



100%

RENEWABLE

ENERGY AUTONOMY IN ACTION

Edited by Peter Droege

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Chapter Nine

Renewable Regions: Life After Fossil Fuel in Spain

Josep Puig i Boix

On the day of the 2007 Summer Solstice, a group of Catalan NGOs made public a study on 100 per cent renewable electricity supply for Catalonia (Doleschek et al, 2007), the north-eastern region of Spain. The authors of the study showed that to switch the present electricity supply system in Catalonia to a renewable one would be within reach if appropriate policies were implemented. Also, some time before, Greenpeace Spain had undertaken a similar study for Spain as a whole (Greenpeace Spain, 2007).

But despite these inspiring studies, the Spanish energy situation is not going in a good direction: increasing energy demand, lack of efficiency, CO₂ emissions out of control, mounting energy dependency on fossil fuels, to name just some of the major problems. To make matters worse, the Spanish government never took the responsibility of asking for a study to assess the challenges of supplying the country's electricity from a 100 per cent renewable system.

Why speak about a 100 per cent renewable energy supply? The answer is simple: the present energy situation is unsustainable because it is based on non-renewable sources that generate energy waste and emissions on a massive scale, both in CO₂ and nuclear radiation. Time is running out for shifting the current energy path to a renewable one. Spain's quandary epitomizes the paradox of many countries that utterly depend on oil and uranium energy imports and fail to comply with the Kyoto Protocol, while sitting on abundant renewable resources: sun, wind, biomass, hydro, or in the words of Samuel Taylor Coleridge (1898), 'Water, water, everywhere, Nor any drop to drink'.

The current situation of renewable energy in Spain

Before the end of the 1990s, Spain began to deregulate energy markets and adopted some national policies to develop renewable energies. A number of big steps have been taken since then. The Law of the Electricity Sector (Ley 54/97) fixed that at least 12 per cent of all primary energy should be covered by renewables. The Renewable Energy Promotion Plan 2000–2010 was adopted

at the end of 1999 and fixed a renewables target of the equivalent of 9.5 mtoe for the year 2010. The updated Renewable Energy Plan 2005–2010 (Plan de Energía Renovable (PER) 2005–2010) was adopted in August 2005 and increased the target for 2010 to 10.5 mtoe.

According to the Spanish Energy Agency (IDAE), at the end of 2007 renewable energy technologies provided 7.1 per cent of primary energy consumption (3.1 per cent biomass, 1.6 per cent hydro, 1.6 per cent wind and the remaining 0.8 per cent distributed between biofuels, solar thermal and solar PV, geothermal and municipal solid waste. Regarding electrical energy, the contribution for renewables was 20.5 per cent (9.8 per cent hydro, 9.0 per cent wind and the remaining 1.7 per cent distributed between biomass, biogas, solar PV and municipal solid waste).

If we take a look at each renewable energy source the situation at the end of 2007 was as follows:

- Wind energy ranks first with more than 15,000MW installed at the end of 2007, with a 30.3 per cent increase from 2006. The goal for 2010 (20,155MW) will be easily reached and perhaps exceeded.
- Solar thermal, with almost 1 million square metres (700MWth) installed, the goal set by PER of 3.5 million square metres in 2010 will not be reached, despite the fact that more than 50 municipalities around Spain have adopted Solar Energy Ordinances (City of Barcelona, 1999). This is also despite the inclusion of a solar thermal obligation in the new Spanish Building Technical Code (CTE – Código Técnico de la Edificación).
- Solar photovoltaics, in contrast to solar thermal, has experienced rapid development in the last two years, reaching 554MWp at the end of 2007 (in contrast to 27MWp installed at the end of 2003). In 2007, solar photovoltaics exceeded the goal of 400MW fixed by PER for 2010.
- Solar thermoelectric or CSP is also booming due to very attractive premiums for developers. The first commercial power plant was operational at the end of 2007 (PS-10, 11MW, near Seville), with the second one (PS-20, 20MW) producing electricity at the end of 2008. Both are based on tower technology, but the group building them, Abener, has already started construction of two projects based on parabolic troughs of 50MW each (Solnova 1 and Solnova 3). Dozens of other projects are being planned and building started; among them, Andasol 1 (feeding electricity to the grid at the end of 2008) and Andasol 2 are the more advanced.

