Chapter 2
The Evolution of the Demand for Primary Energy and Electricity in Spain

In the past, electricity production in Spain was most dependent on coal, but it transitioned quite rapidly to gas after building the Pedro Duran Farell gas pipeline (1996) connection with Algeria through Morocco and then a second pipeline directly from Algeria (Fig. 2.1). Spain has the largest liquefaction and regasification network port terminals in Europe to produce and transfer liquid natural gas (LNG). Natural gas was implemented rapidly for several reasons: (1) the Spanish government attempted to comply with the Kyoto Protocol by trying to decarbonize, (2) it was accessible in huge amounts via pipeline from Algeria, and (3) Spain has the best regasification infrastructure in ports and one of the best LNG tanker fleets in Europe to bring it from gas producers in Africa. The result has been an increasing dependence on imported oil, gas and a continued, although lessened, use of imported coal, along with a resultant drain of foreign exchange used to pay for the imported fossil fuels (Fig. 2.2).

Recent Evolution of the Spanish Electricity Supply

Spain first implemented a special program to develop renewable energies in 2004. Given that most of Spain is a dry, even semi-desert country, with extremely abundant sunshine, it would seem to be one of the most reasonable places in the world to develop an extensive solar power system (Fig. 2.3). This would require a substantial program integrating engineering, grids, financial incentives and good policy. Consequently, the Spanish government started a very large program with the objective to reduce Spanish dependency on fossil fuels and to minimize the foreseeable economic impacts of meeting Al Gore's Kyoto Protocol on climate change. Spain basically followed the German "feed-in-tariff" (FIT) policy approach to renewable energies. This policy is based on the government requiring utilities to provide renewable generators with a long-term fixed price for electricity, based on either a system's generation costs or fixed premium tariffs paid on top of the spot market

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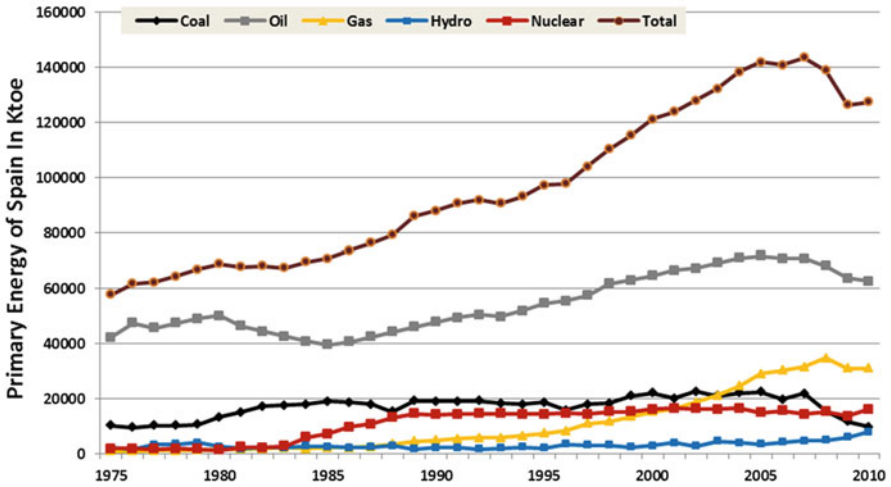

Fig. 2.1 Evolution of primary energy generation in Spain (1975–2010). *Source*: La energía en España (2010). Ministerio de Industria, Turismo y Comercio, p. 333). This source does not include renewable energies outside of hydropower (1 kilotonne oil equivalent = 42 terajoules)

