 38.7 TWh in 2000 to 102.1 TWh in 2008, which makes biomass the second largest renewable electricity source in the EU. Germany has more than quadrupled its biomass electricity generation from 2000 to 2008. The second largest bioelectricity producer, Sweden also almost tripled its bioelectricity production, while in Finland growth has been slower. According to the document entitled "The Market for Biomass Power Plants in Europe" electricity generation from biomass in the European region is expected to increase by 2,900 MW by 2013, especially in the UK and France. Currently, about 800 biomass power plants are operational in the European Economic Area.

Chapter 8 provides to the readers the latest information on the use of nuclear energy for the generation of electricity. Currently, the EU-28 generated in 2013 a total of 833.2 TW or around 25 % of its electricity from 131 nuclear power reactors currently in operation in 14 countries. According to expert opinion, and based on the commitments adopted by the European countries regarding the Kyoto Protocol, the above-mentioned proportion should be maintained or increased in order to meet the 2020 target, with an increase in the actual wattage generated to meet increasing power demand.

If no actions are taken to solve the above-mentioned problems in the coming years, the participation of nuclear energy for electricity generation in the European region will decline notably due to the following reasons:

- There are only 18 nuclear power reactors under construction in 6 countries, three of them EU member states. These 6 countries are: Belarus (2), Finland (1), France (1), Slovakia (2), Ukraine (2), and the Russian Federation (10);
- The closure of 98 nuclear power reactors, due to the extinction of their exploitation license;
- The prohibition of the construction of new nuclear power reactors in Belgium, Switzerland, and Germany;
- The implementation of the phase-out policy adopted by a group of European states, such as Germany and Sweden, among a few others.

Finland is one of the two European states that is constructing a third-generation PWR, the so-called "EPR system". It was expected initially that the nuclear power reactor under construction would be connected to the electric grid in 2009, but a delay in the construction of the unit has made it impossible to respect this deadline. The possible date for the connection of the nuclear power reactor to the grid is 2018. The other EU country that is constructing a third generation of nuclear power reactor is France. French state-owned power generating company, Électricité de France (EdF), is building, since 2007, an EPR system in the country. At the same time, in Eastern Europe the Bulgarian government awarded a contract for the construction of two units, Slovakia has two units under construction, Poland has taken the decision to build a nuclear power plant in the future and is taking the necessary steps for the implementation of its decision, and Romania has restarted building a nuclear power reactor that was mothballed 15 years ago. Within the European region, Russia has the largest plan for the construction of new nuclear power reactors in the coming years with ten units under construction and Ukraine has two units.

Outside the EU, the Swiss parliament approved the closure of nuclear power reactors currently in operation in the country, when the operating lifetime of the country's five existing units ended. Germany will shut down all of their current units in operation before 2022. On the other hand, the British government has planned to build ten nuclear power reactors in the coming years and the industry has requested the British's government to reduce regulatory and planning risks associated with the construction of nuclear power reactors in order to encourage the private industry to support the construction of new units in the country in the future. In other EU countries, with the exception of Poland and perhaps Lithuania, their governments have decided not to use nuclear energy for the generation of electricity in the future.

Chapter 9 provides a summary of all chapters.

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