All these developments have been implemented in line with FiT policies since the 1990s (RD 2828/98), and based on some policies adopted in the early 1980s (Ley 82/1980). But why have some Spanish regions developed renewable energy assets while others have not, despite the fact that national policies apply for all regions (RD 436/2004)? For example, and referring to wind (see Table 9.1), some regions such as Castilla-La Mancha had more than 3000MW at the end of 2007 (or Galicia and Castilla y León with almost

Table 9.1 Wind power in Spain

Regions	Surface km ²	Population 2006	Density hab/km ²	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	kW/km ²	W/hab
				MW	MW	MW	MW	MW	MW	MW	MW	MW	MW		
Aragón	47,720	1,277,471	27	128	208.5	230.4	404.3	733.93	995	1,206.94	1,407.14	1,532.44	1,723.54	36	1,349
Asturias	10,604	1,076,896	102	0	0	0	24.4	73.72	121	146.00	164.01	190.86	277.96	26	258
Baleares	4,992	1,001,062	201	0	0.2	0.2	0.2	0.20	0	3.65	3.65	3.65	3.65	1	4
Cantabria	5,321	568,091	107	0	0	0	0	0.00	0	0.00	0.00	0.00	0.00	3	31
Castilla y León	94,275	2,523,020	27	16	122.2	228.2	352.9	634.93	924	1,523.17	1,816.87	2,122.91	2,818.67	30	1,117
Castilla-La Mancha	79,462	1,932,261	24	0	111.9	348.2	493.2	741.17	1,010	1,585.50	2,017.66	2,281.46	3,131.36	39	1,621
Cataluña	32,113	7,134,697	222	20	58.8	70.7	83.4	86.36	86	94.37	143.87	225.3	347.44	11	49
Comunidad Valenciana	23,255	4,806,908	207	0	2.8	2.8	2.8	20.49	20	20.49	20.49	333.99	590.94	25	123
Extremadura	41,635	1,086,373	26	0	0	0	0	0.00	0	0.00	0.00	0.00	0.00	0	0
Galicia	29,574	2,767,524	94	232	438.1	600.5	937.7	1,314.99	1,579	2,102.21	2,369.28	2,619.64	2,951.69	100	1,067
La Rioja	5,045	306,377	61	0	0	24.4	73.9	203.52	272	346.87	408.62	436.62	446.62	89	1,458
Madrid	8,028	6,008,183	748	0	0	0	0	0.00	0	0.00	0.00	0.00	0.00	0	0
Murcia	11,313	1,370,306	121	6	6	11.22	11.22	11.22	32	48.97	54.97	67.72	152.31	13	111
Navarra	10,390	601,874	58	237	318.4	467.8	554.1	690.51	717	849.86	899.36	916.36	937.36	90	1,557
País Vasco	7,235	2,133,684	295	0	0	24.5	27	26.90	85	84.77	144.27	144.27	152.77	21	72
Ceuta	19	75,861	3,993	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0
Melilla	13	66,871	5,144	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0
Total	505,989	44,708,964	88	834.00	1,476.50	2,273.92	3,243.62	4,828.48	6,203	8,503.92	10,027.92	11,623.02	15,145.11	30	339

Source: Based on data from Asociación Empresarial Eólica

3000MW), while Catalonia had only 350MW? This is despite the fact that the first Spanish grid-connected wind generator was designed, constructed and erected in Catalonia in the early 1980s. Why has Catalonia not been able until now to develop its wind potential, despite Spanish national renewable energy policies that apply to the region?

In order to answer this question, it is instructive to learn from past developments that have led to the present situation in Catalonia and compare these with the case of Navarra.