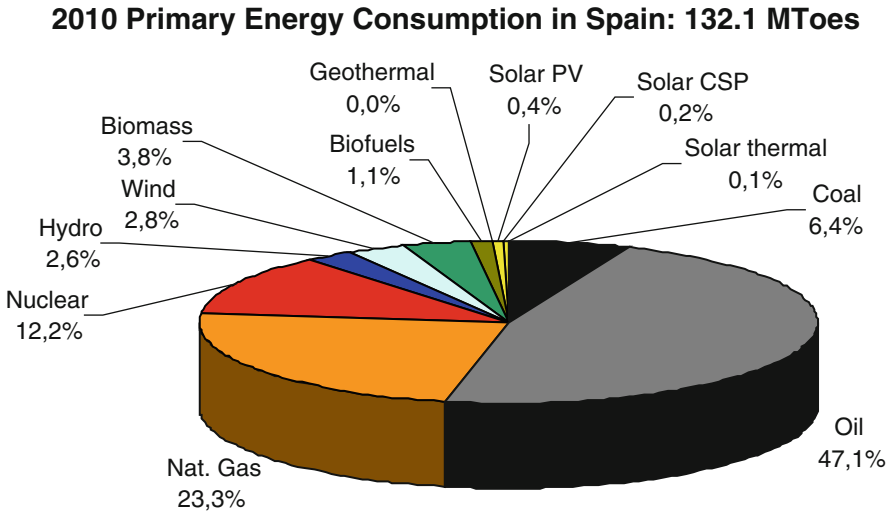

Fig. 2.2 Demand/consumption of primary energy in Spain in 2010. *Source*: Ministry of Industry, Tourism and Commerce, p. 37 (131.2 MToe = 5.5 exajoules) and percentages of each energy source

price for electricity. This policy has encouraged investment in renewable energy technologies such as photovoltaics through long-term subsidies (Fig. 2.4).

Spain had a complex mix of electricity production (Fig. 2.5), which is essentially the same as demand or consumption. During this year, 30% of the electricity was generated from renewable sources of energy, or as much as 44% of the electricity if

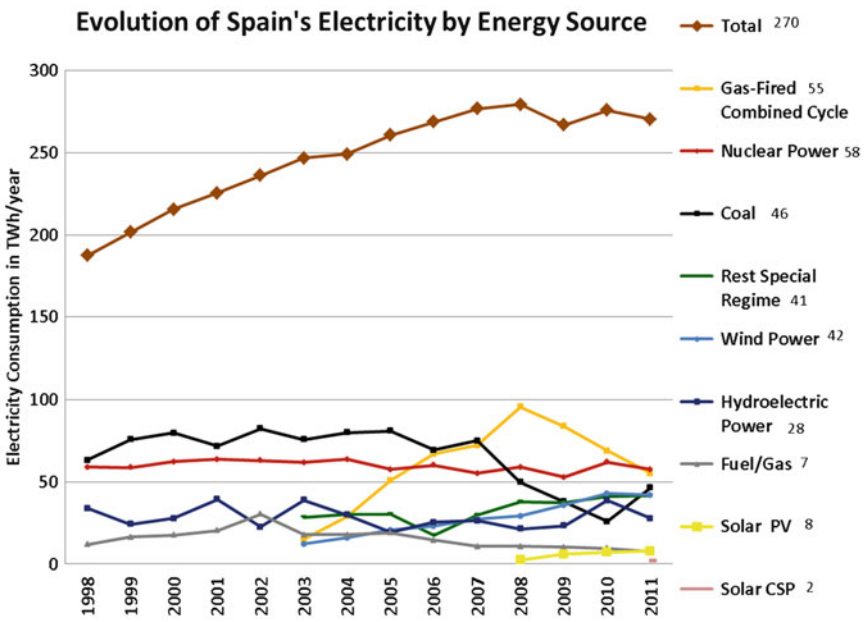

Fig. 2.3 Evolution of the electricity supply in Spain by energy source (1998–2011). These data do not include international exchanges or energy costs for pumped storage or consumption by the supply industries. The "special regime" includes biomass in different forms and electricity generated from waste and cogeneration. *Source*: Red Electrica Española (REE)

cogeneration and waste treatment are included. The feed-in or entry criteria of the different sources are rather complex, but in general terms, renewables have priority of entrance into the grid.

An Overview of the Status of Renewable Energies in Spain

In 2004, the Spanish government introduced the "special regime" to encourage with subsidies (called premium tariffs) low-CO_2 generators, e.g., biomass, solar PV, CSP, wind and cogeneration. Investors started to develop renewable energy technologies in Spain in "feed-in" form (meaning that each would be feeding electricity into the national grid). Soon, Spain became a mature country in this type of connected and distributed electricity generation and network system. Unfortunately, that soon created problems of network capacity in some regions where the power lines or electric substations did not have enough capacity to absorb this type of stochastic (intermittent) energy. Spain had an impressive learning curve under the hand of the Spanish regulators and the main electric power utilities. They managed to overcome most of these problems by combining their expertise.