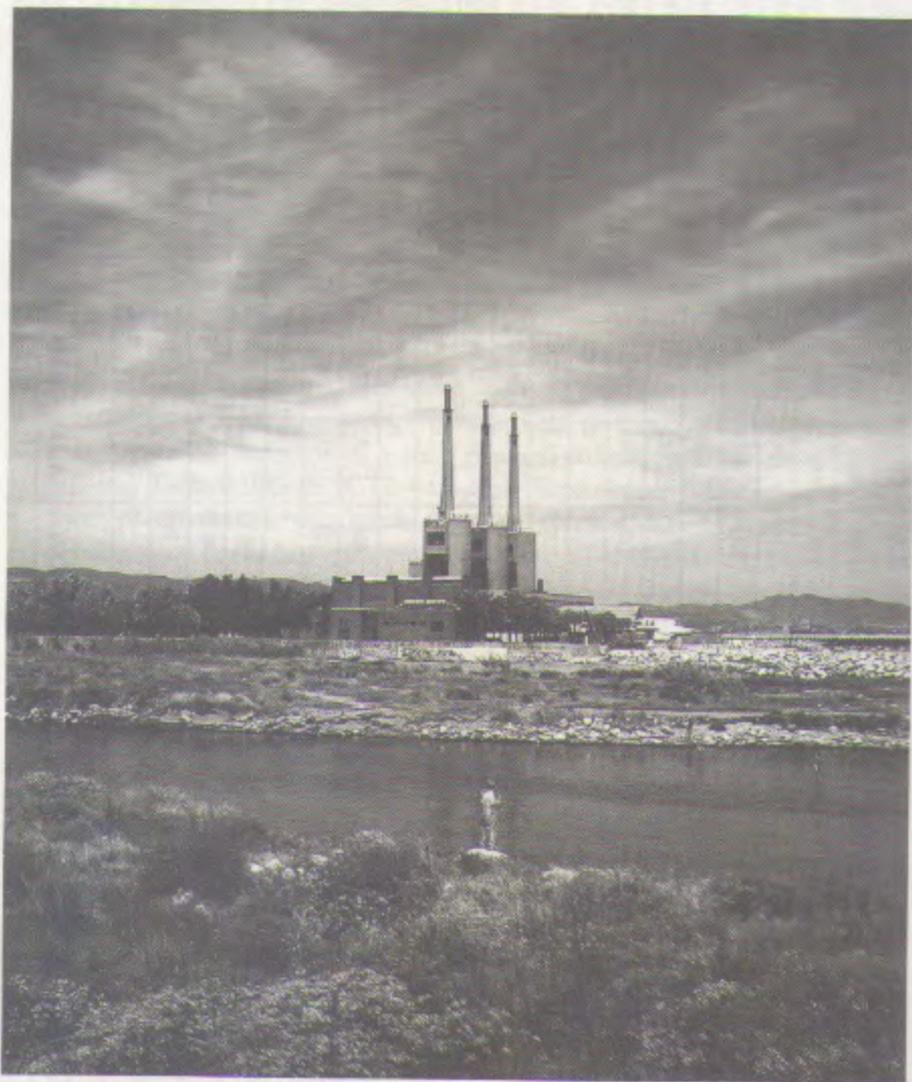


Figure 9.1 Barcelona's San Adrián power plant: The plant displays a sleek design, but despite its much-touted credentials is still a relatively large polluter, emitting 513,193 tons of CO₂ annually at an output of 1.2TWh

Source: Juan Antonio Zamariipa Esqueda

The case of Catalonia

Catalonia is the north-eastern region of Spain, with more than 7 million inhabitants (15.5 per cent of the Spanish population) living in 32,113 km² (6.4 per cent of the Spanish area) with 222 inhabitants/km². In 2007, more than 50 per cent of all the electricity it consumed was generated by three nuclear power reactors (in the mid-1980s nuclear power provided more than 80 per cent of all the electricity to Catalonia).

The first proposal for a renewable-based energy supply for Catalonia was published in the early 1980s (Corominas and Puig, 1982) by people involved with Ecotècnia. This study was inspired by a number of pioneering studies (Lovins, 1977; Groupe de Bellevue, 1978; Todd, 1979; Morris, 1979; Taylor, 1979; Leach et al, 1979; and Lönnroth et al, 1980) carried out in the late 1970s by different groups in various countries.

In Catalonia, two examples show the impact of clear commitments by local or regional governments to achieving results. The first concerns wind technology and the second solar thermal energy. The case of wind involves a private company, Ecotècnia cooperative, that has been successful in developing wind technology since the early 1980s. The case of solar thermal energy focuses on the city of Barcelona that has been leading the process to adopt the first world municipal solar thermal ordinance, having made it mandatory since 2000 that all new and integrally refurbished buildings have to have solar water heating systems. The full story of Barcelona Solar Ordinance has been already published (Puig, 2008), but now details of the Ecotècnia case are published here for the first time.

2008 will be remembered in the wind history of Catalonia as the year in which the Catalan cooperative (pioneer of wind turbines design and manufacture) Ecotècnia, integrated the international group Alstom. Almost three decades had passed since a group of nine persons with high technical qualifications, committed to environmental thought and the practice of alternative technology, started to work to make possible the birth of a cooperative with the goal of developing technology for using renewable sources of energy.

It was in the late 1970s, within the framework of the energy crises and in the constructive fever of nuclear power stations and multinational companies looking for uranium in Catalonia, when a series of circumstances lead the first people interested in the renaissance of the wind energy in Catalonia to get together. In 1978, a graduate wind project (Meseguer, 1978) was presented to the Engineers School of Barcelona. During the month of June, Navarra's Association of Architects organized a special event in Pamplona about alternative energy (Autores varios, 1979), where Tvind School representatives (from Jutland in Denmark) attended and explained their story of designing and constructing a megawatt-size wind turbine with three blades (each 27m long) on top of a 53m tower. Several members of the group, Tecnologías Alternativas Radicales y Autogestionadas (TARA) (TARA, 1977), participated in this

conference and at the end of 1978, a Barcelona underground magazine (Alemany, 1978) published an article explaining how the Danish Tvind schools constructed and put into operation a megawatt-size wind turbine.

On 21 November, the Technical Commission of Energy of the Association of Industrial Engineers of Catalonia was set up. Dr J. Corominas and I attended its founding ceremony as both of us had been very active in initial work of a wind energy subcommittee. From February 1979 until July 1984, I acted as coordinator of this subcommittee and its members went on to found Ecotècnia.

The wind energy subcommittee was very productive, for example, it produced a paper (Puig, 1979) that was presented at the Catalan Conference of Engineering, proposing a wind energy research plan, including a study of Catalonia's wind potential and even the testing of existing wind machines and the development of wind technology. The subcommittee organized the first Conference on Wind Energy in January 1980 (Comissió Tècnica d'Energia, 1980), where the engineer Lucien Romani was invited to explain the French experience in wind technology, especially the experience of the 800kW Best-Romani wind turbine that worked in Nogent-le-Roi (France) from 1958 to 1963, funded by EDF. Also a local manufacturer (Aerogeneradores GEMZ) was invited, as was the builder of a pumping wind machine. The subcommittee organized the first wind energy course in June 1980 (CPE-AEIC, 1980) with members of the subcommittee as teachers. It produced several papers (de Cisneros, 1982; Departament d'Indústria i Energia de la Generalitat, 1981) on wind energy that were presented at the Conference of Industrial and Energy Policies and to the Conference on Studies and Technical Proposals for the development of the technology and energy policies of the government of the Generalitat de Catalunya (January 1981).

In this context a group of people started in the autumn of 1980 to nurture the idea of creating a cooperative for the design and manufacture of wind turbines. This became Ecotècnia. Ecotècnia was the culmination and realization of a long process of debate about the relationship between energy, technology and society. The group began to form in the late 1970s, involving people who had been organizing courses, giving lectures and writing features in magazines about energy alternatives to the official energy policies based on the country's push to nuclear power. In an article published in a Spanish magazine, it was announced publicly that the Cooperative for Technological and Energy Autonomy (CATE) would be set up (Alemany and Puig, 1980).

The debate about the creation of a cooperative structure to develop technology for the use of renewable energy sources started in the autumn of 1980 and was inspired by authors such as Schumacher (1975), Dickson (1975), Bosquet and Gorz (1977), Lovins (1979), the publications of the Open University's Network for Alternative Technology and Technology Assessment (NATTA) and the magazine *Undercurrents* (Harper and Boyle, 1976).

In May 1980, the group of pioneers of Ecotècnia started making contact with the Spanish government body in charge of technology development and

innovation, the CDTI (Centro para el Desarrollo Tecnológico e Industrial) to explore the possibilities of obtaining funding to carry out the technological development of a wind turbine. In January 1981, they presented a first proposal but this was not accepted.

The formal constitution of *Ecotècnia* cooperative was held in the city of Barcelona, on 2 April 1981. The founding capital was 80,000 Spanish pesetas (about €500), coming from 8 people. *Ecotècnia*'s mission was to offer a series of products and services to empower, develop and promote a technology within the reach of anybody, that would provide more autonomy to workers and users, allow a better use of local resources and would be more respectful of the environment, encouraging the use of renewable and non-polluting energies that would not artificially bloat prices due to market restrictions, or because of inferior management, and that would be open to participation and that would be inclusive and egalitarian in the organization of the work needed.

The proposal submitted to the CDTI was ultimately not accepted but nonetheless it had consequences: in August 1981 CDTI announced a competition for the design of a wind turbine prototype of 5–10kW of power, framed under the Spanish Innovation Plan that had been funded by the Spanish government and the CEOE (Confederación Española de Organizaciones Empresariales) (Ministerio de Industria y Energía y CEOE, 1981). *Ecotècnia* started to work on its prototype in September and was one of the four winning groups, together with Gedeón S.Coop., STS S.Coop. and IDE.

While waiting for the result of the competition, I joined in the 1981 European Wind Energy Study Tour of the US, the first expedition of European wind experts to developments in the US, especially such pioneering outposts as NASA's Lewis Research Center, the Wind Test Plant in Rocky Flats, the nascent wind farms in California and in the state of Washington.

The winning of the CDTI competition led to much pomp and ceremony, but despite the signing of an agreement with the Energy Ministry's General Direction of Industrial and Technological Innovation, the contractual document never made it back into the hands of the winners of the competition, and neither did the prize money (€84,000). In order to avoid a public outcry, the CDTI negotiated the funding of 90 per cent of the development cost of the wind turbine prototypes with the four winners. Finally the collaboration agreement with the CDTI was signed in July 1982, which made it possible to implement the projects.

Two significant events accompanied this process: the publication in April 1982 of the first Spanish book on wind energy technology (Puig et al, 1982), starting a series on alternative technologies directed by *Ecotècnia*, and second, the first doctoral thesis about wind energy (Puig, 1982).

Finally the *Ecotècnia* 12/15 wind turbine was installed and connected to the grid in the small rural town of Valldevià (Municipality of Vilopriu, Comarca de l'Alt Empordà, Girona province, Catalunya). The wind turbine was connected somewhat outside the legal context, since then there were no regulations in place. It was a three-bladed wind turbine, each blade 6m long

(12m diameter), mounted on a 10m steel frame tower with 15kW of rated power.