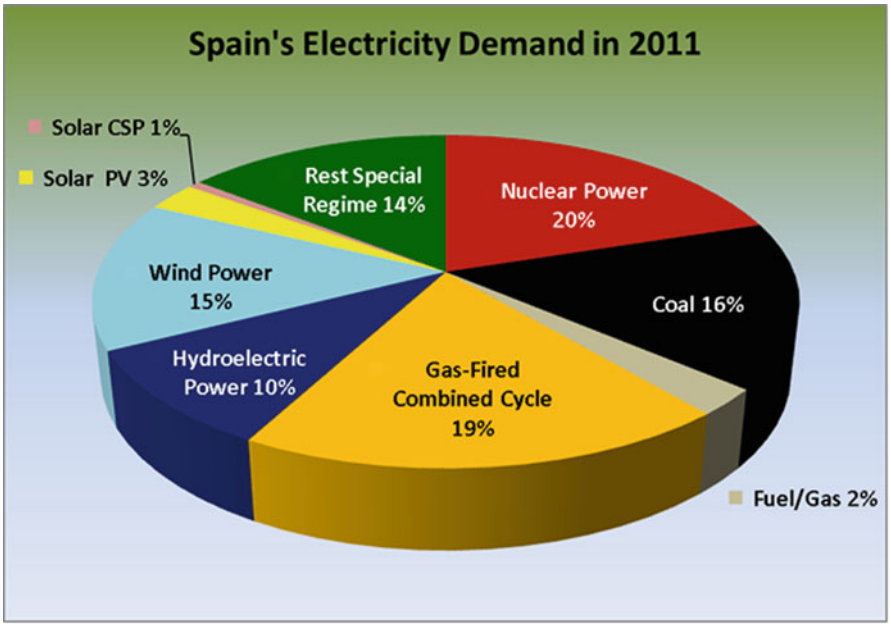

Fig. 2.4 Electric consumption in Spain in 2011. *Source*: Red Eléctrica Española. Preliminary Report 2011

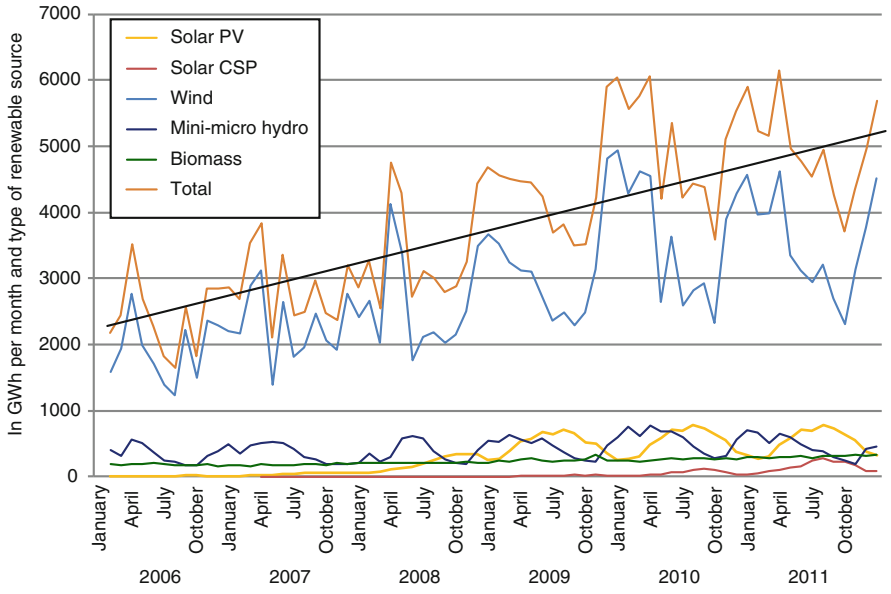

Fig. 2.5 Evolution of feed-in renewable energy expressed in GWh per month in the last 6 years. *Source*: Comision Nacional de Energía. Report of April 2012. Installed power at the end of 2011 was 29,047 MW of these types of renewable sources (27% of total electricity produced that year; www.ree.es. Preliminary report 2011

Three unusual characteristics of Spain with respect to the introduction of renewable, distributed energies are (1) its feed-in system; (2) its unique geography, in the southernmost part of Europe and on a Peninsula; and (3) very few connections and exchanges of electricity with neighboring countries. These characteristics allow Spain considerable autonomy and flexibility in developing its own renewable energy systems. The few international exchanges with France, Portugal, and Morocco are small. Although Spain has been a net exporter of a relatively small amount of electricity in the last few years, it has done so with a very low exchange capacity, due to lack of international interconnections. All of these factors make Spain a unique and interesting location to undertake a thorough EROI analysis of any renewable energy.

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