On 10 March 1984, the official inauguration happened, with a big party on site. The party started at Vilopriu Town Council with a presentation of the cooperative and of the project, accompanied by an ambitious slideshow on wind energy and its role in modern society. Afterwards, the 500 guests moved to the site of the turbine to officially switch it on, not without the obligatory fireworks. TV coverage allowed everybody to witness the birth of modern wind technology in Catalonia, and both national and local press reported the inauguration of the renewable age.

For three years, Ecotècnia's 12/15 wind turbine was a true test case for all the components. The prototype was submitted to the Second Creativity's Award of the industrial engineers, and was rewarded with an honourable mention (with the jury still preferring the wonders of the fossil fuel era for first prize: a diesel locomotive designed for train shunting).

During the delivery ceremony of the prize in June 1984 in a Barcelona downtown hotel, when receiving the award from Catalonia's president, Ecotècnia quoted a previous presidential speech: '*No podemos volver a molinos de viento*' ('We can not return to the times of windmills') (*Noticiero Universal*, 29 May 1982) and spoke of the Californian example of building wind farms.

Ecotècnia 12/15 wind turbine was reported in some international wind technology magazines. The newsletter of the European and UK Wind Energy Associations (*Windirections*, 1984) put a picture of the Ecotècnia 12/15 wind turbine on its front page and reflected it as a major event in wind energy technology in Europe. Also, *World Wind* (1984) magazine published a full-page article where it covered the inauguration and explained the story of the competition. Also, in one of the first wind energy conferences, EWEC '84 (European Wind Energy Conference and Exhibition, Hamburg), organized by the EWEA (European Wind Energy Association), a paper was presented on the evaluation of Catalonia's wind potential and the development of a 15kW wind turbine (Puig and Corominas, 1984).

The Ecotècnia 12/15 wind turbine was the basis from which the first generation of Catalonia's wind machines started to be manufactured (12/30 series), of which Ecotècnia sold and installed 29: 2 in the Castilla-La Mancha region, 4 on a Spanish commercial wind farm, 20 in the Ontalafia (Albacete) and Tarifa (Cadiz) wind farms and 3 more in Los Llanos, Figuerola del Camp and Roses. All these wind farms were included in the first Spanish Renewable Energy Plan (Plan Energético Nacional 1991-2000).

The accumulated experience, made it possible for Ecotècnia to undertake the development of more powerful wind turbines, rated at 150kW. The first prototype, designed and built with the support of the IDAE, was installed at Tarifa, the most productive wind machine (kWh/m²) in Europe. With this machine the second generation of wind energy systems was initiated, which would be followed by the generations of 225kW, 640kW, 750kW, 1250kW, 1670kW and 3000kW (the official inauguration of the first 3 MW wind

turbine took place on 25 July 2008 in Les Colladetes, with the presence of Catalonia's President).

Catalonia started pushing wind technology with almost no support from the Catalan government. It took more than 15 years to see the results of the hard work done by people engaged with the idea that a modern society could be supplied by renewables.

Now, more than 25 years later, the Catalan government continues to avoid making any clear commitments regarding renewable energy sources. For example, its recent Decree for the regulation of wind and solar photovoltaic developments (Generalitat de Catalunya, 2008) was strongly opposed by the main environmental organizations (Greenpeace, Ecologistes en Acció and Eurosolar Spain).

The case of Navarra

The small Spanish region of Navarra (1.3 per cent of Spanish population and 2 per cent of the Spanish land area) with 58 inhabitants/km², became over a short period of time a leader in renewables (mainly wind energy) in Spain.

The process started in 1989 when the Navarra government decided to start working to make the region a leader in renewable energy. The first steps were: to assess the region's wind energy potential and to create a small company, EHN to develop small hydro sites in the region (more than 100 sites with a power capacity of 195MW). EHN built its first wind farm (El Perdón) 15km from the capital city of Pamplona in 1994. In the same year, the Navarra government, through SODENA and with EHN and Vestas, joined forces to set up Gamesa Eólica to supply wind turbines to EHN.

In 1995, Navarra adopted its 1995–2000 Energy Plan with a goal to reach 341MW of renewable energy capacity by 2000. The objectives of the Plan were easily fulfilled and the year 2000 ended with 667MW of renewable capacity installed, of which 474MW were from wind energy. At the end of 2006, the total renewable power capacity installed in Navarra was 1164MW, of which 941MW were from wind on 32 wind farms with 1164 wind turbines.

Navarra is the location of several wind farm developers (Acciona Energía, Eólica Navarra, Gamesa Energía, etc.) and wind turbine manufacturers (Acciona Windpower, Ecotècnia, Gamesa Eólica, Ingeteam, etc.). Also this region has attracted leading national centres specialized in renewables (CENER and CENIFER).

Navarra is also leading solar photovoltaic development, since EHN teamed in 1997 with other partners to create AESOL. This company developed the innovative concept of '*huerta solar*' or solar farm involving ordinary citizens in solar investments. By September 2008 it had developed 18 *huertas solares*, with a power capacity of 61.5MW, involving more than 3500 people, mainly in Navarra but also in Castilla-La Mancha, Extremadura and Aragón regions.

The strong regional political commitment has made the region of Navarra a shining example in renewable energy development. The policy context made

possible the formation of a close partnership between regional government, private companies and financial institutions, and led to results in a short period of time.

The results

From the above the differences between Catalonia and Navarra are evident, despite both regions being subject to the same Spanish legislative framework.

The main difference is the commitment of regional governments: in Navarra a strong commitment to develop renewable energy policies, in Catalonia no real commitment at all.

The main conclusion of these stories is that local and regional governments have to play an active role in developing renewable energies. Without active renewable energy policies at regional or local levels and despite the active involvement of other local actors and active policies at a national level, we will never see a society based on 100 per cent renewable energy.

Another difference between these two regions is the question of energy democracy. In Navarra a private company has created and developed a new concept, enabling the ownership of renewable energy systems by ordinary people. In Catalonia, no private company has followed that path. Only a local NGO, *Fundació Terra*, started in 2007 to pursue the idea in Barcelona, without any support from the city government.

The Solar Catalonia proposal

To reiterate, a pathway to a 100 per cent renewable electricity system for Catalonia was proposed in July 2007 by a group of Catalan NGOs. The main goal of the proposal was to pressure the regional government to change its regional energy policies.

The objective of the Solar Catalonia study is to show that the region would be able to supply its own need for electricity from renewable sources. This fact-based vision of a future energy supply is very important to influence the discussion about the change from fossil and nuclear energy sources towards a sustainable energy system, especially, as the ongoing discussion regarding the possibilities of renewable energy and efficient design has been negatively influenced by data on the availability and potential of these technologies.

The goal of the project is to show that a sustainable, renewable and efficient energy system is capable of supplying Catalonia's current needs. The study does not assume any major changes in lifestyle, living standards or demographic composition. There are no assumptions regarding future economic development in terms of GDP or the like.

Although Catalonia has shown strong economic growth over recent years, it did not perform well with regard to energy intensity. It is quite clear that energy intensity in the Catalonian economy must be reduced in order to shift to a sustainable energy supply and to make a contribution to climate

protection. The scenarios within the work highlight a development towards halving electricity intensity in the three most important sectors of electricity consumption until 2050. This means making great efforts to improve the efficiency of electricity use, but the authors are convinced that this is feasible from a technological point of view. Further technological development towards more efficient appliances will assist such a development and in the restructuring of our economies. Redefining the relationship between energy consumption and wealth may be necessary but, in the end, climate change and its serious consequences will force us along this path. One fact is quite clear: we have to start now in order to keep the transition smooth and to avoid the most serious consequences of climate change.

Taking this proposed course of action will lower Catalonia's electricity consumption to the 1993 level until 2025 and to half of 2003's electricity consumption by 2050. Although further reductions will be harder to achieve the further we step into the future, a certain level of energy intensity will remain. Reducing energy intensity by half sounds very difficult, yet this means only undoing the increase experienced between 1993 and 2003. The remaining effort of efficiency improvements does not seem like an insurmountable goal.

Two scenarios show the feasibility to achieve a fully renewable supply, one until 2035 (Fast Exit Scenario) and the other until 2045 (Climate Protection Scenario). This is not a matter of potential but of setting and pursuing ambitious goals, encouraging policy and people and – of course – the financial investments Catalonia and its people are willing to take. The scenarios show that the financial aspect is not that big an obstacle as one might expect. With an annual investment into renewable capacities peaking at €104 (2006 value) per inhabitant in the Fast Exit Scenario and €85/capita in the Climate Protection Scenario, the financial burden to achieve a clean, climate-friendly electricity supply in Catalonia is moderate in the authors point of view; in 2030 investments would be €103/capita in the Fast Exit Scenario and €68/capita in the Climate Protection Scenario.

These financial figures reflect the peak investments during the whole development considered in the study. The calculation of the average annual payments for the two different scenarios results in €58 per inhabitant a year in the Climate Protection Scenario and €84 per inhabitant per year in the Fast Exit Scenario.

Compared to the Catalonian GDP (€181,029 million in 2005) the annual costs of the scenarios are 0.2 per cent of GDP for the Climate Protection Scenario and 0.3 per cent for the Fast Exit Scenario, on average.

Any energy supply system must guarantee sufficient production and distribution of electricity, heat and fuels to meet the demand for energy at any time throughout the year, usually using different energy conversion technologies. Energy is supplied in the form of electricity, heat or fuels, with heat and fuels having the advantage that both can be stored for later use and can be easily transported. So it is not necessary to consume heat and fuels immediately or directly at the production site. Heat can be stored in thermal

reservoirs and distributed via DH networks. In contrast to heat and fuels, which dissipate with time – thus setting a limit on storage time and distribution distance – fuels from biomass or hydrogen do not have quite this limitation in storage time or in transport (depending on the fuel type – solid, liquid or gaseous), although some storage losses must be considered here as well.

The situation is completely different with electricity. The necessity of producing enough electricity, on demand and on time, makes this type of energy the most critical component in an energy supply system. While electrical transport via the public grid is quite unproblematic, storing electricity directly on a large scale is material and cost intensive. Also, storage in batteries and accumulators can involve the use of toxic substances. Therefore this option is not considered in the study as it is not appropriate for a sustainable energy supply system. Indirect storage can be used, for example, pumped hydro storage systems.

An energy supply system that is based almost completely on renewable sources increases the focus on timely energy dispatch and supply due to the fluctuating nature of some renewable energy sources, such as solar and wind. Including such fluctuating sources into the public electricity supply means that the power produced by those sources might decrease relatively fast. Of course electricity production from fluctuating sources can be estimated by weather forecasting but a portion of uncertainty still remains. Fortunately, there are other renewable technologies with the ability to deliver energy on demand; hydropower and geothermal power plants give direct access to renewable sources, while co-generation and other energy sources can use fuel from renewable sources (for example, hydrogen or biomass).

The challenge in designing a highly renewable electricity supply system (up to 100 per cent renewable) is to find the combination where advantages of each renewable source add up to a functioning and reliable system, while disadvantages are balanced out. Especially in the electrical system the need for reserve capacities, necessary as a back up for fluctuating sources, can be minimized by choosing the right combination of renewable technologies to minimize fluctuations. Demand management can also be introduced to get a better alignment between production and demand.

In the study the authors only studied the dynamic behaviour of the electrical system in the 'Fast Exit' scenario. This was done without optimizing the electrical energy system. The simulation was done for four typical weeks (in spring, summer, autumn and winter), with typical weather of the year 2006 (Generalitat de Catalunya, 2006). The optimization of the supply system and the introduction of modern electrical grid management methods (for example, demand management) will be investigated in a later study by Eurosolar Spain.

Considering the four simulated weeks as representative for all the four seasons of the year, the supply system according to the Fast Exit scenario is capable of supplying all the electricity demand in Catalonia. Generally solar and wind performance levels are substantially higher during spring and summer than they are in autumn and winter. Due to the strong spring and

summer performance of fluctuating suppliers (solar and wind), it is often the case that photovoltaics, solar thermal power and wind energy can supply far more than the total electricity demand.

During the winter, the adjustable suppliers have a dominant role as a result of the decrease in solar radiation together with generally lower wind speeds. Looking at the big picture, climate variation over the year, with strong solar and wind performance during the warm periods, favours the system described here because the adjustable suppliers (hydropower, geothermal and biomass) have to contribute most during those times when they can be operated in the best way. While a high utilization of hydropower coincides with higher precipitation levels, geothermal and biomass plants can mainly be operated during times when there is a high demand for heat, thus giving the opportunity to take advantage of highly efficient CHP plants.

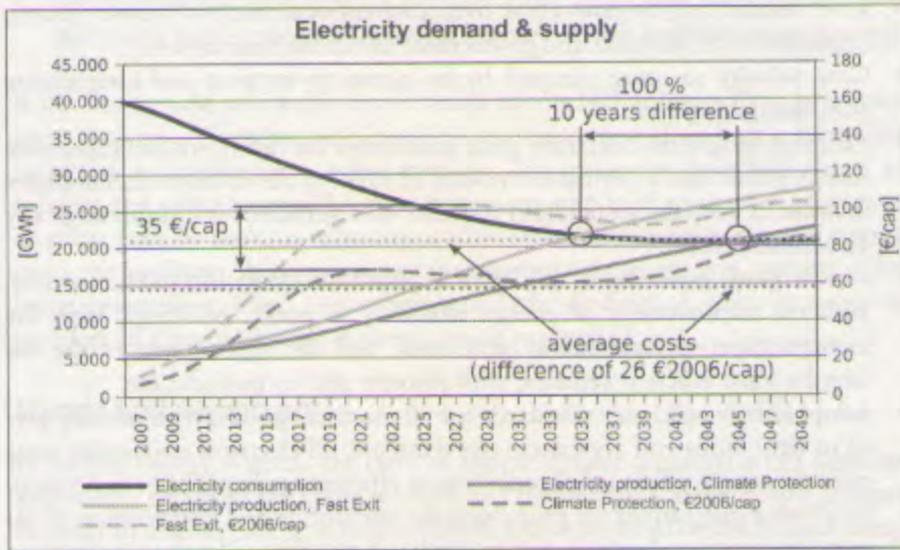


Figure 9.2 Development of electricity demand and two supply scenarios of Solar Catalonia

Source: Doleschek et al (2007)

General policy measures for going 100% renewable

The policy measures that the authors of Solar Catalonia propose in their study will perhaps help to change the situation. Economic, legal and institutional conditions for the energy system must fundamentally change and indeed this must happen soon. In practice, we will need to rely on a mixture of instruments and measures. In addition to what is described and planned, significant additional measures have to be taken to realize a sustainable energy future.

General political measures

Below is a list of suggested general political measures that would facilitate the path towards 100 per cent renewable energy supply:

- Adopt a set of rights and responsibilities that guarantee the democratization of the energy systems (see below).
- Develop a land use plan for renewable energies, based on a realistic picture of renewable energy potentials.
- Establish preferential areas for wind energy, according to the potentials and locations in each developed scenario.
- Assess and restructure the use of coastal areas for offshore wind energy, focused on the best locations.
- Set up an energy supply regime that favours renewable technologies as the first option whenever a new plant should be built.
- Give primacy of co-generation over conventional thermal power plants, combined with biomass and geothermal use as the first choice.
- Give priority to using pumped hydro plants to support and compensate fluctuating suppliers.
- Establish long-term electricity price guarantees for newly erected renewable energy plants and a permanent review of FiTs for the different technologies in order to keep the installation stimulus on a sufficient and technologically diversified level.
- Start a 'green government' initiative in public buildings and public services, with the improvement of energy efficiency in public buildings, with the incorporation of local energy generation and the replacement of the car fleet by most efficient vehicles, with priority give to biofuels, etc.
- Adopt energy efficiency standards for all electrical goods, with priority given to light bulbs and appliances (for example, all electrical appliances must meet the energy efficiency of today's most efficient appliance after two years).
- Establish a programme for promoting the monitoring and visualization of energy consumption (domestic, services level) in a way that will make consumption visible to users and more understandable than the reading of meters.
- Introduce, without delay, education and training on renewable energies, facilitating the fastest way to introduce and expand renewable technologies with assured quality.
- Introduce financing, legal and fiscal mechanisms and regulations in order to facilitate the above measures and technology research.

Besides the general policy measures it is also necessary to initiate concrete programmes and commitments such as:

- Establish a micro-co-generation programme with ambitious targets.
- Establish a solar roof programme with ambitious targets.
- Arrange an annual green community competition regarding local renewable energy generation.

- Arrange an annual 'zero energy buildings' competition.
- Establish a wind energy programme based on small (less than 5MW) wind farms with ambitious targets.
- Establish specific commitments, goals and targets to use public buildings for solar energy production and to start immediately emblematic or 'lighthouse' projects in the roofs and facades of the public buildings.
- Directly address celebrities/prominent entities to act as models and champions for utilizing solar energy or renewable energies in general.
- Promote local energy self-sufficiency programmes prioritizing the combined use of renewable energy resources existing in the area.
- Promote the development of a network of agencies or local energy centres independent of public authorities and energy companies, but with their participation, in order to pass the information about renewable energy and energy efficiency to the population.
- Create equitable partnerships between rural zones and urban zones, given that many rural zones could have a surplus of renewable sources of energy.

R&D has created renewable and efficient energy technologies for a permanent energy supply. Together, the political community and industry must take measures to implement a solar strategy. The measures described above are feasible and make sense. The most important step is to start now, since every day that goes by without enforcing a solar strategy only increases and complicates the problem. Because energy consumption is increasing, money is still being invested in fossil fuel systems and the finding of ways to solve the problem of climate change is merely being postponed.

Energy and democracy

In current energy systems, the right of people to take decisions is not respected and energy decisions are taken without any involvement of the people affected. In order to democratize and help establish a decentralized or distributed energy system in ways that are efficient, safe, clean and renewable, it is important for a society to recognize a set of basic energy rights. These rights are:

- the right to know the origin of the energy one uses;
- the right to know the ecological and social effects of the manner in which energy is supplied to each final user of energy services;
- the right to capture the energy sources that exist in the place where one lives;
- the right to generate one's own energy;
- the right to fair access to power networks and grids;
- the right to introduce into power networks energy generated in-situ;
- the right to a fair remuneration for the energy introduced into networks.

These rights have to be matched by a set of basic responsibilities:

- the responsibility to find out information;
- the responsibility to ask for information;
- the responsibility to generate energy with the most efficient and clean generation technologies available;
- the responsibility to use the most efficient end-use technologies available;
- the responsibility to conserve and use the generated energy with common sense, avoiding any kind of waste;
- the responsibility to limit oneself in the use of any form of energy;
- the responsibility to exercise solidarity with those underprivileged societies that have no or limited access to a clean means of energy generation as well as its final use.

Guaranteeing these rights should be one of the tasks to which governments give absolute priority. Exercising these responsibilities should be considered the fundamental duty of the responsible persons who depend on the sun as the source of energy. By adapting lifestyles to the solar energy flows (both direct solar energy and its indirect forms), people will discover that fewer costs of every kind will have to be borne in order to sustain life and prosperity on planet Earth.

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